Environmental Concerns in Rights-of-Way Management

12th International Symposium

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Environmental Concerns in Rights-of-Way Management

UAA
UTILITY ARBORIST ASSOCIATION

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PREFACE

The 12th International Symposium on the Environmental Concerns in Rights-of-Way Management (ROW 12) was held in Denver, Colorado on September 23rd–26th, 2018, and brought together a total of 411 ROW practitioners with diverse backgrounds and interests from around the world to share their knowledge and advance the practice. When the symposium series first started in 1976, two primary objectives were set: (1) to provide a forum for discussion of the environmental impacts that result from siting, constructing, using, and maintaining ROWs, and (2) publishing practical information on ways to reduce the environmental impacts and developing multiple uses of ROWs. These objectives continue to endure, as demonstrated by these proceedings, which highlights the rich research and advancements relevant to our industry.

While the primary objectives of the symposium series continue to endure, the challenges associated with environmental management of ROWs are rapidly evolving. The symposium series seeks to capture the topics and themes timely to the challenges faced by the attendees with an objective of sharing information to advance the practice. Increasingly challenging are the large-scale fires, hurricanes, floods, and other severe weather events that affect infrastructure, including ROWs. As a result, for the ROW 12th Symposium, Steering Committee chose a theme of "Managing Rights-of-Way in a Changing Climate" to spur dialogue amongst the diverse knowledge base of those attending.

Many attendees responded to the topic with their papers and engaged discussions. Each day of the symposium was anchored by a morning plenary focusing on the topic from a different perspective. The opening plenary featured Dale Sands, the Chair of the ARISE-US, the United Nations private sector initiative to create risk resilient societies, who spoke about climate resiliency from the perspective of safeguarding infrastructure investment to reduce economic losses from disasters. The opening plenary also included a panel discussion on the topic. The second plenary featured Jerome Davis from Xcel Energy, who spoke to the issue from a utility management perspective. Doug Benevento, the U.S. Environmental Protection Agency's regional director spoke at the final plenary.

The program featured 80 presentations that were selected from more than 120 submissions based for their relevance to this symposium, innovation, and scientific rigor. These papers represent the leading edge of managing environmental concerns of ROWs, and touched on the topics of vegetation management (VM), wildlife, regulatory, project planning, Indigenous and stakeholder engagement, pollinators, climate change, and emerging technologies. Each paper underwent a comprehensive peer review process, and special thanks are extended to the authors for sharing their work as well as the peer reviewers equally dedicated to the excellence of the papers you'll find in these proceedings.

We invite you to explore the symposium proceedings as a resource that includes a wealth of information sure to be relevant to your own challenges of ROW environmental management. And as you work to steward the environmental values linked to ROWs, we invite you to share your learnings at ROW 13 in Charlotte, NC, planned for October 10-13, 2021.

———

Carmen Holschuh, Jacobs
ROW 12 Conference Chair

ACKNOWLEDGEMENTS

Planning the Environmental Concerns in Rights-of-Way Management Symposium takes three years of hard work by a diverse and dedicated group of professionals located throughout North America. These volunteers serve on two critical committees. The Steering Committee provides overall leadership in the planning of the symposium and is supported by the Local Planning Committee, which helps ensure attendees will experience the local culture and have the opportunity to observe regional challenges and successes in rights-of-way management.

Carmen Holschuh of Jacobs provided overall leadership of the ROW 12 Symposium, serving as the chair of the steering committee. Steering committee members contributed to the planning of the event, participated on specific sub-committees, and moderated sessions at the conference. Our Steering Committee for ROW 12 included Alexandre Beauchemin, Josiane Bonneau, Mike Boyle, Alex Brown, Eric Brown, Curtis Campbell, Darrell Chambers, Philip Charlton, Allen Crabtree, Jean Doucet, Jim Downie, John Goodrich-Mahoney, Rich Hendler, Susan Innis, Brian Kortum, Richard Law, Normand Lesieur, Rick Loughery, Kevin McLoughlin, Will McMillan, Randy Miller, Pamela Money, Rebecca Moores, Dean Mutrie, Diona Neeser, Eleanor Nelson, John Peconom, Linda Postlewaite, Pamela Jo Rasmussen, Sara Sankowich, Mitchell Shields, Cameron Shankland, Doug Stewart, Mike Timpson, and Robert Young. Without their willingness to take time from their valuable schedule, the symposium would not have been possible.

The Local Committee volunteers were led by Rebecca Moores and James Downey. The committee included: Bridger Pentilla, Susan Innes, Eleanor Nelson, and Katie Braly. This committee was key in developing the tours, recruiting locally relevant speakers, and choosing the wonderful venues that made the event great.

Jim Downie and Carmen Holschuh organized and moderated the three opening morning plenary sessions. We thank the three plenary keynote speakers who shared their insights and knowledge, including Dale Sands, Jerome Davis, and Doug Benevento.

Allen Crabtree moderated the panel discussion that was part of the Monday opening plenary. He has taken on this challenge for many years and his ongoing commitment is worthy of a note of special appreciation. Panelists for the ROW 12 panel included Nolan Doesken, Fletcher Johnson, Thomas Krzewinski, Jim Martin, David Huard, and Dale Sands. The panel discussion came about as part of a coordinated effort by a plenary panel team led by Allen that included Dean Mutrie, Jean Doucet, Alexandre Beauchemin, Rich Hendler, Booker Holton, Pamela Money, Pamela Rasmussen, Jim Downie, and Michael Boyle.

The Utility Arborist Association (UAA) provided the support necessary for an event of this size and success. Eleanor Nelson served as the event manager under the leadership of Diona Neeser (Operations Manager), Philip Charlton (Executive Director), and Sara Sankowich (UAA Board Champion).

The symposium was dependent on the time and effort of all of these individuals. Equally important was the time and effort put in by more than 100 authors, presenters, and panelists who each contributed to an engaging program highlighting innovation and best practice in our industry. We wish to recognize the quality of their contributions. We also acknowledge the efforts of their peers who participated in the technical review of the papers submitted, a key role in enabling the publishing of this proceedings.

Finally, we want to recognize our sponsors. Those companies listed on page viii & ix, gave generously in support of ROW12.

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12th International Symposium

Environmental Concerns in Rights-of-Way Management

PART I

Opening Plenary Session

Plenary Session
Welcoming Remarks

Environmental Concerns in Rights-of-Way Management
12th International Symposium

STEERING COMMITTEE CHAIR COMMENTS

Carmen Holschuh

Carmen Holschuh, Steering Committee Chair, opened the Plenary Session: "Thank you so much for welcoming us as here to the Rocky Mountain. I'm so happy to be here this year. I'm from beautiful Victoria, British Columbia (BC) and like many of you, I'm getting to visit Colorado and Denver and check out the sights and get to meet lots of great people. I work for Jacobs and we're so excited to be the hosts this year."

"Colorado doesn't only have really beautiful mountains. It's also got some pretty incredible people. I'd like to introduce Jim Downie, who is currently a lead ECI environmental consultant."

Jim welcomed the group: "Have a good time while you are here in Colorado. The tours were great, and I thank Becky Moore and Bridger Penttila for putting together the logistics and arranging them. It was a tremendous amount of work and they've been working on the tours for two years. The other person I want to recognize is Brent, who did a fantastic job on our tour talking about transmission wildfire protection and declining forest health."

Carmen continued: "It's been three years since ROW 11 in Halifax and it's been three years of preparing to kick things off today. In those three years there have been lots of changes. There have been a series of devastating hurricanes that have affected communities and infrastructure in so many locations. For example, we've got some colleagues here from Duke Energy who've just been putting in Herculean efforts to restore power after Hurricane Florence."

"There have been extensive and intense wildfires. Quite a few of you have seen fires burning as you were flying down to Denver. The human environment has been undergoing a lot of changes as well, including ongoing socio-political context changes and regulatory changes. There is a focus on Indigenous reconciliation. It's becoming more and more difficult to get social acceptability of new infrastructure projects. All of these changes make it so important that we come together here every three years to share ideas and share knowledge, to challenge each other, and help move the practice forward."

"This Symposium has a long history. It started in 1976, led by Mississippi State University Professor Emeritus, Dr. Dale Arner. He believed in a symposium that included representatives from industry, from government, and from Academia—a diverse group of people with strong knowledge in their fields. The symposium was intended to present a forum for discussion of environmental impacts that result from the siting, construction, and use and maintaining of rights-of-way (ROW). The proceedings from these symposia were intended to draw together and publish practical information on ways of reducing the environmental impact of ROWs. That vision has continued in the past 11 symposia since 1976 and continues today with ROW 12 here in Denver."

"The twelve symposia have been held throughout U.S. and Canada over the years. These diverse locations have given us an opportunity to learn a lot about the differences of dealing with some of the issues and concerns and challenges in our field. Would everybody for whom this is your first ROW Symposium please stand up. [first time attendees stood up] That's amazing and gives me chills. Welcome and thank you so much for being here. Now. Let's do the opposite. Let's see who's been here for a long time."

"If you've attended two or more ROW Symposia, please stand up. So that's everybody who wasn't previously standing." [some attendees stood up]

"So how about if you've attended more than five, stay standing. Everybody else can sit down." [some attendees remained standing]

"Right on. How about if you've attended more than eight, stay. Eight or more stay standing." [some attendees remained standing]

"That's three pretty distinguished gentlemen right there. That's right. Yeah. How about nine? Ten? Eleven?"

"And who have been to all twelve symposia"? [Kevin McLoughlin and Allen Crabtree remained standing, having attended all twelve symposia since 1976]. "Thank you, Kevin and Allen. That's amazing. Thank you for continuing to stick with this and for continuing to share your knowledge."

Jim then gave this challenge to the group: "In the next three days, you will hear some great speakers with ideas and solutions you can learn from. I think the most valuable part of this this next three days together is going to be the opportunity to build relationships. I found that the hallway conversations often wind up being some of the most meaningful things that happen here. I encourage you to take the time to do that and collaborate on how to take ROW management to the next level."

"I recommend that each of you pick one thing over the next three days that has just really grabbed your heart and mind and just focus on that one thing when you get back home. Make an effort to do something with something you learned or an idea, or to grow a relationship with a colleague you meet here. Pick one thing you're going to go back and do differently than you were doing before you came here."

"You're going to get to listen to cream of the crop. The theme for this conference is Managing ROW in a Changing Climate. I think we can generally all agree that the climate is changing and wanted to focus on how we can better manage ROWs for critical infrastructure for resiliency and sustainability."

"We will have a keynote speaker each day. Today's keynote will be presented by Dale Sands, who will comment on things from an international level. Tomorrow, we're going to have Jerome Davis, Regional Vice President with Xcel Energy, who will speak from a local perspective on some of the challenges that they're having and some of the solutions that they're implementing. On Wednesday, Doug Benevento, who is the Regional Director of the EPA appointed by the Trump Administration, will talk about a federal perspective."

"We are anticipating being able to get the proceedings out in a timely fashion."

"I've never been part of anything as complex as this symposium. We have a huge team of dedicated volunteers who have made all this happen. I want to thank you and I take just a couple moments and recognize the local planning committee. Becky Moore has been the fearless leader of the committee and has done a fantastic job. I'd like to also recognize Katie Braley, Pam Rasmussen, Susan Innis, and Bridger Penttila for all their hard work on the local committee, pulling together the local flow and the flavor of the event, the tours, last night's reception."

Carmen said: "I'd also like to recognize all who were involved in the steering committee. Their vision and hard work have made this symposium possible. They also put in lots of hard hours pulling this together, reviewing papers, providing guidance, and helping shape the program and keep the symposia's consistency and vision. Please stand as I call your name."

Larry Abrahamson
Alexandre Beauchamin
Josiane Bonneau
Calum Bonnington
Mike Boyle
Alex Brown
Eric Brown
Curtis Campbell
Darrell Chambers
Allen Crabtree
Ed Cunningham
Jean Doucet
Jim Downie
John Goodrich-Mahoney
Rich Hendler
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Will McMillan
Randy Miller
Pamela Money
Rebecca Moores
Dean Mutrie
Chris Nowack
Linda Postlewaite
John Peconom
Bridger Penttila
Pamela Jo Rasmussen
Sara Sankowich
Mitchell Shields
Cameron Shankland
Doug Stewart
Mike Timpson
Robert Young

"Thank you so much you all for your involvement over the last three years."

"We also want to thank the UAA, who owned the event, and they really do a ton of the work in the background. And you know, I feel like the committees are the ideas people and then there's somebody that must do the heavy lifting. I want to thank Diona Neeser and Philip Charlton from the UAA and our heroic conference manager Eleanor Nelson. Thank you!"

"We truly have an International Symposium here in Denver. We've got people here from Canada and the U.S., from Australia, New Zealand, the UK, and from Norway. We are really excited to have you here and really looking forward to chatting with you and learning about how things work in your country."

Jim then spoke about some of the symposium sponsors: "We want to recognize Jacobs as a Platinum Sponsor and the host sponsor. They're the ones that footed the bill for the reception last night. Let's give them a big hand. And the other major sponsor was Xcel Energy who is a diamond sponsor."

Carmen then closed with comments: "Thank everyone for being here and for sharing their knowledge, spending countless hours preparing papers, and challenging each other as we work together as a group of 400 to drive our practice forward. And so, without further ado. I want to introduce Allen Crabtree, who will moderate the Plenary Panel discussion and has been working with our keynote today, Dale Sands."

INTRODUCTION OF KEYNOTE SPEAKER

Allen Crabtree

Thank you so much and welcome everyone. You will be entertained, educated, amused, and maybe even angered by some of the comments from our panel and from our keynote speaker. I'd like to introduce our keynote speaker.

Mr. Dale Sands is Principal for MD Sands Consulting Solutions, LLC that provides environmental sustainability and resilience services globally. Dale was elected to serve on the United Nations International Strategy for Disaster Risk Reduction (UNISDR) ARISE Board 2018–2019, the Private Sector Alliance for Disaster Resilient Societies. Subsequently, Mr. Sands was elected to serve as Co-Chair of ARISE, working with Ms. Mami Mizutori, Special

Representative to the UN Secretary General. ARISE is a private sector organization with over 140 member companies focused on the Sendai Framework disaster risk reduction goals. Dale was also the Principal Investigator for UN-funded "Disaster Resilience of Small to Mid-Size Businesses in New Orleans Historic Corridors (2016), co-developed the first Disaster Resilience Scorecard based upon the UN's Ten Essential for Disaster Risk Reduction; the Scorecard is an innovative tool to assess preparedness of communities to respond to, and recovery from, natural disasters. He has more than 45 technical publications and presentations and frequent invited speaker on resilience topics. Dale is also Mayor, the Village of Deer Park (IL).

Dale will share his broad experience in climate change resiliency planning on a national and international stage and put these concepts into the context of managing ROWs. I'd like you to welcome Dale Sands, please.

Dale Sands

Co-Chair, United Nations International Strategy for Disaster Risk Reduction (UNISDR) ARISE Network

President, The Village of Deer Park, Illinois Deer Park, IL 60010

KEYNOTE ADDRESS

Managing ROWs in a Changing Climate

Thank you. It's a delight to be here with you today and talk about disaster and climate resilience. This is increasingly relevant in the changing climate scenario that we find ourselves in. I define resilience as the ability of a system or community exposed to hazards to resist, absorb, accommodate, and recover from the effects of a hazard in a timely and efficient manner, including the preservation and restoration of its essential basic structures and functions.

Natural catastrophes since 1980 have increased about fourfold. These events are hydrologic, meteorological, geophysical, and climatological. Hurricane Sandy was a Category 1 storm and in six hours, caused almost 70 billion dollars of damage striking New York and east coast cities. Hurricane Andrew in 1992 that caused over $26 billion of damages that occurred, with 600,000 buildings and houses destroyed. It was a Category 5 storm with 150 to 175 mile per hour (mph) winds.

World-wide, we are experiencing a wide variety of natural disasters, including floods from extreme rain events, wildfires, fires from droughts, and warmer weather that has led to more pests. Storm surges and rising sea levels as the ocean warms and raises the water are causing severe problems. Hurricanes, tornadoes, and even earthquakes are also disasters of concern globally. Twenty-one of the 30 most costly hurricanes have occurred since 2000. One reason is that there are so many people living on the coast and that is not going to change in our lifetime.

At stake, as severe climate effects continue to increase, are human lives, property, and damage costs. Over a million people have died from natural disasters around the world, and two billion people have been affected—this is almost a third of the world's population. There have been $4.5 trillion of damages just in the last 10 years. Last year, there were 700 major natural disasters around the world.

Environmental issues are becoming more prominent, more severe, and with a higher likelihood of occurring over the next several decades. While the awareness of disaster risk reduction has grown significantly in the last few years, the U.S. is still lagging behind in responding to these disasters. The U.S. population in 1970 was 200 million people and has grown today to 335 million, and many of them live in cities in coastal locations that are highly vulnerable to natural disasters. The U.S. is experiencing the highest losses of any other country in the world in the last 10 years, but the connection between building code and enforcement, for example, is very uneven. Ninety percent (90%) of the building codes in the U.S. are designed for 90 mph winds. This construction is not adequate when there is a hurricane of a 140 mph winds.

FEMA projected recently that $1 spent for adaptation can save $6 in response costs. Adaptation before disaster hits can reduce disaster losses by 60 percent. The cost benefit ratio for active resilience efforts is becoming more favorable. We're going to invest 50 trillion dollars in infrastructure to improve disaster resilience to climate change in the next 30 years.

What can we depend on from an insurance standpoint? Insurance is a partial solution, but not a complete solution. The national flood insurance program is capped at 250,000. and only 44 percent of the losses have been covered by insurance in North America. Last year's three hurricanes created $215 billion of damages, but only $92 billion was covered by insurance. Just because you have insurance—don't let that discourage you from taking resilient actions in your home or your business or your community.

Local resilience initiatives are important in our communities. Every time we resurface a street in my Village, we upgrade our drainage. We put in concrete culverts and we're cleaning out drainage pathways. My Village is 60 years old. In many of the neighborhoods a lot of the ditching and trenching has silted in and hasn't been addressed. So that's an example of the infrastructure responsibility that can be done at the local level.

The UN's Sendai Framework disaster risk reduction goals were established to address disaster reliance, including by governments and an increasing role by the private sector. Sustainable development goals have been set and seven global objectives have been established. The U.S. is a signature to the goals.

One of the goals is to substantially reduce the numbers of people affected by disasters and reduce disaster mortality. Another is to reduce economic losses, and another is to increase the number of countries that have national and local disaster risk reduction strategies by 2020.

Let's look at how we can strengthen disaster risk governance to manage risk. For example, can we take lessons learned in New York City from coastal flooding and apply them to Cape Town, South Africa? Can we take the lessons learned from Chicago in the early '90s of the extreme heat waves and apply that learning in Pakistan or Bangladesh? For tornado, storm surge, and hurricane warnings, we need to have better siren and communications systems. Think of Thailand, where 250,000 people died with no investment in a warning system.

We created something at the UN level called the private sector Advisory Group to get more private sector input in collaboration with the public sector to achieve the outcome and goal of the framework. There are chapters that have been formed now around the world and more are being formed that really bring the public and the private sector together.

I want to talk about just a couple of other things that are going on right now as well that are private sector contributions.

The 10 Essentials for Disaster Risk Reduction are an excellent framework and a good guide. The private sector is very involved. We created the first-ever disaster resiliency scorecard, which is an algorithm of about 110 characters to helps communities and businesses rank their exposures and resiliency.

"Built to Last?" is a video that is going to be premiered at the Cannes Film Festival next month. PBS has been showing it around the U.S. It's an excellent video, well done, and was done by the private sector as a tool to develop awareness.

Moody's and Standard & Poor's have now begun to rate companies on their disaster resilience. What exposures do they have and what liabilities might they have? We try to create a better vision of the future and climate change needs to be a part of that. We need to be looking back over the last five or ten years and then speculate what the next five or 10 or 20 or going to be.

The National Climate Assessment Report is prepared every four years by the government. I had the opportunity as one of the few private sector people to participate in this. There are chapters on adaptation and mitigation—a lot of really excellent information. It really builds a lot of awareness. I think it'll be a really impactful document.

Some of you may have heard of the global compact, you know, that's an industrial organization set up by the UN. There are principles that you agree to in the global compact. Almost 10,000 companies are members. They've established the global compact cities program with public and private sector collaborating. 20 cities have been tentatively selected with the public and the private sector of pledged to work together to improve resilience.

There's a wonderful program that the Rockefeller Foundation conceived of and implemented called the 100 resilient cities. $100 million dollars were set aside for a hundred cities. If your city was selected, you would get funding to hire a chief resiliency officer for two years, and you would get funding to and assistance to develop a resiliency plan. New York City and New Orleans were two of the first resiliency plans that identified about $20 billion. There are 32 cities in North America that received this support. It's only a two-year horizon, but many of the cities have seen the value and have continued on with the effort. Boulder, Colorado, is one of the cities and is the only non-coastal city on the list. It's been a phenomenal program and has really built lot of awareness. This really added a lot more momentum to looking at resilience.

The UN established a program in 2010 called "making my city resilient." There are 3,900 early adapter cities around the world in 28 countries. Seventy-three (73) capital cities have pledged to make their city resilient. They have access to one another and to a wealth of information that's available. Many of these 3,800 cities are outside of North America and particularly are outside of the U.S. I think the U.S. has about six cities that have signed up.

There is also an ISO standard that's going to be issued with sustainable development indicators for city services and quality of life with over 60 indicators. They've developed five aspirations, five levels of participation, and ultimately, a city resiliency index. Cities will compete on the basis of "my city is more resilient and you should live here." The ISO standard is a big step forward.

So, with that, I want to summarize. I hope I've given you a sense of the elevating your awareness even more.

The importance of disaster risk reduction needs to continue to grow because there's much more work we need to do. For every storm that hits us, we find that there's things that we can do differently. Better insurance is part of the solution and the insurance industry is working hard on this as well—firms like FM Global. FM Global has 5,000 employees and they believe that every disaster loss is preventable. FM Global is a mutual, owned by the shareholders, and by the people that have policies. The company has rebated last year $400 million to their shareholders because of losses that were not incurred.

Homeowners are becoming more and more aware of building codes. The good work that South Florida has done is a good example. The Sendai framework is a good framework for the public and the private sector to work together and we can really be a tremendously powerful team in addressing this issue.

So, I hope that you found this both interesting and building your awareness. I think we're going to really see a difference in the next five to 10 years, but it's going to take that long and there are still countless cities that have not yet implemented any kind of a resiliency strategy. We want to engage with them and help them. We want to look at these capital projects. We want to consider the weather of tomorrow not the weather of yesterday. We want to look at these risks and be able to define a better path forward.

Thank you for your attention today.

QUESTIONS

We have time for just a couple of questions. And while Dale is answering, if I could have the panel come on up and take their seats.

Are there any questions for Dale?

[question from the floor] You mentioned the national climatic assessment report that's coming out the end of the year and I wondered whether you could comment on some of the political implications of that report and what kind of politics we might see woven into it given the climate and the government right now?

Dale Sands: That's really a good point because we did spend a lot of time on that topic, trying to anticipate and guess what the response would be. My story was to focus on resilience and weather trends and natural disaster losses. They're all real and are not speculative. They're not "what if we're experiencing this," and so really we try to take more of an applied approach rather than a theoretical approach and we can build on some good practices where activities had been taken to lessen the losses and took more of a practical approach rather than a theoretical because of that concern. Thank you.

[question from the floor] Thank you very much for a very informative talk. Have you seen communities and cities and governments incorporating natural systems in ecosystems into resiliency planning and recognizing the natural systems that pull carbon out of the atmosphere? So, there's mitigation especially with forests and wetlands?

Dale Sands: The short answer is yes, and I think in my Village in particular where we've actually implemented Rain Gardens for flood control. In my area, where we had constant flooding, we put the Rain Garden in and we haven't had a flood there for many years now. We've got to do a better job at communicating the importance of that as an option.

Thank you—we have time for one more question. Yes, sir.

[question from the floor] Lots of great information on the economic impacts. I guess I'm not surprised, given the U.S. economy versus some of those other nations that we scored so poorly, but my question really has to do with land use related change. Much of what you talked about were building codes, but can you offer any comments on trying not to build in an areas where we're vulnerable?

Dale Sands: You know, that is an issue. I remember talking to an East Coast CEO who was so frustrated and ready to quit because the mayor had just decided to allow an apartment complex to be built over the CEO's objections. That's an ongoing battle. We've got to continue to work harder at getting officials to understand the risk that they're creating. We've got a way to go there. We really do.

Plenary Session
Panel Discussion

MANAGING ROW IN A CHANGING CLIMATE

Allen Crabtree

The Panel today will be discussing measures to deal with the management of ROWs in a changing climate. We are going to focus on this one aspect of global climate change and will refrain from debating the causes of climate change or measures to reduce global warming. These issues are too big to delve into here today, and we will leave them to climate scientists and politicians at the local, state, national, and international level to deal with—and we hope that they do so in a timely fashion.

Climate change, however, is real and is affecting all of us. The changes that we are seeing in our climate, and will continue to see in the future, pose some very real challenges for managers of ROW that provide critical services to consumers. These include heat waves and disastrous wild fires affecting electric transmission and distribution (T&D) lines, more frequent and extreme storms that bring flooding and ice storms, melting permafrost affecting pipelines, drought that affects hydroelectric flows, rising sea levels and impacts to coastal infrastructure including utilities and roads, and many other impacts on a scale and frequency that ROW managers have never had to deal with in the past.

Assessing and addressing these climate-related problems, as well as anticipating and planning for future problems, are now the focus of many ROW managers, from an operational, investment, and policy perspective. Our Panel today will discuss the impacts from meteorological, geophysical, hydrological, and climatological events, and the ways that vulnerability is being evaluated and operating assets are being protected and hardened.

I'd like to introduce the Panelists who will be discussing the issue of Managing ROW in a Changing Climate.

David Huard, PhD

Specialist, Climate Scenarios and Services

Co-coordinator, Energy program, Ouranos

Tour Ouest, 19e étage

Montréal, Québec H3A 1B9

Dr. David Huard is a specialist on climate scenarios and services and coordinates the energy program at Ouranos, a consortium on regional climatology. He has also worked as a consultant, providing scientific solutions to academics, governments, and public utilities in the fields of Arctic sea ice modeling, hydrological forecasting, extreme event probabilities, and climate data analysis.

Dr. Huard works at the interface between energy sector professionals and climate scientists, relaying the needs of energy professionals to academia, while also translating science advances into climate products and services that can be used by engineers and decision-makers. His mandate is to understand climate-related risks to energy sector activities and support efforts to implement evidence-based adaptation measures that reduce exposure to hazards or build resilience in the face of extreme events. He has taught at the college level and at l'Université du Québec à Montréal and has worked as a scientific consultant to various companies, departments, and agencies.

He holds a Doctorate in Water Science from INRS-ETE (Institut national de la recherche scientifique—eau, terre, environnement) and has conducted postdoctoral studies on modeling sea ice at McGill University.

Fletcher Johnson

Director, Vegetation Management (VM) and Ancillary Programs

Xcel Energy

Saint Paul, MN 55117

Fletcher Johnson is the Director of Xcel Energy's Vegetation Management & Ancillary Programs (VMAP) department for Xcel Energy. VM includes management of approximately 50,000 miles of electric distribution, 20,000 miles of electric transmission, as well as substation and gas sites utilizing more than 600 contracted line clearance workers. Ancillary Programs includes wood pole inspection and treatment for approximately 1.7 million distribution and 320,000 transmission poles.

This work is spread across the company's diverse eight-state geographic territory from the temperate forests of Wisconsin, mountains of Colorado, plains and agricultural areas, arid conditions of the Texas' panhandle, and urban areas throughout. Working with Xcel Energy for the last 20 years and with a great staff has brought the most learning. He believes you always need to be looking for new or innovative ways to perform the routine work.

He has a B.S. in Urban Forestry from the University of Minnesota and holds various vegetation-related credentials and certifications.

Thomas G. Krzewinski

Principal and Senior Geotechnical Engineering Consultant

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Mr. Krzewinski is an internationally recognized expert in the field of Cold Regions Geotechnical Engineering, with over 40 years of experience. He has considerable experience with geotechnical engineering investigations, laboratory testing, and facility/infrastructure design projects for heavily loaded foundations and familiarity with geotechnical conditions throughout the Northern Reaches of North America. His experience includes work on large infrastructure and industrial development projects such as the Trans Alaska Pipeline System (TAPS), the Red Dog Mine in Northwestern Alaska, many ADOT&PF transportation projects, railroad facilities, and hundreds of structures and earth embankments.

He holds a B.S. in Civil Engineering from the University of Minnesota and has completed Graduate Studies of Soils Engineering, Materials Engineering, and Geology at the University of Minnesota and Graduate Studies in Arctic Engineering and Earthquake Engineering at the University of Alaska.

Jeff Lukas

Research Integration Specialist

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Mr. Lukas is Senior Associate Scientist with the Western Water Assessment (WWA), a NOAA-supported program within the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder. For the past 20 years, he has collaborated with natural resource managers and other decision-makers in the Rocky Mountain West to identify and assess climate-related vulnerabilities and help them prepare for an uncertain climate future. He was lead author of the 2014 Climate Change in Colorado report for the Colorado Water Conservation Board, summarizing the latest science on observed climate trends and future climate projections for the state.

He has diverse experience working with forest managers in the Rocky Mountain region to better understand disturbance and vegetation change, particularly in light of climate variability and climate change. This work has included conducting tree-ring studies of fire history and stand development, synthesizing research on recent bark beetle epidemics, and examining the potential future impacts of climate change on forests.

He holds a B.A. in Geography from the University of Colorado Boulder and an M.S. in Forestry from the University of Montana.

Randy Lyle

Fire Program Manager

San Diego Gas & Electric

San Diego, CA 92123

Mr. Lyle manages the Fire Science and Coordination program under the Director of San Diego Gas and Electric's Fire Science and Climate Adaptation group. He was first employed as a Fire Coordinator with the company in 2007. The Fire Coordination group of five retired fire professionals provides a conduit between the utility and first responders and serves the company as Subject Matter Experts for all things fire.

His previous experience was with the California Department of Forestry and Fire Protection (CAL FIRE), where he retired as a Division Chief after 32 years of service covering all aspects of wildland fire prevention and control. Mr. Lyle was involved at the programmatic level with the California Fire Plan, GIS, and fire aviation.

Recently, Mr. Lyle helped shape the California Public Utility Commission's effort to produce a new High Fire Threat District Map. This map is now in use to determine where regulations governing electric utility design, construction, and operation apply across the landscape.

His past Incident Command System (ICS) qualifications included Incident Commander, Operations Section Chief, Air Operations Branch Director, and Agency Representative and he was a Unified IC on the 2003 Cedar Fire in San Diego [for the first three days]. Mr. Lyle has been closely involved in Wildfire Control Operations for the past 44 Fire Seasons and he brings a unique perspective to the tactical and strategic aspects of the impact of climate change on the frequency and intensity of wildfire.

Jim Martin, PhD

Chief, Gas Branch 3

Federal Energy Regulatory Commission

Washington, DC 20426

Dr. Martin is the branch chief for Gas Branch 3 in the Division of Gas, Environment, and Engineering, Office of Energy Projects, Federal Energy Regulatory Commission (FERC). He has worked for the FERC for 20 years. Prior to becoming branch chief in 2011, he managed the environmental review of several large pipeline projects and served as the Coastal Resource Manager for the Division. Dr. Martin is an environmental scientist with special experience in wetlands and aquatic resource issues.

He has two Masters' degrees in Environmental Science and Public Policy from Indiana University and a PhD in Environmental Science from George Mason University.

Biographical information on the panelists is available at the door when you came in to the Plenary Session and is also posted on the ROW 12 Website. The panelists' discussions will be included in the proceedings.

QUESTIONS FOR THE PLENARY PANEL

Sequence of questions and responses – I'll direct each question to one of the panel who has an opportunity to respond, followed by anyone else on the panel to add their supporting or detracting thoughts. War stories of specific incidents or measures (provided they are brief) are welcome if they help ground the comments. Our objective is to educate and broaden the outlook of the audience of issues and responses that they may not have had to deal with in their own work.

1. Building Resilience to Extreme Weather Events

The Global Risks Report for 2018 identifies that environmental risks have grown in prominence in the 13-year history of the organization, and the trend has continued to the present itself. Among the most pressing environmental challenges facing us are extreme weather events. The horrific damage done by hurricanes and flooding in 2017, as well as widespread power outages of ice storms in the U.S. Northeast, have strained the ability of communities and utilities to respond. What measures can be taken to build resilience into existing energy facilities? What measures can be taken to plan for future extreme weather events and be able to respond adequately to these risks?

Dr. Huard: If you already know and are equipped to deal with risks, such as flooding and wildfires, then there currently are design—values exist or norms or regulations to manage the disaster. Climate change, in my experience, brings very little risk, but it changes the intensity and the frequency of those events. What people can do is look into the future and see how those risks evolve and update design values and norms and standards to take them to count into their regular activities. The problem that I see currently is that those regulations are lagging behind the risk profile that utilities face.

What happens right now, at least in Canada and elsewhere in the world, is that utilities have large-scale research projects to evaluate the impacts of climate change on their activities and then they implement solutions without regulations. I'll give you one example of this. In the UK, 10 years ago, a study was done with academics and utilities to look at climate change impacts on the T&D in the electricity sector. One of the conclusions of that study was that temperatures would increase by eight degrees Celsius by mid-century, affecting the carrying capacity for overhead lines by around 4–9 percent. The increased temperatures would increase line sag and potential for arcing.

Western utilities then took their current ratings of 50 degrees Celsius and raised it to reflect the predictions and then increased the pole height for wooden poles between one and two feet. Building that kind of response in the typical maintenance schedule of the utilities cost will be nothing. Two feet more is invisible to the customer, but you're increasing your resilience to heat waves and potential lines arcs. My feeling is that by looking into the future and using the data that's out there about future conditions can be very useful. There are often large uncertainties around the predictions, but that's probably the most cost-effective way to deal with some aspects of climate change and to be flexible in managing risks.

To build resilience, it's not going to come from regulators. That's my experience. It's going to come from proactive utilities banding together and finding solutions that work for them.

I could give you examples in Quebec about the flooding. There's a trade-off when you mitigate risks. You also often provide incentives for people to increase their exposure to this risk. If you build a dam on a river to reduce likelihood of floods for many flood events, people will build houses closer to the river. For the most of the majority of events, the dam manager is able to manage the river flow, but then comes this one in 50 or 100 year event that exceeds the regulating capacity of the dam and then people get flooded and they're wondering why the utility couldn't respond to this additional risk.

My message is that by mitigating risk, we need to be careful about how people respond to this reduce risk level, to not create additional exposure to these same risks.

Moderator Crabtree: Randy Lyle – have you something to add?

Randy Lyle: David mentioned building T&D poles taller. I know there are utilities who have undertaken a wood-to-steel program in the backcountry. It was expected to take about 12 or 13 years to complete, but we'd like to do that a little sooner. One of the things they're doing is building taller. It's very visible. It gets the conductors up and out of the way of everything on the ground. It does seem to make sense to me.

Moderator Crabtree: David's comments reminded me of a controversy that is still ongoing in the State of Maine. We had some very bad ice storms and Central Maine Power proposed to build resilience into their existing network to respond to future weather events like it. The plan comes with a huge price tag and there's a great deal of pushback from the State Public Utilities Commission and from consumers. What is your advice to resolve issues like this?

Dr. Huard: There is no easy answer. What are the values that are going to help decide which options are best? People have different values about these things. Some people are willing to take risks and live in flooding areas. If they're willing to take this risk and consequences—I just don't want First Responders to get injured or killed because you have to respond to the negligence of other people. So that's where I draw the line. In terms of cost, we drastically underestimate the amount of money that we're going to have to put in to maintain the level of service that we're used to today. And that kind of scares me.

Moderator Crabtree: Dale—One of your comments was who should take the lead in building resilience. Should it be the government, the regulators, the utilities, or other entities?

Dale Sands: That's a very good question and it's not an easy one to answer. Remember the scourge of fires and the Great Fire of London, and the great fire in Chicago? Eighteen thousand (18,000) structures were burned and were rebuilt from wood to brick to help prevent future conflagrations. The insurance companies also took a lot of responsibility for the creation of fire departments.

And there is a parallel today with natural disasters. By expanding awareness and developing building codes and differentiating on insurance premiums from one facility to another, organizations like FM Global believe they can drive change in the right direction. It's hard to regulate this per se, although the Sendai framework calls for creating disaster risk reduction plans at the country level. I think that's something to consider at least in our U.S. market that the insurance industry can be a shaping force here.

Our infrastructure is definitely aging. I had the real privilege for four years to work for a gas utility when I was going through college. We actually replaced wood pipes that were still in use and we lost a lot of gas through those. You need to have also a repair and maintenance schedule that's perhaps a little more aggressive than what the accountants may say is appropriate.

Moderator Crabtree: We've been talking about resilience in existing facilities, but if we are planning and constructing new energy infrastructures, what's the approach to take? What should be done to plan for extreme weather events with new facilities?

Fletcher Johnson: I can answer this question just in terms of vegetation and having a vegetation program because that's my background. That's what I'd be most comfortable speaking to, and I would say that the risk that vegetation poses to an electric utility for T&D is perhaps one of the greatest risks in need of managing for reliability in terms of duration of an outage and frequency of an outage.

Having a solid vegetation program will actually mask a lot of deficiencies you may have in your infrastructure itself. If you don't have vegetation contact with your lines, you have some resilience and you're not going to notice problems. Conversely, if you are having a lot of tree contact, it's going to make a lot more obvious to you deficiencies in your infrastructure. Your infrastructure is not an overnight procedure. It takes lots of money and it takes lots of time.

Storm-hardening your system or distribution grid resilience is something that Excel Energy, along with some of our peer utilities, have been working on with EPRI. One aspect of that would be building into your system a level of coordinated failure. Let me—let me describe the picture of a typical distribution system. You would have your pole and your cross arm, you'd have your insulator. You'd have your conductor and then you'd have the wire tie connecting or tying your insulator. When you have something impacting that system, having the pole fail and cross them, fail is the worst case scenario. It's the longest duration of an outage, the most expensive to repair, and a risk of cascading failure as well. One pole falls and other ones may fall down the line.

So, with coordinated failure and designing that into your system, you wouldn't necessarily want the conductor to break. The most ideal would be to have the wire tie fail and have that be the weak link in that system. So, it's like a basic design concern. You need to just think it through. There's a risk with wildfire ignition potentially having the wire go down, but the benefit that you're going to have is you may still have the outage occur, but the response time to restore and the expense of restoring is far less to be able to put the conductor back up.

Another important thing to do is recognizing your aging infrastructure. Maybe it's pre-1960. Maybe it's more recent than that as well. It certainly has weakened due to age and likely was built to a lesser spec or design standard. So, knowing where that is and combining it with your exposure risk paints a more comprehensive picture. I'll use trees as the example. Having higher tree densities is one of the number one causes of issues both in blue sky days, but extreme weather as well, for utility. The condition of the infrastructure, as well as your exposure risk, can point you in a direction of where rebuilding your system should occur and targeting those dollars to relocate facilities to a more accessible location.

I think we mentioned design standard. One thing that Excel has done a number of years ago was with our design standard on the distribution side. For resilience, we have increased the pole class size by one size and over what had previously been on our design standard for probably decades similar to what David was talking about the UK, sure, in so that it helps protect against the pole being the weak link and failing again.

You know on the transmission side, I don't have a lot of examples of it. I mean our knowledge of it, our transmission system is already built to a more robust design standard to begin with, so we really haven't—on our on our system—changed that design spec anytime recently. One reactionary thing that we've had to do in the Red River that is the North border between Minnesota and North Dakota and is prone to flooding. We have a substation that is in that flood plain and we have had to build dikes around it, use removable flood panels in order just to manage that risk when we have had it because moving a substation. It's another example of "it's not an overnight procedure." It might it might not be something that you cannot get approval to move and so needing to have a reactionary protection method in there is something we've had to do lastly.

I think part of the question had to do with kind of developing your risk assessment processes. And this is where I will bring it back to vegetation again, but I think it could apply to anything. We're working to stop outages from happening to begin with. One thing you can do is investigate the outages that you do have. You need to have a definition of kind of what are you trying to accomplish? So, what could be preventable and non-preventable through your program? So, by investigating your outages, you're going to be able to identify data trends and determine where might your spec or guidelines need to be adjusted so that you can build more resistance or resilience back into your program again.

Moderator Crabtree: One of the things that panelists have touched on was rising water levels. Let me throw this to the whole panel.

2. Planning and construction of new energy infrastructure to deal with anticipated sea level rising and storm surges

Sea levels are predicted to continue to rise with the melting of polar ice caps, which in turn will have the potential for impacting coastal energy infrastructure, including transformers, electric distribution, pipelines, and roads. Extreme weather events will contribute to larger storm surges such as we saw with Hurricane Sandy in New York, with resulting devastating impact on energy infrastructure in the city. These extreme weather events have encouraged some utilities to develop a comprehensive risk-assessment process to prioritize the planning, siting, and constructing of new energy facilities. What sort of measures are being taken to help ensure that new energy infrastructures are resilient to the challenges that climate change is bringing? What sort of risk assessment process should utilities develop if they have not already done so?

You're in New York and your energy infrastructure and your transportation infrastructure is inundated by Sandy. What are you going to do to build new so that you'll have some protection against what's likely to happen again? Dale, you talked about Miami, and I've seen a lot of stories about the rising sea levels impacting everything. They're not just transmission lines, but also roads and sewage treatment plants and so forth for the panel. What should be done for rising sea levels and Coastal impacts. Building new and replacing old?

Dr Huard: Look at what Con Edison, the New York electricity utility, did years ago. They found one answer was to raise substations one meter. They realized that buried lines are harder to maintain and repair than overhead lines. They got $1 billion from the state to harden their infrastructures, so that that's something that's already ongoing. I don't know if that's like a model to replicate elsewhere, but certainly a good reference.

Moderator Crabtree: Anyone else have any experience in this particular conundrum?

Randy Lyle: It's not my daily expertise, but I work in the climatology group and I know that in San Diego Gas and Electric's service territory, there are two or three substations that, given current levels of sea level rise predictions, are expected to be inundated and need replacement before too long. So, the companies are beginning to look and assess and figure how they're going to reconfigure and where they're going to rebuild. All of that takes a lot of time, not to mention money, but it takes a long time.

Moderator Crabtree: Would that be relocation or hardening the facilities where they are?

Randy Lyle: Mostly they're talking about trying to relocate and just get out of the area altogether.

Moderator Crabtree: All right, but again, like you said Dale, this is a not a problem with a short-term solution.

Dr. Huard: I'd like to add one thing. Hurricanes hit one place in one spot and flooding from rivers is a regional problem. But rising sea levels affect all coastal areas at the same time. Everyone is going to be affected and that's something I don't—I don't think people consider that much, like the fact that it's a related event, not independent one.

Moderator Crabtree: Let us consider the impact of climate change on the melting of permafrost.

3. Melting of permafrost and impact on buried pipelines

There have been problems with pipelines that are buried in permafrost being exposed as the permafrost melts. Access roads built on permafrost to service oil and gas facilities in the north now have a shorter season when the roads are frozen and can be used for heavy vehicles to resupply the facilities. There are challenges even for above ground pipelines like the Trans Alaska TAPS system. How widespread is this problem and what measures are or can be taken to address the impacts? How significant is the potential for subsidence on energy and transportation facilities?

Thomas Krzewinski: Well, that's a whole bunch of questions. Alaska is dealing with significant coastal erosion due to increased severity of storms plus the degrading of the permafrost. A number of village relocation projects are happening as we speak here. I won't mention the villages, but there are several on the list as vulnerable on the north slope of Alaska.

A warming trend is affecting the active layer depths on the North Slope of Alaska, which in turn affects the viability of the road system and the gravel pad system. The seasonal roads are being affected by the warming trend and the shorter winter season. The winter construction season is typically used by the oil industry to do their exploration work to test for oil in winter and remove the evidence of that test before they decide whether they're going to proceed with production in that area. So, shortening that season has a drastic impact on the oil industry.

And then the southern reaches of the permafrost in Alaska which is 80 percent permafrost. So north of the Chugach Range on the southern part of the state, permafrost is probably going to be short lived. The warming trends are starting to affect that permafrost already. It's marginally frozen. It exists in a 32-degree Fahrenheit temperature. So, it doesn't take much of a warming trend to make that permafrost not viable any longer.

So, bouncing back to the North Slope the with the winter roads. There are firms that are looking at techniques for enhancing the ice and snow roads and paths for to increase the length of the season. They can operate by layering systems using insulation and placing high-strength plastic interlocking pads on top of the snow and ice. This allows a little bit of an increase in the season. All those things are being looked at.

For the permanent road systems and pad systems, the norm that was established during the heyday of oil industry back in the '70s and early '80s are being destroyed. The five-foot pad to keep the active layer within the constructed section is now becoming a six- or seven-foot pad because of the changes in the climate and that's affecting new construction making it more expensive. The old roads and paths are starting to degrade. So, it's a fairly serious consideration.

TAPS was my first project out of college was the trans-Alaska pipeline system. I was heavily involved in the design. It's a below-ground pipeline for 400 miles and a pipeline of blue chrome for another 400 miles. The blue chrome pipeline was designed to not be affected by permafrost, which means that it was either buried within the stable permafrost soils or bedrock.

The pipe itself is not settling, but the climate change has changed the degradation of the material over the pipe. More is visible when you fly over Alaska and look at the below-ground pipeline and see a depression that's occurring. Groundwater flows and surface water flows and maybe increased erosion in the area. They're things that will have to be dealt with in those fashions.

The above-ground pipeline was the design for handling permafrost areas that are now not stable. It involved a fairly robust thermal analysis, which placed thermosyphons, or heat extractors, on most of the piles along the pipeline and those heat extractors chilled down the permafrost during the winter time by extracting heat and chilled it down enough to survive the warm weather in the summertime where the thermosyphons are dormant.

The thermal piles are now being challenged by the warming trends. We have areas in the southern part of the pipeline that are settling. We have areas where the only permafrost left is the cylinder around the pile where the heat extractors are doing their job.

And we have areas that are heating. The active layer has increased so much that the frost jacking effect of the seasonal frost layer is starting to pull those pipes out of the ground.

The saving grace on the elevated pipeline is that it's very robust. It's built on a two-piles system with a cross beam and it's got a cradle system that's on a Teflon skid so small movements in the power system can be easily adjusted for. But as more and more areas are being affected by the degrading permafrost, different solutions will have to be envisioned and enacted. Some of those would be switching the piles to conventional static load piles without the heat extractors and just putting them in deeper and going to solid material to support the pipeline.

The engineering profession in Alaska is very sensitive to the warming trends that are being predicted. And those are very much becoming a part of the designs for future thermally designed facilities. So future facilities are designed to handle the warming trend for the life of the project and they handled in a couple of different ways. They can handle it by enough redundancy in the passive heat extraction process to last the life of the project or they can be designed to switch over from passive heat extraction to refrigeration active refrigeration at some men point in the project and the initial construction is done in a way that it can be switched based on a monitoring system that tells you what's happening in the foundations for the facilities. There is a very clear recognition of a major problem and probably a very expensive effort to engineer around it in the future.

Dealing with an immediate problem—is there a long-term solution? The long-term solution for roads is probably to go to more permanent roads, and I think we're should bite the bullet eventually here and understand that the North Slope oil production is here to stay and maybe we shouldn't be going through the expense of the winter road construction and trying to do winter pads and so on and so forth and just bite the bullet and build an all-season road.

Moderator Crabtree: David, have you, in your Canadian experience, experienced anything similar to permafrost problems?

Dr. Huard: Not so much. What we see is reduced sea ice cover in coastal communities that drives a lot of the additional erosion. Not so much new storms, but rather decreased protection from storms by reduced sea cover.

What we see in the north of Quebec is mostly good news for the electricity sector, because we're expecting more rainfall—like something around 10–15% by the mid-century. For electricity producers, that's like money in the bank for them in other areas. And what's interesting about Alaska and Northern Quebec and other Arctic countries is that they're undergoing increased climate change compared to, like, mid-latitude regions. They had some time to think about it and some of them have come up with interesting solutions. The Icelandic energy utilities have a couple of power stations that are internally glacier-fed. And as you might guess, glaciers with increased temperatures melt faster than 10 years ago. They started thinking about what—how this is going to impact their production. They made projections about the increased glacier melt into the design of new infrastructures and they upgraded some turbines based on those evaluations.

The Northern Regions are the place to ask how people are like handling these issues today and draw their experience to avoid making the same mistakes that they've done.

Moderator Crabtree: I hope you're all listening because you're going to be in the middle of it in the next few years. Let's switch gears a little bit from permafrost to wildfires.

4. Drought and wildfires impact on infrastructure

The past several years has seen a hotter and drier climate, especially in the American west. As a result, the increased flammability of fire fuel in the forests has promoted larger, more catastrophic wildfires, which have threatened electric T&D lines as well as above-ground pipeline facilities. What is being done to assess wildfire risks and implement fire prevention measures? In addition, wildfires allegedly caused by electric lines are recent concerns and question the adequacy of ROW maintenance procedures by utilities.

Randy Lyle: In response to the changing fire environment in California I'd like to show you a regulatory tool to try to assess fire risk and then mitigate the fire threat. Here is a graphic of a high fire threat map for California that assessed wildfire risk and provide for various fire prevention measures in areas designated as Tier 2 and Tier 3. To build the map we looked at historic fire perimeters and the modern landscape. We looked at fire perimeters back to 1960. We used a layer called fire thread from the Cal Fire Think Tank. Fire hazard severity zones drives some building codes and then known local conditions. The notion was that we're building this map for 10 years and it will govern regulations.

Tier 2 was described as where there was an elevated risk for destructive utility associated fires. Tier 3 was extreme risk for destructive utility associated fires. Different regulatory processes or rules and regulations applied in each of these Tiers. Tier 3, for example, applied Rule 18 and Geo 95 Rule 18 to prioritize safety hazards. It went down to six months and for them to be repaired in Tier 2 went down to 12 months to have those repaired.

Here are a couple more examples of the map uses—timing of trimming. I know a lot of folks are involved with trimming and conductor clearances in response to the grid starting fires. One consideration is public safety power shut offs. Not a popular notion. Our fire group kept telling our executives that the only way you can guarantee not to have fires is to shut the power off.

This template for California looked at the past and projects into the future. It could also be used as a template for the other Western States facing the same climatic change. The methodology was sound and it was a collaboration of regulators, scientists, utilities, and intervenors. This map would be a good tool for planning of new facilities and building resilience into old facilities.

Moderator Crabtree: Let me throw a question at you, Jeff. The hotter temperatures have an impact on insect species. Hotter and drier conditions in the western Forest have encouraged populations of bark beetles and other destructive insect species, which, along with water stress, have resulted in increased tree mortality and their susceptibility to wildfires. How extensive is this problem and what measures are being taken to address it, because it seems to me like your bugs are driving this problem? Is that true?

Jeff Lukas: To some extent yes, but as with many things we have it's an "it depends." It depends on the forest type. It can depend on the region and the climatology of that region. It depends principally on the time since investigation. So, if you've seen, you know, beetle-infested parts of the West after the trees died, you have a red phase that lasts a couple, three, four years with the needles are still on the tree and this is the most volatile period for fire risk. Then, once the needles fall, trees are going to call Gray phase for a period of a decade or more while they're standing. Your fire risk is actually reduce; you've changed the fuel complex. You've reduced fine fuels in the canopy. And so, your green trees are actually, in general, more hazardous than those standing great trees and Randy. Is this something that you plugged into your formula? Yeah. In fact, the thing that's not really captured on the map anymore something called Zone 1 and Zone 1, whereas tier 2 and 3 or Stanford 10 years old one is the timber mortality areas that will change as the CAL FIRE and for service change from year to year to year. So, they fall under the most extreme. Okay. So, to give an example from Colorado, when we had the very extensive mountain pine beetle.

Stations ramped up in the early to mid-2000s. There was an expectation from elected officials, our senators, all the way on down through the general public especially those living in those Mountain areas that the infestation would be inevitably be shortly followed by devastating wildfires and that didn't happen—very case you in Colorado, very few of the fires were in or exacerbated by Beetle infestation within the fire foot. Encouraging. Yeah, but we still had devastating wildfires. Right? And the point is that green forest green trees burn, really. Well, if the climate is in the weather, I should say is dry and hot enough to support fire spread. So, to get back to the bigger story of The Beetles. It is a big problem across tens of millions of acres. We expected to get worse in the future. These are—these are native beetle species—the pine beetles, the spruce beetle, and the pinion ipps beetles among many others. Those are the most notable ones. They have co-evolved with their host tree species pines and spruces and Douglas Firs over millions of years and these beetles tend to be at fairly low levels in the forest, you know, and what we call endemic levels until there is some kind of trigger. It could be a drought. It could be windrowing sending a lot of trees down in one area. It could be some other pathogen something producing additional stress on the trees and you have more susceptible trees.

The beetles overcome the trees' natural defenses and then it erupts into epidemic levels of beetles, you know, going up. The population has got many orders of magnitude. And so, these infestations have happened, you know, every several decades for a given area around the West. This is, you know, part of the system, part of the natural cycle if you will, but what happened really starting around 2000. It was the early 2000s onward to today is you have, you've had regional and synchronous epidemics of historically unprecedented size from Mexico all the way up through BC affecting, involving several different beetle species, mountain pine beetles being the best known, and contributing maybe half of the total infested area.

Unprecedented tens of millions of acres affected across the West and in Alberta and BC, and then impress it ended in beetles infesting trees all the way up to tree line, which had not been seen before infesting further north in Canada than it had seen previously infesting what had previously not known to be host species. Mountain pine beetle successfully attacking spruces and true firs and in Alberta, jumping from Lodgepole Pine into Jack Pine, which does not have natural defenses to the mountain pine beetle and is a major component of boreal forest. So, we're seeing unprecedented behavior in many different ways. It's truly a gloom and doom prediction, you know.

Moderator Crabtree: Oh, thank you. It just means more work for all of us Jim. We have not heard anything from you yet, but I want to throw something at you as the regulator on the panel. I remember back when I was actively consulting a lot of the work I did was wetland restoration and wetland creation is mitigation for highway projects and rights-of-way for transmission lines.

5. Drought and wetland mitigation measures

Wetland creation, restoration, or banking have been accepted practices to mitigate for the impact to and loss of wetlands from routing pipeline and electric transmission lines as well as highways. What could the impacts be if drought minimizes or destroys wetlands that were part of an impact mitigation agreement? How does the concept of "no net loss" factor in, and do performance bonds play a role? What could be the impact of proposed changes to wetland rules by the U.S. Government, including incentives for wetland banking?

Dr. Martin: Well, that's a good question. My agency doesn't have any regulatory authority over wetlands—that is the Army Corps of Engineers (USACE) and in conjunction with Environmental Protection Agency (EPA). There are a lot more wetland banks now than there used to be. I think there's 1,500 or so or approved banks in the U.S. That number has increased by 50 some percent over the last 10 years or so. The reason that banks are preferred by everyone is it's easier for a project to buy credits in a bank than to create its own mitigation and it's easier for the Corps of Engineers to monitor and maintain regulatory oversight over the mitigation. That's incentive for the bank and it's also a way for a new entity to generate revenue.

I talked to headquarters of the Army Corps of Engineers and their opinion is obviously very important, but there are eight regional divisions of Corps of Engineers. And each of those has multiple districts. A lot of the specific decisions and approaches are generated at the local as opposed to headquarters level. Headquarters indicated that, in general, something that they would call an act of God would not be something they would likely go after. Now, in addition to drought, there are catastrophic weather events and associated climate change. Some of those have been anticipated and written into some of the agreements between the Corps of Engineers and the bank owner. One District that I talked to has, in most of their bank contracts, escrow accounts to cover natural disasters, which includes droughts, but also hurricanes and other things. I don't think it's widespread, but I think it has been initiated. Whatever costs the bank more money will ultimately cost the purchaser more as those costs will get transferred. Mitigation occurs within a specific watershed where the impacts occurred.

Moderator Crabtree: Thank you Jim. And so, I understand there is no consistency in dealing with wetland mitigation banking. What I'm hearing you say is that here is a wonderful opportunity for our audience to be the experts on mitigation banking.

We have almost run out of time for the panel discussion. We always have lots of questions from the audience so I'm going to hold off the additional questions that we had prepared for the panel.

I would like to entertain any questions that the audience may have, on points that the panel or our keynote speaker have covered and others we have not.

Question from the floor: Yeah, sort of kind of a connected thing between Jim and Thomas there in Canada. We used to rely on winter construction as mitigation for wetlands. We got, you know, the northern half of Canada is muskeg until you get into the permafrost and in Northern Alberta. We used to build pipelines in the wintertime and happily call that mitigation for wetlands, but we're losing that construction season now, so I guess maybe Jim, do you see companies have to come up with more creative traffic ability solutions because you can't rely on frozen soil?

Dr. Martin: Those are things that we're looking at developing, and we're reviewing some in a project in Alaska right now. It's not an issue that's really come before us but we are exploring all manner of different measures that could be used in order to construct outside of the winter season and still afford a similar level of protection. I don't think that there's a summer construction method that can be done as cleanly as ice roads and that kind of construction, but you know, we're looking for suggestions.

Thomas Krzewinski: I can add a little bit. I think what's happened in the past for oil development in Alaska has been a bunch of secret plans made by each individual oil company and what that resulted in is a lot of arterial roads that probably could have been combined into a single road that serves a certain part of the oil field development rather than all these individual roads to separate pads and so on and so forth. That just takes upfront planning and getting the oil companies to at least accept that there's going to need to be a corridor established for all-season traffic that minimizes the disturbance to the tundra by getting rid of all those other arterial roads. It sounds like a tall order.

Question from the floor: As a third-generation Californian, I can tell you, I'm very tired of fire season and I can tell you that this concept of resiliency is maybe the only thing that will save us. I don't see it just as a utilities issue, because they have all these overhead lines. If those are put under ground, somebody has to pay for them. But what I see is if we get to a crisis where the insurance companies decide that they won't provide the insurance to our homes. We are going to have to do something to make them resilient, no matter what happens in fires. I think this concept needs to gain in our communities and needs to be gained at and done at my level at my home in my community.

Moderator Crabtree: Dale, do you want to comment on that? Obviously, someone has listened to your Keynote.

Dale Sands: It's a big issue and there's personal responsibility that needs to come into play. I mentioned the over-reliance on insurance, but when you hear that tornado siren, you better take it seriously. Think about Joplin, Missouri. A category five tornado and hundreds of souls lost their lives. I used to hear these tornado warnings and just ignored them, but not anymore. There is a real imminent threat in Oklahoma, Tornado Alley, where they're adopting a more rigorous fortified building code that I mentioned earlier. Not every home is going to be fortified, but it is a start. There are communities with code enforcement officers who are trying to become more proactive both to educate the residents, but also to engage with the private sector as well. That is not a quick fix.

Think of Sendai, Japan, where they had a tragic earthquake. They had an hour notice that the tsunami was coming. Japan is a really highly developed country and 20,000 people died. Many of them in their cars couldn't get out. Thinking about those evacuation pathways. There needs to have a resiliency plan and expect that it will be annually updated. Automotive companies are requiring their Tier 3 providers to have a resiliency plan after what happened to Toyota. There was an interruption caused by the earthquake that cost them a billion dollars of their supply chain.

CLOSING COMMENTS

Allen Crabtree

I would like to thank the panel for their comments today, and the audience for their insightful and timely questions. We tried to impart the message today that there isn't a single simple answer to dealing with climate change. All of us are affected by the changing climate no matter what your discipline and your expertise, your area of employment is. We are all affected by it.

As Jim said earlier in his introductory comments, we want you to take home from here at least one thing that impressed you that you may have an opportunity to develop further and maybe make some changes at your level. That's the charge that we give to you.

I have one minute left. So, if the panel has any 25 words or less—summation words they'd like to make to tell these people as they go from this plenary session, please do so. Let me start with Thomas: Any words of wisdom?

Thomas Krzewinski: My area of expertise is permafrost degradation. The cost of doing business in Alaska is very extreme and dealing with permafrost degradation is adding to the project cost. Costs for both mining and oil and gas projects are significant. Whatever we can do to streamline the process would be helpful to the economy of the state and the energy independency of the nation.

Dr. Huard: Contact technical consultants for support and advice for adaptation. I'm sure there are some near you. Contact them and get to know them to see what they can help you do. We're going to need a nerd interdisciplinary input to keep continuing to generate ideas. And thank you for inviting me to come here.

Fletcher Johnson: Understand the condition of your system and of your infrastructure now. Define what is your risk tolerance that you have and analyze your data to see how your system's responding to events now and that can help you determine your path forward.

Dale Sands: Become engaged in this issue in your community. In the private sector, when our employees go home at the end of the day, their public sector members get engaged. Work with your community to help raise the awareness of the importance of resilience. There are resources, like prevention web—must be a hundred articles a week that come out from that—about improving in your awareness. So, get involved and please join me. We have 140 companies. We probably need ten times at the amount of work to do and so join me in becoming a member.

Randy Lyle: I'm thinking in terms of ignition management and what that might mean to any of the disciplines here at my utility. We're initiating the collect ignition data, analyze that ignition data, and then act to mitigate.

Jeff Lukas: We need to watch for thresholds in both our ecological and other environmental systems, as we experienced one of your changes in climate will have responses from those systems will often be nonlinear and we need to look for thresholds, even especially those that have not been exceeded in the past.

If you have questions for the panelists, most of them will be here for the rest of the week. Corner them. The biographical sheet that you got when you came in also has their contact information. If you have a question, send them an e-mail.

I want to turn this now over to Carmen and Jim to close us out and send us off to lunch.

Jim Downie presented tokens of appreciation to the panelists and thanked them for their contribution to the symposium. He then had announcements about the location of the four sessions at the property and cautioned everyone to watch for cars in crossing the valet parking area to some of the sessions.

Carmen Holschuh had tips for speakers giving papers and dismissed everyone to lunch and wished them a productive symposium.

12th International Symposium

Environmental Concerns in Rights-of-Way Management

PART II

Climate Change

Bird-Caused Fires in ROWs

James F. Dwyer, Richard E. Harness, Tamara Gallentine, and Andrew H. Stewart

Keywords: Bird, Cause, Eagle, Electrocution, Fire, Hawk, Ignition, Raptor.

Liability risks are increasing for electric utilities when wildfires start on rights-of-way (ROWs) and then spread, causing injury or loss of life, damaging private property, or resulting in substantial firefighting expenses. Electric utilities invest in vegetation management (VM) to prevent ignitions resulting from contacts between trees and powerlines, but may overlook fire risks posed by bird contacts. Our objective was to provide new insight into bird-caused fire risk. We evaluated fire records from Beale Air Force Base in California in 2016 and 2017. In 2016, there were no bird-caused fires at powerlines. In 2017, there were five bird-caused fires, including one that burned 292 hectares (ha) (722 acres; 2.9 kilometers [km]^2) off the base. We also monitored online reports attributing fires in ROWs to bird contacts. From January 1, 2014 through December 31, 2017, we identified 93 reports, including 78 in North America. Most (n=45; 58 percent) fires in North America occurred during the summer months, and California had more fires (n=17; 22 percent) than any other state. Mitigating the risks of bird-caused fires in ROWs can be accomplished by retrofitting overhead electric systems to prevent birds from simultaneously contacting two or more conductors at different electric potential.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Powerlines have been implicated as ignition sources in large and destructive wildfires in various places around the globe, including the U.S. (Keeley et al. 2011), Australia (Cruz et al. 2012), Chile (Vargas 2016), and Spain (Guil et al. 2018). As a consequence of increasing costs associated with fighting and recovering from wildfires, electric utilities in the U.S. are coming under increasing scrutiny and liability for the effects of wildfires which start on utility rights-of-way (ROWs). For example, Cal Fire, the state of California's Department of Forestry and Fire Protection, recently initiated a series of lawsuits against several investor-owned and municipal utilities throughout the state to recover costs associated with fighting fires attributed to powerlines. Individual civil suits and class action lawsuits are also being pursued in California. To manage fire risk, electric utilities in fire-prone areas typically focus on clearing vegetation from ROWs because vegetation contacts with powerlines are a frequent ignition source. Clearing strategies usually center around mechanically trimming trees that have the potential to grow up, into, fall, be blown down onto, or drop branches across powerlines. Clearing sometimes also includes spraying herbicide or defoliant around the bases of power poles to reduce ignition risks from possible arcs and sparks generated by equipment operation.

Electrocuted wildlife can also cause fires (Lehman and Barrett 2002; Haas et al. 2005; Guil et al. 2018). In the U.S., wildlife species involved in animal contacts can include climbing mammals, climbing snakes, and birds. In this document, we focus on collecting evidence of bird contacts igniting wildfires. We do so to provide the electric utility industry with information that can be useful in evaluating the entire suite of fire ignition risk points. This also provides electric utilities with a more complete suite of information useful in assessing costs and benefits of implementing an Avian Protection Plan (APP) as described by the Avian Powerline Interaction Committee (APLIC 2006) and by the U.S. Fish and Wildlife Service (USFWS) (2005).

Bird-caused fires on distribution lines result from birds perching on power poles and simultaneously contacting an energized wire and a path to ground (phase-to-ground), or two energized wires of different electric potential (phase-to-phase). Either type of contact consistently results in electrocution of, or an electric shock injury to, the bird (APLIC 2006; Dwyer 2006; Dwyer and Mannan 2007), and occasionally results in an arc flash that ignites the bird's feathers. When the burning bird drops to the base of the power pole, a wildfire may be ignited. In a worst-case scenario, such as the case in Chile where 15 people were killed by a bird-caused fire (Vargas 2016), the consequences of such a fire may greatly outweigh the costs of prevention.

Our objective is to provide new evidence of bird-caused fire risk for electric utilities. The evidence presented here comes from two very different sources. First, we provide a summary of bird-caused fires at Beale Air Force Base in northern California. Second, we provide a summary of news reports of bird-caused fires from around the world. After demonstrating that bird-caused fires occur, we provide a summary of strategies to mitigate bird contacts.

METHODS

Beale Air Force Base

Beale Air Force Base (Beale) encompasses nearly 9,307 hectares (ha) (23,000 acres; 93 kilometers [km]$_2$) where nearly 4,000 military personnel are stationed. Distribution electric power is supplied to Beale by nearly 2,000 power poles. We evaluated records of wildfires at Beale in 2016 and 2017 to identify fires caused by bird contacts, and of those fires, to identify hectares burned on Beale. These fires were reliably identified by on-base personnel with relevant expertise. As a conceptual surrogate for fires spreading beyond ROWs, we also evaluated a fire caused by a bird contact that started on Beale and burned onto adjacent properties. The data from Beale were limited in scope, leaving open the question of whether concerns of fires caused by bird contacts with overhead powerlines had any application to electric utilities elsewhere. We address this question through our monitoring of Google Alerts.

Google Alerts

A Google Alert is a content detection and notification service provided by Google LLC ("Google", Mountain View, CA) wherein a user can provide keywords to Google, and Google then provides a daily e-mail containing links to new content including the keywords provided. From January 1, 2014 through December 31, 2017, we monitored the results of three Google Alerts. The Google Alerts were for the key words "bird (and) fire," "eagle (and) fire," and "hawk (and) fire."

Google Alerts do not include any filtering, so a Google Alert on "eagle (and) fire," for example, could provide links to any new article by any news agency with "Eagle" in the name any time those agencies placed an article on their websites containing the word "fire." To identify only new content describing a fire caused by a bird in a powerline ROW, we assessed each article in each Google Alert by reading the content of all articles which appeared to have the potential to be relevant. We then discarded articles that were not relevant—for example, bird electrocutions that did not start fires, fires started by bird nests on residential light fixtures, etc. Because the Google Alert data were published by journalists rather than professional fire investigators, any given report could be questioned. However, many reports attributed fire causation by quoting professional firefighters at the scene or by including photos of charred avian carcasses, increasing the likelihood that reports were correct. Reports originating from a wide variety of independent news sources were considered to have increased credibility. Although photographs were often included in news reports, none of those photos are included here due to copyright limitations. However, the web addresses for all news reports evaluated in this study are available by contacting the authors (see Additional Information). Interested readers may follow those links to view original reports and to view photos. Because web addresses often expire, we also copied the text and photos provided in the reports to our own archives. These archives are available for review upon request, but cannot be included as a publicly available appendix due to copyright limitations.

RESULTS

At Beale, zero of 15 fires in 2016 and five of 22 fires in 2017 were attributed to bird contacts with powerlines (Figure 1). Bird-caused fires resulted in 97 ha (240 acres; 1.0 km^2) burned on Beale (mean=48 acres/fire), and when one fire spread off-base, an additional 292 ha (722 acres; 2.9 km^2) burned. None of the bird-caused fires recorded at Beale were duplicated through Google Alerts.

Google Alerts enabled us to identify 20 fires in 2014, 34 fires in 2015, 16 fires in 2016, and 23 fires in 2017 (93 fires total) caused by bird contacts with overhead powerlines (Table 1 and Table 2). Of these, 78 fires were in North America (Figure 2), 10 fires were in Australia, three fires were in Europe, and two fires were in Asia. Of the fires in North America, 68 were in the U.S. (Figure 3), and these were most frequent in summer (Figure 4). Within the U.S., 17 fires were in California, seven were in Texas, and the remainder were scattered throughout 21 other states with no more than four fires identified per state. Many of the reports we identified through Google Alerts included images similar to those we collected at a bird-caused fire that we observed prior to beginning this work (Figure 5). For example, we received photos of burned vegetation surrounding a charred bird carcass at the base of a power pole.

Figure 1. Charred bird carcasses at the base of a power pole on Beale Air Force Base, where a bird-caused fire occurred on an electric power ROW in 2017

City	ST/PR /DI	Country	Date	City	ST/PR /DI	Country	Date
Galena	KS	USA	1/13/14	Bembridge	IOW	Scotland	6/17/15
Narrabri	NSW	Australia	2/11/14	Santa Barbara	CA	USA	6/19/15
Montville	CT	USA	4/7/14	Lewiston	ID	USA	6/25/15
Beaver	PA	USA	4/18/14	Emmett	ID	USA	6/26/15
Mumbai	MH	India	4/30/14	Segovia forest	SG	Spain	7/2/15
Wichita Falls	TX	USA	5/7/14	Kamloops	BC	Canada	7/3/15
Anthony	TX	USA	6/2/14	Alton	IL	USA	7/6/15
Lisbon	IA	USA	6/3/14	Cleveland NF	CA	USA	7/17/15
Stockton	CA	USA	6/16/14	Vernon	BC	Canada	7/23/15
Heppner	OR	USA	6//14	Noank	CT	USA	7/27/15
Tiffin	OH	USA	7/7/14	Roseburg	OR	USA	7/27/15
Kamloops	BC	Canada	7/8/14	Jamestown	CA	USA	7/30/15
Sequin	TX	USA	7/14/14	Spearfish	SD	USA	8/7/15
Pasco	WA	USA	7/29/14	Cedar City	UT	USA	8/18/15
Thunder Bay	ON	Canada	8/4/14	Cascade Locks	OR	USA	8/28/15
Wairarapa	MWT	New Zea	8/5/14	Bayswater	WA	Australia	9/6/15
Hope	AR	USA	9/26/14	Weiser	ID	USA	9/8/15
Los Angeles	CA	USA	11/7/14	West Kelona	BC	Canada	9/9/15
Sandy Hook	NJ	USA	11/14/14	Rosetown	SA	Canada	9/10/15
Clewiston	FL	USA	12/3/14	Berserker	QLD	Australia	9/16/15
Otago	OTA	New Zea	1/15/15	Reno	NV	USA	9/21/15
Welcome Bay	BOP	New Zea	1/20/15	Yreka	CA	USA	9/29/15
Taupo	NTL	New Zea	2/18/15	Fort Hall	ID	USA	10/2/15
Oyster Creek	NJ	USA	3/22/15	College Station	TX	USA	10/2/15
Dennis	MA	USA	5/18/15	Casper	WY	USA	10/2/15
San Diego	CA	USA	6/9/15	Brownwood	TX	USA	10/7/15
Martinez	CA	USA	6/16/15	Ellensburg	WA	USA	10/21/15

Table 1. Locations of bird-caused fires in ROWs identified through Google Alerts in 2014 and 2015. ST/PR/DI indicates State, Province, or District, depending on the county. New Zea indicates New Zealand. See text for Google Alert search terms.

City	ST/PR /DI	Country	Date	City	ST/PR /DI	Country	Date
Soor	CG	India	5/1/16	Steiner	TX	USA	5/4/17
Brick	NJ	USA	5/3/16	Salinas	CA	USA	5/18/17
Lubbock	TX	USA	6//16	New Cuyama	CA	USA	5/23/17
Maumelle	AR	USA	6/22/16	Three Rivers	CA	USA	5/26/17
Loveland	CO	USA	6/30/16	Smithfield	UT	USA	7/3/17
Banning	CA	USA	7/5/16	Los Banos	CA	USA	7/9/17
Rio Linda	CA	USA	7/8/16	Topeka	KS	USA	7/9/17
Wareham	MA	USA	7/18/16	Bella Vista	CA	USA	7/23/17
Livingston	MT	USA	7/22/16	Penticton	BC	Canada	7/25/17
Littleton	CO	USA	7/23/16	Baker	MT	USA	7/28/17
Spokane	WA	USA	7/25/16	Spokane	WA	USA	7/28/17
Berthoud	CO	USA	8/1/16	Redmond	OR	USA	8/2/17
Sandy	Bd	UK	8/17/16	Onida	SD	USA	8/2/17
Whately	MA	USA	8/23/16	Eden	NSW	Australia	8/18/17
Penticton	BC	Canada	9/5/16	Palo Alto	CA	USA	8/23/17
Santa Barbara	CA	USA	9/19/16	Great Falls	MT	USA	8/25/17
Great Falls	MT	USA	10/3/16	Penticton	BC	Canada	8/27/17
Pahrump	NV	USA	12/7/16	Regina	SA	Canada	9/5/17
Gippsland	VIC	Australia	1/15/17	Hampton	VA	USA	10/2/17
Carandooly	NSW	Australia	1/20/17	Napa County	CA	USA	12/5/17
Prescott	AZ	USA	4/20/17				

Table 2. Locations of bird-caused fires in ROWs identified through Google Alerts in 2016 and 2017. ST/PR/DI indicates State, Province, or District, depending on the county. New Zea indicates New Zealand. See text for Google Alert search terms.

DISCUSSION

Our high-quality data from Beale has very little possibility of mis-attributed causation, but the information was narrow in scope and limited to relatively few events. Our data from Google Alerts were low quality, with a higher possibility of mis-attributed causation for at least some events, but were broad in scope and included a large number of events. These two complimentary data sets, each pointing to bird contacts as causative for fires on ROWs, lend credibility to one another. Guil et al. (2018) conducted a similar analysis of fire ignition data from 2000–2012 throughout Spain and identified 30 records of wildfires caused by animal contacts, including but not limited to birds. Similarly, Pacific Gas and Electric (PG&E) reported 117 animal-caused fires to the California Public Utilities Commission (CPUC 2018) from 2014-2016. Presumably, some animal-caused fires were attributable to birds, though the animal type is not reported. Other studies, including Lehman and Barrett (2002), Haas et al. (2005), and Manville (2005) provide passing references to bird contacts resulting in fires, but do so without providing original data. Viewed collectively, our data, together with various other publications on the topic, suggest bird-caused fires may be occurring more frequently than is currently recognized. This suggests that the risk of bird-caused fires warrant ongoing monitoring and active risk management by electric utilities. Flawed risk assessment regarding fires may be particularly important because bird-caused fires tend to be ignited in landscapes where trees are rare (Guil et al. 2018), whereas common fire ignition risk mitigation strategies by electric utilities tend to focus on activities such as tree trimming to avoid tree contacts. Electric utilities are encouraged to consider bird-caused fires as an ignition source in their fire risk management strategies to avoid liabilities associated with this cause.

Because bird-caused fires derive from electrocutions, mitigating bird-caused fire risk can be achieved simply by retrofitting power poles to mitigate

Figure 2. Global Locations of Bird-Caused Fires in ROWs from January 1, 2014 Through December 31, 2017, as identified through Google Alerts. See text for Google Alert search terms.

Figure 3. North America Locations of bird-caused Fires in ROWs from January 1, 2014 through December 31, 2017, as identified through Google Alerts. See text for Google Alert search terms.

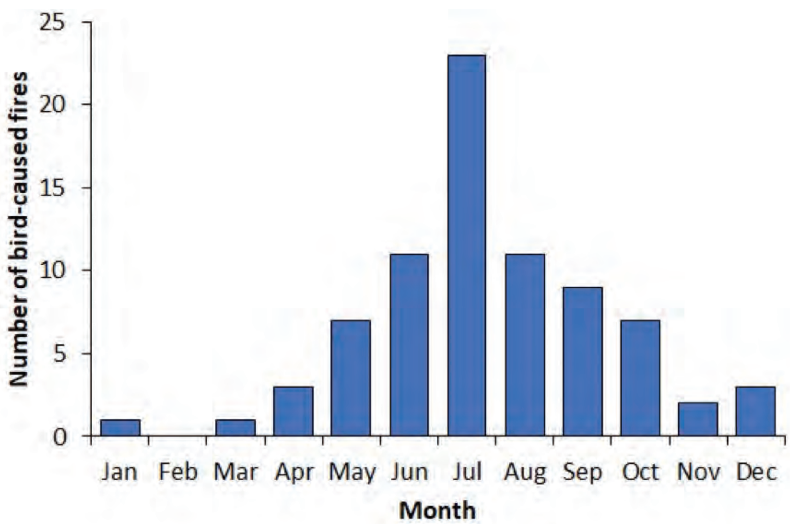

Figure 4. Month of Bird-Caused Powerline Fires in North America from January 1, 2014 through December 31, 2017, as identified through Google Alerts. See text for Google Alert search terms.

bird electrocution risk. Mitigation strategies are known as retrofitting, which includes processes termed redirection, separation, and insulation (APLIC 2006; Dwyer et al. 2017; Eccleston and Harness 2018). In all three approaches, the goal is to modify power poles to create 152 centimeters (cm) (60 inches [in]) of horizontal clearance and 102 cm (40 in) of vertical clearance between potential phase-to-ground and phase-to-phase pathways. These clearances are designed to allow perching by Golden Eagles (*Aquila chrysaetos*), a commonly electrocuted species in North America (Mojica et al. 2018). Because Golden Eagles are larger than all other electrocution-prone bird species in North America (except California Condors [*Gymnogyps californianus*] which are spatially limited), mitigation plans designed for Golden Eagles also protect smaller species (APLIC 2006).

Redirection uses perch discouragers and supplemental perches to shift birds away from high-risk locations on power poles, typically while allowing perching to continue at low-risk locations on the same pole (Dwyer et al. 2017; Eccleston and Harness 2018). Redirection was initially a preferred approach to retrofitting when problems of avian electrocution were first recognized in the U.S. in the 1970s (APLIC 2006). However, because redirection allows exposed energized equipment to persist, and electrocutions also can persist, redirection has become the least preferred mitigation strategy in current avian protection planning. Redirection now tends to be used selectively on locations where neither separation nor insulation can be effectively applied (Dwyer et al. 2016a; Dwyer et al. 2016b)—on overarm switches, for example. Redirection tends also to be used in coordination with insulation such as covering the jumpers in the case of overarm switches.

Separation is accomplished by reframing poles to increase the distance between potential contact points (Dwyer et al. 2017, Eccleston and Harness

Figure 5. View toward power pylon where a bird-caused fire occurred (*left*). View of bird carcass (flagged) near the base of the power pylon where a bird-caused fire occurred (*right*).

Figure 6. Incorrectly retrofitted power pole. Lower jumpers are covered, but no other retrofitting exists on the pole. The nestling just visible in the Red-tailed Hawk (*Buteo jamaicensis*) nest on the center transformer is at high risk of electrocution (*left*). Thoroughly retrofitted power pole. Triangles on each crossarm illustrate redirection, 10-ft upper crossarm illustrates separation, and covers on jumpers, cutouts, arresters, and transformer bushings illustrate insulation (*right*).

2018). Though ideal for new construction of tangent poles in wide ROWs, separation is impractical as a modification strategy for existing poles that would need to be reframed, impractical for equipment poles that require energized and grounded components in proximity to one another, and impractical in ROWs designed for standard 2.4 meters (m) (eight feet) crossarms.

Most current APPs focus on insulation because insulation does not have the same drawbacks as redirection and separation have (APLIC and USFWS 2005). In this context, the term insulation applies only to protecting against electrocution during incidental contact by birds, not during human contact (APLIC 2006; Dwyer et al. 2017; Eccleston and Harness 2018). Insulation offers three primary advantages over other mitigation strategies. First, when applied correctly, insulation does not allow exposed energized pole-top components to persist. Second, insulation does not require reframing of poles. Third, except for covering jumpers, insulation can often be applied with a hotstick from the ground, facilitating rapid, cost-effective reduction in bird electrocution risk. Insulation is widely used to cover all energized components on power poles. This includes conductor covers and dead-end covers on primary wires, jumper covers or insulated wires on jumpers, disks on switch insulators, covers on fused cutouts, caps on surge arresters, and covers on all energized bushings on transformers, reclosers, capacitors, potheads, and any other pole mounted equipment (Figure 6). Illustrations of insulation are available from a variety of sources, including APLIC (2006), Dwyer et al. (2017), Martín et al. (2017), and EDM International, Inc. (EDM 2018). In all cases where pole-mounted equipment is retrofitted with insulation, the insulation on jumpers connecting the equipment must extend inside the cover on the equipment because even very small seams where covers abut can allow electrocutions to persist (Dwyer and Mannan 2007; Dwyer et al. 2017).

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Additional Information

While conducting this study, we populated a Microsoft Excel document containing the title, story, and web address for each news report used in the Google Alerts portion of this project. This document also contains the date of the story, and the City, County, Region (State, Province, or District), and Continent where the reported fire occurred. This document is available by contacting the authors (*jdwyer@edmlink.com*) or by contacting EDM International Inc. (*info@edmlink.com*).

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Incorporating Potential Climate Change Effects on Valued Components in EAs: A Review and Case Study

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Keywords: Government, Human Use/Impact, Mitigation.

Environmental assessments (EA) consider potential project effects on valued environmental components. The temporal scope is for the life span of the project and is often measured in decades. In this time scale, climate change can have direct effects on valued components: for example, it does so by exceeding physiological thresholds of organisms, or indirect effects, through habitat changes or by altering biotic interactions with other species. Interactions between potential project effects and climate change effects can create additional risk; however, climate change effects on valued components are rarely considered. We posit that EAs should not only include an evaluation of potential project effects, but also the potential effects of climate change on valued environmental components and interactions between the two. Paradoxically, little guidance is available to practitioners regarding tools and approaches for such integration. Here, we review currently available tools and guidance and provide recommendations for practitioners. We further provide a case study of a recently completed EA for a Canadian mining project, focusing on the assessment of potential climate change effects and project interactions on five terrestrial wildlife species. We find that a scalable approach incorporating downscaled projections of climate change in the life span of the project, combined with vulnerability assessments for key valued components, provides a broadly applicable framework for integrating climate change into EAs.

Environmental Concerns in Rights-of-Way Management
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INTRODUCTION

Environmental assessments (EAs) are a tool to assess potential environmental risks of a proposed project. While methodologies vary across jurisdictions, the generic approach is to identify and estimate potential negative environmental effects resulting from the construction and operation of the project, propose mitigation methods to avoid, reduce, or offset those effects, then estimate residual effects remaining after mitigation. These residual effects inform the determination of the significance of negative environmental effects, which in turn informs the decision whether to permit the project.

Climate change confounds the process of EAs in three important ways. First is the effect of the project on climate. Most projects emit some greenhouse gases (GHGs) through construction and operation, thus contributing to global climate change at some scale. It is important to estimate these emissions to allow decision-makers to assess the relative risks and benefits of a proposed project and to determine the degree to which it hinders or contributes to national, regional, and local commitments to reduce GHGs.

Second, climate change can have direct and indirect effects on project infrastructure. Extreme weather, sea level rise, permafrost thawing, and increased frequency and duration of flooding or wildfires are all examples of climate change effects that can alter the viability of a project. Many jurisdictions require an assessment of the effect of the environment on the project. In an era of changing climate, these effects cannot be assumed to be consistent with historic trends. Thus, assessments of effects of the environment on the project should include if and to what degree climate change may have an influence.

Finally, EAs consider potential and residual effects to valued environmental components (VECs)—an element of the environment that has scientific, social, or cultural significance as a result of the construction and operation of the proposed project. To do so, the current (baseline) case is compared against a future case that incorporates the construction and operation of the project. This comparison assumes ecological conditions remain relatively consistent between the baseline and future case. In many cases, especially in long timescales, this assumption can no longer be made. Thus, an understanding of how climate change may affect the future case provides for a more accurate assessment of potential and residual project effects.

We take the position that climate change effects should be incorporated into EAs to better identify risks to VECs. This will help to design more effective mitigation measures, long-term monitoring approaches, and adaptive management measures. We discuss approaches to integrate climate change into EAs and we provide the example of an EA for a mining project on Baffin Island, Nunavut, Canada.

Scope of This Review

Proposed projects may interact with climate change in three ways. The International Association of Impact Assessment (IAIA) recommends the following considerations to address the scope of climate change in EAs (adapted from Byer et al. 2018):

1. Estimated GHG emissions of a project, including:
    a. Contributions of the project to climate change.
    b. Measures to mitigate emissions.
2. Effects of climate change on project infrastructure.
3. Effects of climate change on project-associated valued components (i.e., environmental, social, or economic values), including:
    a. Assessment of climate change effects on valued components and interactions with potential project effects.
    b. Mitigation of those effects.

This review focuses primarily on the third. That is, identifying, assessing, and mitigating risks to valued environmental components as a result of climate change, including potential interactions with project effects.

The following clarifies terminology used in this paper. First, a distinction can be made between climate change mitigation and adaptation. Climate change mitigation refers to efforts to reduce GHG emissions in order to lessen the effects of climate change. EAs may be used as a tool to assess the GHG contributions of a project before they occur. Compliance with local, regional, or national objectives or commitments may be considered here.

Climate adaptation includes actions taken to help communities and ecosystems cope with changing climate conditions in order to moderate harm (Field et al. 2014). In the context of EAs, adaptation includes predicting and adapting to climate change effects to the project itself or VECs.

Project mitigation differs from climate mitigation in that it refers to efforts to reduce the residual effects of the project on the environment (or social or economic values).

Potential Climate Change Effects and Project Interactions

Projects and climate change can have both direct and indirect effects on VECs. Direct effects from projects are considered those that result from physical habitat alteration. In terms of species and ecosystems, this would include the removal of a species, community, or their habitat. Indirect effects occur where a project component or activity influences a species or ecosystem indirectly. For example, edge effects can alter the microclimate of a forest stand; noise may cause avoidance; roads can create impediments to movement corridors; hydrological alterations can alter the function of a wetland community.

A comprehensive summary of

potential climate change to species and ecosystems is not possible here; many will likely not be known until they occur. However, it helps to categorize potential effects to help identify where risk may occur.

Direct effects of climate change are those that affect the physiology of a species. This can affect survival or reproduction, for example, through exceedances of physiological limits, changes to sex ratio, exposure to weather-related disturbances, and changes to daily period.

Indirect climate effects refer to those that affect the conditions species depend on for survival and reproduction or ecosystems or ecological communities depend on for existence. Effects to habitat quality and quantity are considered indirect. These can include breeding, foraging, migratory, or winter habitats. Changes to vegetation communities can occur through drought, extreme weather events, fire frequency and intensity, and many other factors. Aquatic communities can be affected by water temperature, salinity, alkalinity, and a host of other factors.

Project and climate effects can be negative or positive. Negative effects of projects are typically considered in EAs, but positive effects through offsetting, habitat compensation, or other management measures should also be accounted for.

Potential project effects are estimated in an EA by comparing a baseline case against a conceptual future case in which the difference between the two is the construction, operation, and (sometimes) decommissioning of the project. Other factors are held constant so that the comparison is completed as a snapshot of current conditions. The influence of other projects is considered in the estimation of cumulative effects, but not project-related residual effects. The lifespan of many projects stretches into decades, well within the range of measurable effects from climate change. Thus, risk to a species or organism is not captured entirely when the effects of climate change are not considered. We argue that a full accounting of the effect of multi-decadal projects on VECs ought to include changes to the baseline case resulting from climate change.

Interactions between project effects and climate change effects can happen when both affect a particular VEC, whether positive or negative. Interactions can be additive, where both factors push in the same direction; they can be subtractive, where one is positive and one is negative; and they can be multiplicative, where the scale of the effect of one factor influences the scale of the effect of the other.

Guidance on Incorporating Climate Change in EAs

The incorporation of climate change into the EA process is an evolving field. The inclusion of climate change in EAs is not known to be required by legislation or regulation in any North American jurisdiction, although the federal Impact Assessment Act (Bill C-69, third reading June 20, 2018) requires that impact assessment of a designated project must take into account "the extent to which the effects of the designated project hinder or contribute to the Government of Canada's ability to meet its environmental obligations and its commitments in respect of climate change" (House of Commons of Canada 2018).

Irrespective of regulation, the scope of an EA is often defined with the inclusion of input from government regulators and other stakeholders. Increasingly, these stakeholders are requesting the inclusion of climate change concerns into the process.

Several jurisdictions have provided guidance on incorporating climate change into EAs. The Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment (Canada FPTC 2003) provides general guidance to EA practitioners to include climate change considerations in project EAs. It includes methods to estimate a project's GHG emissions, sources of information for practitioners, and a methodology to "encourage the consistent consideration of climate change in the EA process across federal, provincial, and territorial jurisdiction…" The document focuses primarily on the estimation and mitigation of GHG emissions and identification of risks to the project from climate change.

Provincially, Ontario (ON Ministry of Environment and Climate Change 2017) and Nova Scotia (Nova Scotia Environment 2011) have provided non-binding guidance documents on incorporating climate change into EAs.

The U.S. Council on Environmental Quality published guidance for Federal agencies on how to consider GHG emissions and climate change effects in National Environmental Policy Act review in 2016, which was subsequently withdrawn in March 2017 (U.S. Council on Environmental Quality 2017). At the state level, only Massachusetts provides guidance on incorporating climate change into EAs (Commonwealth of Massachusetts 2015), but several state agencies, such as the Washington Department of Transportation (Washington State Department of Transportation 2014), and the California Department of Transportation (California Department of Transportation 2011), include assessments of potential climate change effects in their planning process. A useful summary of available guidance is provided by the Columbia Law School Sabin Center for Climate Change Law (Columbia Law School 2018)

Previous Examples of Incorporating Climate Change in Mining EAs in Canada

A review of the integration of climate change into mining EAs in Canada was completed in 2014 (Rodgers et al. 2014). They reviewed six past mining EAs completed between 2004 and 2010 to assess how well climate change was addressed. They found that the approach to environmental impact assessments focused primarily on the

Project's impact on the environment and lacked emphasis on the implications of changing environmental baselines or the impact of the changing environment on the project. The attention to climate change impacts and adaptation within the mining EAs was limited and inadequate, with inconsistencies and unsystematic approaches to addressing the risks. Data availability, data quality, climate science expertise, uncertainty in model results, and differing regional expectations were noted as challenges within EA development. The manner in which climate change adaptation was considered and applied throughout the selected EAs appeared to be largely focused on enhancing the resiliency of mine site infrastructure, predominately for operational periods, and seldom as part of closure and post-closure phases. They found that there is a need to utilize more robust methods of assessing climate change risk in development of adaptive management strategies as a means of dealing with future weather and climate. They further found that much of the available guidance on incorporating climate change impacts and adaptations into project-level EAs were dated and inconsistent across provincial/territorial boundaries.

METHODS

Approaches for Integrating Climate Change

The following presents a framework for addressing interactions between climate change and proposed projects. Other tools and approaches are likely available and worthy of merit. Practitioners are encouraged to complete research of their own to ensure the tools and approaches used are best suited for project purposes.

Scoping

A critical step in the development of an EA is the definition of a Terms of Reference (TOR) that clearly identifies its geographic, regulatory, and scientific scope. The scope of consideration of climate change interactions should be included at this stage so that expectations and approach are agreed upon by proponents, regulators, and other stakeholders. Many projects will not justify the inclusion of climate change due to geographic location, existing conditions, or project or temporal scope. Important considerations to include during the development of a TOR are:

- *Project lifespan.* Projects with a short lifespan may have little or no interaction with climate change. Those planned on a decadal time scale will likely experience changing conditions as a result of climate change.
- *Existing conditions.* Projects may be more or less vulnerable to climate change depending on location. Concerns such as sea levels rise, melting permafrost, or risk of increased frequency or severity of floods and wildfire should be considered.
- *Existing climate change concerns or stakeholder interests.* Regulators or stakeholders may have a particular interest in potential interactions with climate change. Existing concerns with particular species, ecosystems, or vulnerability of the built environment may warrant inclusion of climate change in the TOR.
- *Regulatory framework.* Few, if any, jurisdictions currently require the inclusion of climate change in EAs. As regulations evolve, this may become more commonplace. In some jurisdictions, proponents are required to assess potential effects of the environment on the project; in these cases, climate change should be considered as a contributing factor. In other jurisdictions, proponents are encouraged through guidance to consider the effects of climate change during the cumulative effects assessment phase. Jurisdictional regulatory bodies should be consulted early in the planning process for guidance on these matters.

Conceptual Framework

Integrating climate change into EAs requires responding to one or more of the following questions:

1. Which GHG emissions will the project have in its lifespan and how could those emissions be mitigated, if necessary?
2. What effect will climate change have on the project?
3. What effect will climate change have on VECs, do they interact with project effects, and how could they be mitigated if necessary?

Tools for Assessing Potential Effects and Interactions

Emissions Estimates

Estimates of lifetime GHG emissions meet question #1 of the conceptual framework; namely, what emissions will the project have within its lifetime and how could these emissions be mitigated if necessary. Both direct and indirect emissions can be considered. Direct emissions would be those resulting from construction, operation, and decommissioning of a project. Indirect emissions would result from the effects a project may have on energy use and balance. For example, a pipeline may consider their upstream emissions pathways that include emissions associated with mining, transporting, and processing as direct effects. Indirect effects may include the effect of fuel consumption following refinement and delivery as indirect effects. These may be offset by anticipated changes to consumption of other fuels among customers. Some emissions may largely take place outside of the regulatory jurisdiction; for example, emissions from a project shipping fossil fuels offshore would largely take place outside of the regulatory jurisdiction.

Quantified emission pathways may or may not include those associated with shipping offshore and consuming elsewhere.

Downscaled Climate Projections

Any estimate of potential climate change effects relies upon projections of changes to climate parameters, such as temperature and precipitation; however, Global Climate Models (GCMs), as their name suggests, are run at the global scale and projections are not always applicable at the local or regional scale. GCM grid cell sizes (i.e., the scale at which projections are made) have been steadily decreasing with time, but projections of change are still relatively coarse, often as large as 100 km (McSweeney and Hausfather 2018). Projections of change at the project scale will often benefit from downscaled climate projections that are calibrated to local or regional historic and current climate parameters.

Downscaling can be achieved through “dynamical” or “statistical” downscaling (Murphy 1999). Dynamical downscaling uses Regional Climate Models (RCMs) that are similar to GCMs, but run at the regional scale and are able to produce projections at a finer scale (Liang et al. 2004). Statistical downscaling uses observed local or regional climate data to define a statistical relationship between global and local climates (Wood et al. 2004; Hayhoe et al. 2004). While both processes can be used to reduce grid scale size and provide localized projections, neither can eliminate uncertainties associated with the GCMs from which they were derived. Statistical downscaling performs best when local or regional data are abundant, but assumes that fundamental processes will remain true as the climate warms. As a result, it is poorly constrained for long-term future climate projections (McSweeney and Hausfather 2018). Dynamical downscaling is considered more robust, but can require substantial model development and validation so that process can be captured at a finer scale (McSweeney and Hausfather 2018).

Several sources of downscaled climate projections are available to end users, including the Pacific Climate Impact Consortium (PCIC 2018), Climate North America (Wang et al. 2016), the Scenario Network for Alaska and Arctic Planning (SNAP 2018), and Data.gov (Data.gov 2018), among others. Most or all sources provide projections from multiple models; averaging among models is often an option. While these sources provide publicly available data, expertise is necessary to help guide users in choosing appropriate models and interpreting projections properly. Generally, multiple projections should be used, as described below, that may use one or more GCM or RCM, or that employs model averaging using several models as input. It is recommended that end users seek the input of climate scientists for guidance in these decisions.

Scenario Planning

Projections provide estimates of climate parameters based upon a set of assumptions regarding global emissions pathways. A key set of assumptions is the emissions pathway utilized in model runs. These are potential pathways for GHG concentrations in the atmosphere based upon societal behavior, such as GHG emissions, land use changes, energy use, and technology. Most model runs use one or more Representative Concentration Pathways (RCPs) (Vuuren et al. 2011) that are an agreed-upon set of plausible emissions pathways.

Forecasting the effects of climate change should rely upon the use of two or more RCPs. This will provide a range of plausible outcomes to help interpret potential climate change effects. Scenario planning is a structured decision support mechanism to help navigate uncertainty associated with climate change projections and effects and facilitates discussion of potential implications. Scenario planning allows for the incorporation of quantitative and qualitative data and diverse viewpoints to examine the potential implications involved in decision making (Peterson et al. 2003).

Within the context of EAs, scenario planning can be used for scoping, stakeholder engagement, development of mitigation measures, and decision support. At each of these stages, scenario planning can allow a fuller examination of potential outcomes, the implications of project development, and decisions, as well as a sharing of viewpoints among several stakeholders. By facilitating dialogue, it can help develop trust among proponents, regulators, and stakeholders. This approach is largely untested to date in EAs, but has substantial potential for resolving difficult decisions and facilitating a broader understanding of potential climate change effects.

Vulnerability Assessments

The effects of climate change on project valued environmental components can be assessed with vulnerability assessments. Broadly speaking, a vulnerability assessment is used to identify the relative vulnerabilities of the human-built environment, species, ecosystems, or ecosystem services to climate change (Nelitz et al. 2013). They are primarily used to assess species’ risk to climate change, but can be used for any value that is potentially at risk. The key attributes of an effective vulnerability assessment is that they address potential risk pathways in a structured, repeatable manner.

Vulnerability assessments provide estimates of the vulnerability of species through describing several key interactions between them and potential climate change effects. They do so using a structured, repeatable approach incorporating climate change projections in the time period of interest and knowledge of the species’ biology (Glick et al. 2011). In this context, vulnerability is considered the product of exposure and sensitivity to climate change as mitigated by adaptive capacity and can be written as a formula: vulnerability = (exposure * sensitivity)/adaptive capacity.

Estimates of the vulnerability of species are achieved by assessing interactions between climate change and key factors such as phenology, habitat, and biotic interactions. This helps to rank the relative importance of each of the key factors, assess the uncertainty of existing knowledge, and provide an estimate of both the vulnerability of a species as well as the uncertainty associated with that estimate.

Several tools exist to complete vulnerability assessments, but each may have its own biases. As a result, an assessment of the vulnerability of a species on its own should be carefully interpreted. Further value, however, is gained by assessing the relative vulnerability of two or more species using the same approach. While biases may still occur, they will be consistent among taxa.

The comparison of vulnerability of two or more species helps to identify which species are at greater relative risk to climate change, what key factors are consistently important influences of vulnerability, and where the key risks and uncertainties lie for each species. Further, they help to differentiate areas in which the knowledge of potential effects is relatively strong and where more research or information is necessary.

As noted, several tools exist for completing vulnerability assessments. Two more commonly used tools include the Climate Change Vulnerability Index (CCVI) created by NatureServe (Young et al. 2015) and the System for Assessing Vulnerability of Species (SAVS) created by the U.S. Forest Service (USFS) (Bagne et al. 2011). CCVI was considered for this project but was found to be a substantially data-driven approach, relying on estimates of regionally specific downscaled climate change projections.

Landscape Modeling

Landscape modeling can be used to simulate changes with time that result from climate change and other ecosystem or land use changes. Numerous models and model types can be used. Project objectives and scope are important considerations for determining modeling approach(es) (Kerns and Peterson 2014). As with the selection of GCMs, projects benefit from the use of multiple models since each provides one plausible scenario, rather than a prediction of future state. While landscape model outputs are spatially explicit, projections are generally not meant for interpretation at the site scale.

Two approaches that are predominantly used include bioclimate envelope modeling and state-and-transition modeling. Bioclimate envelope models (BEM) infer the geographic area in which a species occurs according to their environmental requirements (Hijmans and Graham 2006; Watling et al. 2013). Climate projections can be used to define probable shifts in habitat envelopes to spatially predict the area suitable for the occurrence of a particular species. This approach provides a useful heuristic, but has limitations in that it does not take into account interactions among species and with the environment, nor does it include phenological, demographic, or behavioral adaptation (Watling et al. 2013). Incorporating these elements requires mechanistic niche modeling (Kearney and Porter 2009), which can be used alone or in combination with climate envelope modeling. Mechanistic models are much more data intensive than climate envelope models and require species-specific information on the effect of climate on fitness traits, which is only available for a relatively small number of species (Watling et al. 2013). Climate envelope models, while more general, are more broadly applicable to a wide range of species (Lawler et al. 2009) and comparisons with mechanistic models suggest generally broad agreement between the two (Kearney et al. 2010).

Dynamic global vegetation models (DGVM) predict changes among vegetation communities over time based upon climatic information such as precipitation, temperature, and water vapor at a large scale. They do so by replicating fundamental ecological processes, such as competition and water and nutrient uptake and loss. An example is the MC1 (Bachelet et al. 2001; Lenihan et al. 2008), which is a DGVM that uses soil and monthly climate data to grow vegetation as time passes. It has biogeography, biochemistry, and fire disturbance modules and can be used to generate simulations within multiple decades at the regional scale. The Vegetation Dynamics Development Tool (VDDT) is a vegetation growth model that moves cells between vegetation classes (i.e., defined by a combination of dominant cover and structure) depending on pathways that depend on deterministic or probabilistic transitions (ESSA Technologies Ltd. 2007).

State and Transition Models (STM) have been used for years to predict spatially explicit, landscape-level changes to vegetation cover with time—most commonly in forestry and rangeland management (Daniel and Frid 2011). STMs were first developed in the 1980s to better describe and predict vegetation cover states (Westoby et al. 1989). STMs introduce a predictive factor by identifying the probabilities of move from one state to another (Daniel and Frid 2011). These models can predict changes among different land cover states that can occur due to land use patterns, fire, foraging, or other inputs that can affect vegetation cover (Bestelmeyer et al. 2017). STMs can be coupled with other model types, such as Timber Supply Models, to help guide management decisions (Carlson and Kurz 2007; Klenner and Walton 2009).

A State and Transition Simulation Model (STSM) is a vegetation model. It is a generalized landscape modeling framework that allows for multiple transition types at each time step and allows for additional state variables for each cell (Czembor and Vesk 2009; Daniel and Frid 2011; Daniel et al. 2016). Recent developments allow for both discrete and continuous state variables (Daniel et al. 2018).

Since landscape modeling is based in part upon ecosystem characteristics, projections of change in ecosystem parameters from climate change can be incorporated. The attributes of STSMs make them ideal for incorporating climate change into models of vegetation dynamics. Again, the combination of models to be included should be carefully considered depending on project scope and objectives. Parameters such as the end result, interim states, rate of change, or the change mechanisms may be important depending on project objectives (Kerns and Peterson 2014).

CASE STUDY

Integrating Climate Change Effects on Valued Components into a Mining EA in Nunavut, Canada

Here we present a case study of the integration of climate change into an EA for a proposed mining project on Baffin Island, Nunavut, Canada. All three components of the conceptual framework—GHG emissions of the project, the effect of climate change on the project, and the effect of climate change on VECs—were addressed in the EA; however, we focus primarily on the last component.

The Nunavut Impact Review Board (NIRB) is the regulatory agency responsible for reviewing proposed projects within the Territory. For several reasons, NIRB has become increasingly concerned about the effect of climate change on infrastructure, species, and ecosystems in recent years (Barry 2017). Climate change is occurring more rapidly in the Arctic than many other areas and the future rate of warming is expected to exceed other areas (Larsen et al. 2014). This is causing concerns for the human-built environment, especially with regard to damaging ice conditions, floods, and melting permafrost that can damage and undermine buildings and infrastructure (NRTEE 2009). Changes to Arctic ecosystems have the strong potential to exacerbate dwindling populations of keystone species such as caribou (*Rangifer tarandus*) (Forchhammer et al. 2002; Post and Forchhammer 2008) and polar bears (*Ursus maratimus*) (Derocher et al. 2004). Many indigenous populations rely heavily on subsistence hunting of species (such as caribou) that are at potential risk to climate change; extreme weather events and less predictable ice development can put local human populations at risk and complicate travel (Laidre et al. 2008; Parkinson 2010; Brubaker et al. 2011). Finally, the Canadian Arctic is a largely undeveloped area that has seen substantial developmental pressures in recent years due to increased mining activity, oil, and gas exploration and the potential for the opening of shipping routes as a result of declines in sea ice.

As a result, the NIRB has increasingly requested proponents to address climate change concerns in EAs. A recent submission for a mine development was denied in part due to uncertainty regarding the potential effects of climate change. The approach taken in this project was an attempt to provide further information regarding potential climate change effects and interactions with project effects and to address some of the uncertainty through generalized and project-specific research.

Climate change to terrestrial wildlife and birds, as well as marine mammals and fish, were assessed with separate vulnerability assessment methods. Vulnerability assessments for marine mammals and fish followed the methodology of Morrison et al. (2015), but are not considered further here. A summary of vulnerability assessment for terrestrial wildlife and birds is presented here.

Methodology

As noted, several tools exist for completing vulnerability assessments. Two commonly used tools include the CCVI created by NatureServe (Young et al. 2015) and the System for Assessing Vulnerability of Species (SAVS) created by the USFS (Bagne et al. 2011). The CCVI was considered for this project, but was found to be a substantially data-driven approach, relying on estimates of regionally specific downscaled climate change projections. In contrast, the SAVS' approach puts a greater emphasis on existing knowledge regarding a species' biology, including interactions with other species, its habitat, and external stressors. Due to the emphasis on existing knowledge that does not rely on regionally downscaled climate projections, SAVS was judged to be a more applicable tool for this Project.

SAVS was originally developed for use in the grassland, shrubland, and desert ecosystems of the American southwest, but is adequately generic that it can be used globally. It involves a process of answering a number of different questions regarding four key factors: habitat, physiology, phenology, and biotic interactions. Each of these factors has four to seven questions; practitioners answer each question and estimate the level of uncertainty of their response. Questions can be answered using a combination of expert judgement and literature research. Questions were predominantly answered using literature research for this project. While more time-consuming, this approach is more transparent because answers must be justified by literature citations.

Once all questions have been completed, SAVS provides an index of vulnerability for each key component, as well as an overall index of vulnerability for the species. Importantly, each index also includes an estimate of the associated level of uncertainty. Results thus provide a better understanding of risks to each species as a result of projected climate change, but also an indication of confidence in the conclusion. This can help to identify where further research may be necessary.

The assessment considered the 2046-2065 time horizon, since it was the most applicable of the three time horizons used in the IPCC Fifth Assessment Report and the project is predicted to be complete by 2040. Three RCP scenarios were utilized to provide a broad representation of potential outcomes. These included RCP2.6, considered an extreme best-case scenario, RCP4.5, a mid-point scenario assuming global efforts to mitigate GHG emissions, and RCP 8.5, an extreme worst-case scenario in which little to no effort is made to mitigate GHG emissions.

For terrestrial wildlife and migratory birds, several indicators were chosen to represent a broad range of potential species' risks to climate change. Species were chosen that were considered key indicators that, among them, will help to elucidate potential risks for a broad range of species. Each were chosen to represent broad ecological roles that together will help to inform a comprehensive view of potential risks to focal species for the project. In the case of migratory birds and wildlife, five species were chosen:

- Caribou: resident mammal
- Snow Goose: predominantly terrestrial migratory waterfowl
- Thick-Billed Murre: predominantly marine migratory waterfowl
- Peregrine Falcon: terrestrial raptor
- Lapland Longspur: migratory songbird

Results

Vulnerability to climate change varied broadly by species. Snow Goose was considered the least vulnerable to climate change of the five species assessed, while Thick-billed Murre was the most vulnerable (Figure 1). Understanding key sources of vulnerability for each species and considering potential effects to other species can be facilitated by considering vulnerabilities associated with each category (i.e., habitat, physiology, phenology and biotic interactions).

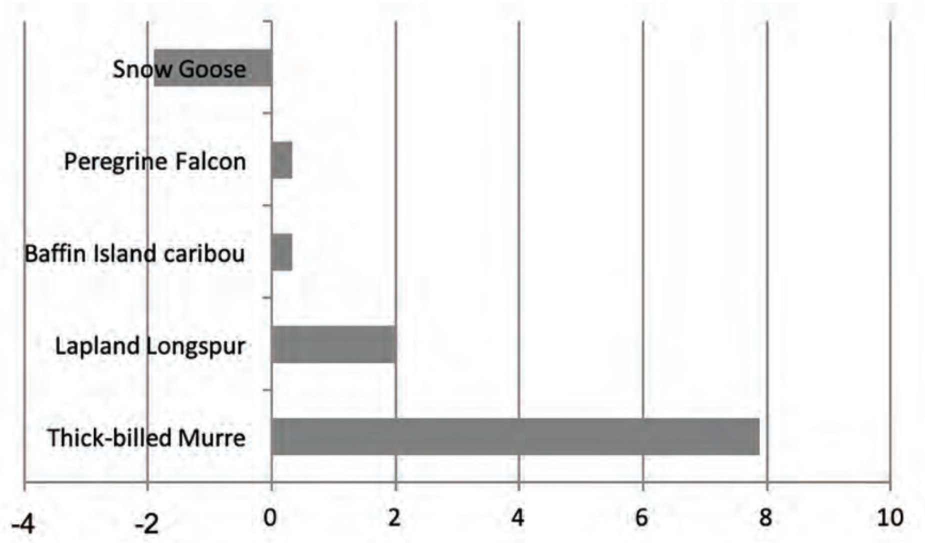

Figure 1. Overall Vulnerability Scores for Focal Terrestrial Species

Habitat vulnerability refers to potential changes in a species' habitat quantity or quality that may affect survival or reproduction. It is broadly differentiated into non-breeding (i.e., those habitat components that are primarily associated with a species survival) and breeding (i.e., those habitat components that are primarily associated with reproduction).

Four of the five species assessed were expected to have some resilience to projected changes in habitat. Caribou may see an increase in both breeding and non-breeding habitat due to expansions in vegetated areas (Arft et al. 1999; Dormann and Woodin 2002; Weintraub and Schimel 2005), decreases in open water habitat (Prowse et al. 2006), and earlier snowmelt (Larsen et al. 2014). Habitat quantity for Lapland Longspurs may decrease due to the northward shift in the distribution of tall shrubs (Boelman et al. 2015; McFarland et al. 2017), but breeding habitat quality is expected to increase due to warmer spring temperatures, earlier snowmelt, and/or associated changes in availability (Grabowski et al. 2013; Liebezeit et al. 2014; Reneerkens et al. 2016; Pérez et al. 2016; McFarland et al. 2017). Additionally, agriculture may increase the quality of winter habitat through increased supply of various seeds for food. The extensive distribution, ongoing range expansion, wide range of habitat utilized, and diversity of prey species consumed (White et al. 2002) will support the Peregrine Falcon (*Falco peregrinus*) in adapting to changes in habitat as a result of climate change and behavioral plasticity is expected to help Snow Goose (*Chen caerulescens*) adapt to a changing climate (Aubry et al. 2013; Hupp et al. 2015).

Thick-Billed Murres (*Uria lomvia*) are expected to have the greatest vulnerability to habitat quality and quantity from climate change among the species assessed. An increase in sea surface temperature is expected to have a negative effect (Irons et al. 2008) and reductions in sea ice cover may reduce prey availability (Laidre et al. 2008). Conversely, earlier ice break up could reduce the probability of reproductive failures that can occur with heavy ice cover (e.g., Gaston et al. 2005) and mobility during the non-breeding season may confer some resilience to changing winter conditions.

Broadly, responses to changes in

habitat from climate change will vary depending on species. Resident terrestrial herbivores are at risk from changes to abundance and distribution of forage species and types. Increasing shrubification of the Arctic, at the expense of other plant types, may negatively impact some herbivore species, such as caribou (Larsen et al. 2014). Predator species that rely on caribou will be vulnerable to fluctuations in prey availability unless they can find alternative prey. Migratory terrestrial birds are expected to be resilient to climate change within their summer habitat, but effects to winter habitat are highly variable depending on location and extent. Migratory marine birds are at risk due to fluctuations in prey availability and ice conditions.

Physiological vulnerabilities are related to direct effects on survival and reproduction, including the potential for exceedances of physiological thresholds, exposure to weather-related disturbance, survival during resource fluctuations, and energy requirements. Vulnerability ratings for most species are relatively neutral, with some resilience exhibited by Snow Goose and Lapland Longspur (*Calcarius lapponicus*).

Physiological vulnerabilities for caribou are relatively neutral, but exposure to weather-related disturbances presents some risk. Extreme weather events from unseasonal warm spells and rain-on-snow events can cause changes in snow pack properties, including ground icing (Loe et al. 2016). Rain-on-snow events and freeze-thaw cycling increase snow thermal conductivity and hardness and decreases snowpack thickness (Sturm and Benson 1997). This can make travel and access to forage more difficult and, in extreme cases, can make forage inaccessible. Areas of suitable habitat are diminished, requiring greater travel in more difficult conditions (Berteaux et al. 2017). The most extreme rain-on-snow events have caused massive reindeer mortality in Norway, Siberia, and Canada (Miller and Barry 2009; Hansen et al. 2014; Sokolov et al. 2016). Peregrine Falcons breeding in the Arctic are vulnerable to extreme weather events. Their cliff-nesting habits (often in unsheltered sites) and relatively long incubation and growth periods make Peregrine Falcon eggs and young vulnerable to inclement weather (White et al. 2002; Anctil et al. 2014; Jaffré et al. 2015). These changes in weather are especially significant because extreme weather events, such as heavy rainfall, are projected to increase in the northern hemisphere (Min et al. 2011)—the frequency of heavy rain events in the Canadian Arctic has increased in the past three decades (Anctil et al. 2014). Inclement weather in the Arctic reduces foraging success, nestling survival, and nesting success (Anctil et al. 2014; Robinson et al. 2017).

Snow Goose exhibits some resilience due to the ability to skip breeding in resource-poor years and increase clutch size in resource-rich years (van Oudenhove et al. 2014). Lapland Longspur can advance breeding with warmer temperatures (Grabowski et al. 2013; Liebezeit et al. 2014; McFarland et al. 2017) and vary their diet according to prey/forage availability (Hussell and Montgomerie 2002). Further, warmer spring temperatures, earlier snowmelt, and/or changes in food availability have been linked to advancements in clutch initiation, increased nest survival, and higher nestling growth rates (Grabowski et al. 2013; Liebezeit et al. 2014; Reneerkens et al. 2016; Pérez et al. 2016; McFarland et al. 2017).

Overall, resident species are expected to have the greatest physiological vulnerabilities to climate change, primarily associated with exposure to extreme weather events such as increased frequency of rain-on-snow and icing events. These can both have direct effects on animals as well as indirect effects through access to forage. Warmer temperatures and earlier snowmelt may confer an advantage to some species. Behavioral plasticity, especially alteration in breeding timing and prey sources, will provide some resilience to change.

Phenological vulnerabilities can result from mismatches in timing between species' behavior and biology and their critical resources. This can occur where species rely on an environmental cue to initiate activities such as migration or breeding, or where a species' fitness is tied to a discrete resource peak that is expected to change. Snow Geese are exhibiting a growing mismatch with food plant phenology (Aubry et al. 2013), including the date of peak Nitrogen content, with the result that gosling body mass and structural size near fledgling can be negatively affected (Doiron et al. 2011). Similarly, a growing mismatch between sea ice clearing, associated with peak prey availability, prey composition, and chick growth rates, with the timing of egg laying, has been observed in Thick-Billed Murres colonies (Gaston et al. 2005, 2009).

Phenological vulnerabilities may be a substantial source of vulnerability, particularly migratory species and those that time activities to environmental cues or discrete resource peaks. Resident animals with behavioral plasticity should be resilient to changes in the timing of resources, assuming the rate of change is not too great. Migratory animals can adapt if environmental cues are present, though the lag time of behavioral change may be a concern. For example, Snow Geese on Bylot Island have advanced their egg laying date by only 3.8 days on average for a change in snow-melt of 10 days (Gauthier et al. 2013). Other species of concern, such as Red Knot (*Calidris canutus*), Red-throated Loon (*Gavia stellata*), King Eider (*Somateria spectabilis*), and Common Eider (*Somateria mollissima*), will likely face similar vulnerabilities.

Vulnerabilities relating to biotic interactions stem from changes in interactions with food sources, predators, diseases, symbionts, and competitors. Thick-Billed Murres show the highest vulnerability to changes in biotic interactions because the extent of summer sea ice is expected to decline (Larsen et al. 2014), causing an associated decline in the abundance of cod, a primary prey item (Gaston et al. 2009). An increase in polar bear predation, as has been observed in recent years on Coats Island, could have significant effects on survival and reproductive success (Gaston and Elliott 2013). Caribou also show some vulnerability resulting from changes in forage species abundance, distribution and cover, an increase in shrubs at the expense of other plant types (Sturm et al. 2001; Tape et al. 2006; Myers-Smith et al. 2011; Ropars and Boudreau 2012), and a reduction in nitrogen content of primary forage species (Heggberget et al. 2002; Turunen et al. 2009).

Changes in biotic interactions are not expected to affect Peregrine Falcon. Snow Goose and Lapland Longspur are expected to display a slight resilience. Primary food sources for Snow Goose are expected to be positively affected by climate change (Gauthier et al. 2013), though a mismatch in phenologies between the species and its food-plants may negate this positive effect. A similar increase in invertebrate abundance, as observed in recent decades (Meltofte et al. 2007; Tulp and Schekkerman 2008; Reneerkens et al. 2016) is expected to positively benefit Lapland Longspur, but phenological mismatches may again negate part or all of this benefit (Grabowski et al. 2013).

Overall, vulnerability associated with changes in biotic interactions primarily relate to food sources. Primarily terrestrial species, such as Snow Goose and Lapland Longspur, may see an increase in the abundance of food sources, but food quality for species such as caribou may diminish. Other biotic interactions such as predators, symbionts, disease, and competitors are either not expected to have a large influence on vulnerability or the results are highly uncertain.

Discussion

Vulnerability assessments provide a means to assess risk to species and ecosystems as a result of climate change and identify where interactions may occur with potential project effects. Where identified, mitigation measures can be implemented to reduce the effect of these interactions. For example, where a certain habitat type or life requisite is shown to be at risk to climate change and is negatively affected by the project, measures can be implemented to avoid or reduce these negative effects. Due to the large degree of uncertainty associated with climate change projections and effects, monitoring and adaptive management plans will often be the most judicious means for identifying and reducing risk to valued environmental components.

While several risks to climate change were identified through the vulnerability assessment in the case study, none were shown to have a direct interaction with potential project effects; thus, it did not justify the enhancement of existing or development of new mitigation measures. Further, existing monitoring and adaptive management programs were judged to be adequate to track changes to focal species over time.

CONCLUSIONS

Potential interactions among climate change, project infrastructure, species, and ecosystems are numerous, varied, and complex. The uncertainty associated with climate projections adds to the complexity of the challenge to integrate it into EAs in a predictable, useful, and structured manner. This review presents one conceptual framework for doing so. Many other tools and approaches are undoubtedly available that may augment or replace some of the approaches suggested here. The discipline is in its early stages and many revisions and refinements are anticipated. In all likelihood, jurisdictions will increasingly request or require the integration of climate change into EAs. In time, methods described here may become commonplace; thus, adopting early on will help practitioners learn and refine tools so that they may be efficiently and effectively applied when necessary.

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Smith is a Senior Biologist with 23 years of experience in effects assessment, ecosystem interpretation, species at risk, and natural resource management. He has extensive experience leading and managing the terrestrial component of small to very large projects, including species occurrence and abundance, habitat assessment, Terrestrial Ecosystem Mapping, and wildlife habitat suitability modeling for numerous terrestrial species at risk. His broad range of experience also includes work on rare plants, forest ecology, and listed ecological communities. The bulk of Smith's work focuses on mitigating the effects of ROW development associated with run-of-river hydropower projects, transmission lines, and pipelines. Most recently, Smith was the vegetation and wetlands discipline lead for a 750-km long linear development project that included an assessment, mitigation, and management plans for potential effects to vegetation, ecological communities, wetlands, and wetland function.

JeffMeggs
Meggs is a Senior Biologist with more than 20 years' experience in the study of terrestrial and aquatic ecosystems, specializing in invertebrate ecology, the ecology and management of threatened species and forest biodiversity, and deadwood management. He has considerable experience in the design and conduct of field, modeling, and monitoring studies related to fish, wildlife, wildlife habitat, coarse woody debris, and aquatic and terrestrial invertebrate communities, as well as expertise in the design and implementation of biodiversity and ecosystem processes research. His inventory, research, and analytical skills are complimented by a background in operational and strategic conservation planning for wildlife and biodiversity within the resource management sector.

Alain Fontaine
Fontaine completed his Master in Science graduate studies in Wildlife Biology to complement his Bachelor's in Science in Wildlife Resources. He has 17 years of experience working as a wildlife technician and biologist in the field of fish and wildlife population and habitat management in Arctic and boreal settings. This knowledge of ecosystems and natural resources, based on academic, field work, and personal experience, allows him to contribute actively to their management and conservation. Throughout his career, Fontaine has represented multiple levels of government (Canada, Alberta and Yukon) in multi-jurisdictional and multi-stakeholder meetings, management boards, working groups, as well as planning and action teams. Fontaine developed extensive experience in designing and planning field biological research and monitoring programs and supervising field staff in a variety of programs and field sites. Fontaine has participated in the EA process through reviewing applications and providing mitigation recommendations to limit impacts on regional wildlife populations and habitats.

Pablo Jost
Pablo Jost is a wildlife biologist and GIS Analyst with more than 12 years of experience. Jost has designed and conducted baseline inventory for wildlife on more than 40 projects across BC, Alberta, and Nunavut. He has 10 years' experience conducting bird studies, including point counts, raptor stand watch, call playback, nest searching, avian habitat mapping and modeling, and acoustic monitoring. He has conducted studies for multiple large, linear developments, hydroelectric projects, and oil and gas. He has knowledge of habitat requirements for all coastal and boreal birds including songbirds by sight and sound. Jost's expertise is in bird studies, but he has designed and conducted surveys for amphibians, invertebrates, small mammals, vegetation, aerial, and ground surveys for ungulates, among others. As a GIS Analyst, he has been GIS lead for large projects across BC and internationally playing key roles in innovative GIS analysis, cumulative effects, data visualization, and data management.

Enhancing Wetland Climate Change Resiliency and Carbon Mitigation on ROW Projects

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Keywords: Carbon Mitigation, Climate Adaptation, Climate Change, Climate Resiliency, Drought Resiliency, Utility Rights-Of-Way Wetland Management, Wetland Creation, Wetland Management, Wetland Restoration, Wetland Mitigation.

Incorporation of emerging climate change science into wetland restoration and creation resulted in an innovative wetland construction methodology, which improved wetland function, climate resiliency, and carbon conservation during the first growing season following construction on a Massachusetts electric transmission line right-of-way (ROW) project. This project provided wetland mitigation through translocation of intact soil and vegetation from the impacted wetland directly to the replication site, thereby minimizing disturbance to soil, microbial, and vegetative functions and reducing temporal functional loss. Objectives for this project were to test and measure the success of this method in enhancing climate change resiliency and conservation of ecosystem carbon, improving ecological function, reducing temporal loss of wetland function, and reducing project costs. Since anaerobic wetland soils normally store greater amounts of carbon than upland soils, this translocation technique has the potential to reduce losses of carbon function and increase climate resiliency while reducing costs compared to a traditionally constructed replication area. The time necessary for the translocated wetland to meet regulatory success was also shorter than that of the traditionally constructed replication site. The translocated wetland resulted in reduced costs because there was no need to purchase nursery stock and manufactured soil or manage the construction site for erosion.

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INTRODUCTION

Functional success of wetland construction projects, whether restoration or creation, is mixed in Massachusetts. The changing climate creates additional challenges for wetland replication due to changing precipitation and temperature patterns that include heavier precipitation, more frequent flooding events and severe storms, variable groundwater elevations, increased drought, and higher temperatures (Melillo 2014; USGCRP 2017). These climate changes compound the existing stresses on wetlands (Erwin 2009; Junk et al. 2013; Mitsch and Hernandez 2013). Simultaneously, wetlands provide significant climate adaptation and resiliency ecosystem services to surrounding ecosystems and human communities (Environmental Law Institute 2008; Keddy 2010; Junk et al. 2013; ASWM 2015; Moomaw et al. 2018). In this paper, resiliency refers to the capacity of an ecosystem to restore healthy ecological processes and functions, as well as complexity and diversity following a disruption, despite possible changes to species and species complexes (Moomaw et al. 2018). Wetlands store disproportionate amounts of carbon in their soils and biomass, relative to the area that they occupy on land surface (Moomaw et al. 2018). Nahlik and Fennessy (2016) report that wetlands store 20-30 percent of the world's soil carbon, while occupying only five to eight percent of global land surface. Therefore, their value to society is likely to increase as the climate continues to change, both in terms of providing climate adaptation/resiliency ecosystem services and in terms of ongoing sequestration of carbon from the atmosphere and storing soil and biomass carbon. Here, the term "sequestration" refers to the conversion of atmospheric carbon dioxide into plant biomass and then into soil organic matter (Moomaw et al. 2018).

Research indicates that although undisturbed freshwater wetlands store more carbon than they emit due to the activities of the microbial communities in their anaerobic soils, newly created, or disturbed freshwater wetlands tend to emit more carbon than they store for a period of time, until they reach a "switchover point" where carbon storage begins to exceed carbon emission. This time period can last decades to thousands of years (Neubauer 2014; Bridgham et al. 2014; Neubauer and Megonigal 2015). It should be noted that saltwater wetlands have a different soil biogeochemistry, and quickly become net carbon sequesterers following creation (Chmura et al. 2003).

If we are to prevent further climate warming that results from emission of carbon from created wetlands to the atmosphere, the first priority should be to avoid and minimize disruption of wetland soils and vegetation. However, when wetland impacts are unavoidable, as is often the case with utility right-of-way (ROW) work, wetland scientists can identify best management practices (BMPs) that minimize loss of soil organic matter and soil carbon while maximizing the capacity of restored or created wetlands to be resilient to changes in climate. This then maximizes a wetland's capacity to provide climate adaptation/resiliency, carbon storage, and traditional ecosystem services to surrounding ecosystems and communities.

In developing the experimental wetland construction methodology outlined in this paper, it is hypothesized that translocating intact soil O and A horizons (dark, organic, rich topsoil layers) and affiliated rooted surface vegetation directly from the wetland impact area to the wetland restoration/creation area will maintain soil structure and microbial and plant communities to a greater extent than traditional construction methods. Traditional wetland replication construction methods typically involve the spreading of wetland impact area soil from stockpiles where the structure and microbial communities have been disrupted or destroyed, or spreading of fabricated compost-based soils, which have no soil structure disrupted or no anaerobic microbial communities, and can have soil biogeochemistry that differs from natural wetlands. Typically, these soils are planted with nursery stock. Development of soil structure and mature microbial communities takes time (Janzen 2016) and as Neubauer (2014) reports, re-establishment of soil carbon function similarly takes decades to thousands of years. It is anticipated that by preserving and translocating wetland soil and vegetation structures, the functions associated with those structures would be preserved to a greater extent than seen with current practices.

It is anticipated that ecological function will be enhanced by using this experimental methodology compared to traditional wetland construction methods, particularly during the first few years following construction. In comparison to a traditional replication wetland, in this type of experimental replication wetland:

- Soil structure is less disturbed.
- Soil pedons from the impact area are less disturbed.
- Soil microbial communities are less disturbed.
- Native seed bank stored in the soil is preserved and translocated.
- Soil–root contact is less disturbed.
- Soil surface remains vegetated (reducing desiccation, erosion, and opportunities for invasive species).
- Native wild plants adapted to site conditions are utilized, rather than nursery stock.
- The wetland is likely to experience less impact from drought, due to greater vegetative cover and better retention of soil moisture during hot, dry months.
- Plants experience a shorter amount of time in transit.
- Temporal wetland loss is likely to be reduced.

It should be noted that the successful achievement of these advantages will be dependent upon the successful establishment of an appropriate water table and wetland hydrology that is similar to the area from which the material was removed. Should a wetland hydrology similar to the impact area fail to be established, it is anticipated that shifts in soil microbial and plant communities would likely occur, and successful establishment of wetland functions may be altered. Similarly, success is more likely to be achieved when impact area "donor" wetlands have cohesive soils containing strong root structure and the capacity to be cut, removed, and placed into the receiving wetland creation site with little loss of soil and vegetation during the translocation process.

Utility ROWs are excellent locations for application of this experimental translocation methodology because they are typically maintained without tree cover, thus facilitating translocation of shrubs and herbaceous vegetation, with intact root systems embedded within the soil pedon. Alternatively, on forested sites, translocating intact soil O and A horizons and affiliated rooted vegetation is likely to be very difficult due to the presence of mature trees.

A New England Power Company (NEP) doing business as National Grid electric transmission line ROW project site in Winchendon, Massachusetts provided an opportunity to apply and test the experimental translocation hypothesis and methodology. As mitigation for approximately 461 meters (m) squared (4,960 square feet[f^2]) of impacts to wetlands associated with a ROW utility access road upgrade project, NEP constructed approximately 330 m^2 (3,550 $f^{\wedge 2}$) of wetland replication that included areas of both restoration and creation, and restored a hydrologic connection to approximately 151 m^2 (1,630 ft^2) of disturbed wetlands. These activities provided a total of 481 m^2 (5,180+ ft^2) of wetland restoration and creation, which exceeds the 1:1 ratio for mitigation required by the permit under the Massachusetts Wetlands Protection Act. The 330 m^2 of wetland replication included an area of experimentally constructed wetland restoration and creation (Experimental Replication Area), utilizing the translocation method discussed above as well as an area of traditionally constructed restored and created wetland (Traditional Replication Area).

LITERATURE REVIEW

A wetland construction approach similar to the experimental translocation method discussed above is referenced in the U.S. Army Corps of Engineers (USACE) "New England District Compensatory Mitigation Guidance" (2016), which states, "Transplanting entire blocks of vegetation with several inches of the original wetland soil substrate from the impact areas has been found effective in establishing mitigation wetlands." The approach used in Winchendon went further by preserving the full O/A horizon (i.e., topsoil), rather than "several inches," and by identifying protection of climate adaptation/resiliency, carbon sequestration, and carbon storage functions as replication objectives. According to USACE (Ruth Ladd and Cori Rose, *personal communication*, April 16, 2016), the block transplanting approach is not implemented very often in New England. In this recent conversation, USACE knew of only two or three instances where block transplanting had been implemented.

In a literature search, studies utilizing the exact methodology employed in Winchendon were not found, but some studies implementing similar approaches were identified. A study by Brown and Bedford (1997) found that establishment of wetland species, both in terms of number of species and cover area, were improved when wetland soil was transplanted into a drained wetland during wetland restoration activities as compared to control plots and to areas treated by mowing and plowing. In addition, areas where transplanted wetland soil was installed exhibited fewer invasive species. This study noted the relatively low cost of using the transplanted soil seed bank as a source of plant propagules.

Wilhelm et al. (2015) report that carbon dioxide (CO^2) emissions were significantly reduced on a peat reclamation site when the Peat Block Reclamation method was used. In this method, the researchers removed blocks of the top ~0.3 m of peat, then harvested deeper peat, and then replaced the top ~0.3 m of peat, which floated in the flooded pit. However, they noted that methane fluxes were very high, due to post-treatment flooded conditions. No calculation of the net carbon balance was provided. The experimental sphagnum floating mats were more productive than reference plots, indicating successful transplanting of sphagnum. This study encompassed only the first two years following treatment. Additional longer-term studies and total carbon accounting would be valuable.

Waddington et al. (2009) reported that carbon dynamics were restored faster at a peat reclamation site using the Acrotelm Transplant Peat Extraction Method, compared to Vacuum Harvest or Block Cut extraction methods. In this method, the living peat layer (the acrotelm) is removed while deeper peat is harvested. The living layer is replaced following removal of underlying dead peat material. The authors conclude that this method, "…has the potential to greatly reduce the carbon footprint of the Canadian horticultural peat industry." Cagampan and Waddington (2008) reported similar acceleration of restoration of carbon dynamics and accumulation using the Acrotelm Transplant Method during peatland rehabilitation.

After short term monitoring of transplanted moss layers in degraded or reclaimed peatlands, Murray et al. (2017) observed that methane fluxes were lower at the degraded/reclaimed site following transplanting of the moss layer. However, they also found elevated carbon releases at the donor site (i.e., site where moss layers had been obtained). They did note that vegetative recovery at donor sites appeared to be rapid, and that prevention of carbon releases at the reclaimed/restored site outweighed additional carbon releases at the donor sites (Murray et al. 2017).

These studies provide some support for the idea that transplanting or translocating wetland soil and/or vegetation certain conditions can lead to greater ecological function and restoration of carbon dynamics.

COMMUNICATION, APPROVALS, & COST SAVINGS

Typically, in Massachusetts wetland impacts are mitigated through the creation of new wetlands or restoration of wetlands that have been converted to uplands. Newly created wetlands are usually located adjacent to existing wetlands which border or connect to other surface waters or streams. Then, these wetland restoration and/or creation areas, also referred to as replication sites, are monitored for two or more growing seasons to ensure they meet the requirements of the Massachusetts Wetlands Protection Act and any permit conditions.

The original permit approvals for this project included the creation of two wetland replication areas. During the course of the project, discussion was held on the possible translocation of the wetland plants from the impact area to the largest replication area. The proximity of the impact area to the replication area presented a perfect opportunity for translocation. However, approval to use this non-traditional methodology needed to be obtained from the client (NEP) and the local permitting entity (the Winchendon Conservation Commission).

Communication with NEP, the Conservation Commission, and the contractor was essential to the success of this project. BSC Group, Inc. (BSC) first discussed the translocation idea with the client and relayed the ecological benefits. Additionally, in explaining this innovative methodology, the cost and time savings for NEP and the contractor were emphasized. Cost–savings for NEP and the contractor were likely to result from implementing the experimental translocation methodology because:

- Soil is moved from the impact area only once, reducing transportation and labor costs, as compared to stockpiling soils
- Costs for purchase, transport, and installation of off-site supplemental compost-based topsoil is eliminated
- Labor costs associated with stockpiling, as well as associated costs for monitoring including installation/removal of erosion and sedimentation materials are eliminated
- Nursery stock, wetland seed mix, mulch purchase, transportation, and installation costs are eliminated
- Wear and tear on machinery is reduced
- Functional success is more likely (assuming appropriate wetland hydrology is established), thereby lessening the likelihood that remedial or reconstruction costs will be incurred
- Two years of monitoring (as typically required under the Massachusetts wetlands protection act regulations) or repeated replanting from loss of plants or unforeseen circumstances was unlikely
- Likelihood of erosion and sedimentation issues is greatly reduced due to the significant reduction of exposed soil following replication area construction
- Costs associated with invasive species treatment are likely to be reduced due to maintaining indigenous species and soil surface cover

These cost-saving measures as well as the innovative nature of the procedure were presented to the client. Based on our relationship with the client, as well as the information presented, NEP accepted the translocation methodology. Additional wetland replication square footage was needed to meet permit requirements, so a 46 m2 traditional wetland replication site was proposed directly adjacent to the recently translocated wetland replication site.

Having the two replication sites side-by-side (Figure 1) created a unique opportunity to study and compare the

Figure 1. Plan showing experimental replication wetland, traditional replication wetland, impacted ("donor") wetland, reference (existing) wetland, and other existing wetland

success of the two replication methodologies. NEP was again approached for approval to conduct a detailed monitoring study comparing the translocated wetland site to the adjacent traditionally planted wetland replication area. A scope of work for the monitoring study was prepared and provided to NEP for approval. NEP understood the benefits of the study and immediately approved the study, thereby funding the research provided herein. Furthermore, the change in replication plans and methodology required approval from the local Conservation Commission, and the Conservation Commission accepted the change as a simple field change.

METHODS

Construction Methodology and Site Conditions

Construction of the translocated restoration/creation area using the experimental method (Experimental Replication Wetland) occurred on March 3, 2016, while the plants were still largely dormant. Normal rainfall conditions existed. A light dusting of snow was on the ground at the time of construction, and, according to data from the Birch Hill Dam Station (RYLM3), located at 42° 37' 57" N, 72° 7' 25" W along the Millers River in Royalston, temperatures ranged from -9 to 9° C (15 to 48° F). 0.5 cm (0.21 inches [in]) of rain fell on March 3, 2016, and 1.3 cm (0.5 in) of rain had fallen the day before. Following construction of the Experimental Replication Wetland, it was determined that additional square footage was needed to meet permit requirements, so an additional created wetland was constructed using traditional methods (Traditional Replication Wetland) on June 6 and 7, 2016. No rainfall had occurred during the preceding two days, but immediately following the construction of the Traditional Replication Wetland, approximately 2.4 cm (0.96 in) of rain fell. Temperatures ranged from 16 to 26 o C (60° to 78° F).

A drought (D0 rating, on US Drought Monitor Scale, *http://droughtmonitor.unl.edu/aboutus/classificationscheme.aspx*) was declared for the Town of Winchendon, where the project is located, beginning on May 10, 2016. A D0 rating indicates "Abnormally Dry" conditions. The drought was upgraded to a D1 rating ("Moderate Drought") on July 5, 2016 and upgraded again to a D3 level ("Extreme Drought") on September 13, 2016. On November 1, 2016, the rating level was reduced to D2 ("Severe Drought), with no change through January 30, 2017. The wetland replication areas received supplemental watering once during the last week of July in 2016.

Experimental Replication Wetland

Prior to moving wetland soils and vegetation from the impacted wetland to the Experimental Replication Wetland site (see Figure 1), the contractor excavated existing upland soil from the restoration/creation area, as is typically done to prepare a wetland restoration or creation site. The contractor then used a backhoe to excavate and move intact blocks of soil that varied from approximately 20 cm to 46 cm (eight in to 18 in) in thickness and including O and A horizon material, some of the underlying B horizon (mineral soil, low in organics) material, and rooted shrubs and herbaceous vegetation, from the wetland impact area to the Experimental Replication Wetland. The contractor placed the blocks of soil and vegetation in proximity to each other, sometimes immediately abutting, but sometimes with gaps between blocks.

Traditional Replication Wetland

Adjacent to the eastern side of the Experimental Replication Wetland, the Traditional Replication Wetland (see Figure 1) was created by excavating the uplands to the design elevation and then backfilling with approximately 30 centimeters (cm) (one ft) of topsoil that was a mix of compost and mineral soil. Nursery stock composed of wetland plants native to Massachusetts (1 gallon, 0.9 m) (3 ft) on center cinnamon fern (*Osmundastrum cinnamomeum*), 3 gallon, 1.8 m (6 ft) on center highbush blueberry (*Vaccinium corymbosum*), and wetland seed mix, specifically selected as species that were present in the impacted wetland, were planted, and a wetland seed mix was spread across the soil surface. Straw mulch was scattered over the seeding for stabilization and to assist in seed growth, and the site was watered following planting.

Photograph 1. March 3, 2016—normal rainfall conditions. Experimentally constructed wetland replication area (Experimental Replication Area), following translocation of soil and surface vegetation, on construction day. Photo source: Theresa Portante.

Data Collection

The Experimental and Traditional Replication Wetlands, as well as a Reference Wetland (see Figure 1) immediately adjacent to the Experimental Replication Wetland, were monitored during the fall of 2016. Data plots were established in each of the three wetlands, and standard USACE data sheets (Wetland Determination Data Form: Northcentral and Northeast Region, Version 2.0) were completed in accordance with the Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region (Version 2.0) (USACE 2012 Regional Supplement) (USACE 2012). Desktop data such as U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soil mapping were reviewed. Additionally, more quantitative vegetative and soils data were collected and analyzed, as reported below. In order to collect more quantitative data, including assessment of species diversity and richness, data plots were sized to conform to species diversity and richness methodology (3-meter by three-meter shrub/scrub plots with nested one meter by one meter herbaceous plots). These plot dimensions are similar to plot dimensions specified in the USACE 2012 Regional Supplement and the Massachusetts Department of Environmental Protection (MA DEP) Handbook on Delineating Bordering Vegetated Wetlands (Jackson 1995) and were deemed sufficient for use with both the MA DEP and the USACE methodologies. Due to budgetary constraints, only one vegetative plot was monitored in each of the three wetlands. However, these plots are considered to be relatively representative of the areas being monitored, particularly given how small the replication areas are.

Photograph 2. March 3, 2016—normal rainfall conditions. Experimentally constructed wetland replication area (Experimental Replication Area), following translocation of soil and surface vegetation, on construction day. Photo source: Theresa Portante.

Photograph 3. March 3, 2016—normal rainfall conditions. Newly translocated shrubs and herbaceous species and underlying blocks of soil on construction day (Experimental Replication Wetland). Notice gaps (red arrow) between blocks of soil/vegetation in some locations. Red circle identifies a translocated block of soil and vegetation. Photo source: Theresa Portante.

Photograph 4. March 3, 2016—normal rainfall conditions. Well-vegetated ground surface at the Experimental Replication Area on construction day, following installation of soil and vegetation blocks. Photo source: Theresa Portante.

Vegetation was monitored during an Extreme Drought (level D3) on September 19, 2016, and hydrology and soils were monitored during a Severe Drought (level D2) on November 18, 2016. Temperatures during the fall of 2016 were above average (*https://www.usclimatedata.com/climate/royalston/massachusetts/united-states/usma0866/2016/10*). Vegetative senescence was only partially evident on November 18, 2016, and the growing season appeared not to have ended yet, based on observation of multiple green, photosynthesizing herbaceous species.

Vegetation Methodology

Vegetation measures included species diversity and richness (Margalef's Diversity [or Species Richness] Index and Simpson's Dominance Index), percent cover, percent wetland indicator species, and presence/absence of invasive species. The formula for Margalef's index is:

$$d_1 = (S-1) / \ln N$$

where S= number of species and N= total number of individuals (stem count). This richness index standardizes the number of species encountered against the total number of individuals encountered and therefore is a measure of how "rich" (diverse) a sampling plot is. In this index, a d_1 of 0 indicates no diversity. The index has no upper bound.

The second index used was a Dominance Index (sometimes called Simpson's Dominance Index) which measures the "evenness" of the community. The index is given by the formula:

$c = 1-\sum(n_i/N)^2$ or $c=(1-D)=1-(\sum n(n-1)/N(N-1))$

where n_i = count per species and N= total count. This index is a measure of whether a sample is dominated by any one (or a small group of) species or is more heterogeneous. This index is bound between 0 and 1. In this index, a "c" of 0 indicates that one species dominates the sample (low or no diversity), and a "c" of 1 indicates that all taxa are equally represented (i.e., no one species dominates, or high diversity).

Hydrology Methodology

While conducting soil evaluation and sampling at the nine soil pits on November 18, 2016, soil saturation and elevation of standing water in soil pits were measured (using a tape measure from the top of the soil pits). Prior to November 18, 2018, an informal assessment of soil saturation and moisture in the top few inches of soil was conducted in various locations in all three wetlands.

Soil Sampling and Laboratory Methodology

Soil profiles were logged, and depth-to-water-table and soil saturation was measured (using a tape measure from top of pit) on site at three soil pits per wetland. Soil samples were collected from each horizon in each of the pits. Soil samples were air dried and sent to the University of Massachusetts Amherst Soil and Plant Nutrient Testing Laboratory (UMass Lab), where they were tested for the following parameters:

- o Total Organic Carbon/Total Organic Matter
- o Carbon to Nitrogen Ratio
- o Total Nitrogen
- o Modified Morgan Extractable Nutrients (P, K, Ca, Mg, Fe, Mn, Zn, Cu, B, S, Pb, Al, cation exchange capacity, base saturation, and pH)

Photograph 5 & 6. June 6, 2016—Drought Rating "D0"—Abnormally Dry. Translocating blocks of soil/vegetation at upland buffer edge of the traditionally constructed wetland replication area (Traditional Replication Wetland). These photos show the translocation technique, but are showing soil and shrubs that are being salvaged and translocated from upland excavated to construct the Traditional Replication Wetland. They are being planted in upland buffer to the Traditional Replication Wetland. Photo source: Gillian Davies.

Photograph 7 & 8. June 6, 2016—Drought Rating "D0"—Translocating blocks of soil/vegetation at upland buffer edge of the traditionally constructed wetland replication area (Traditional Replication Wetland). These photos show the translocation technique, but are showing soil and shrubs that are being salvaged and translocated from upland excavated to construct the Traditional Replication Wetland. They are being planted in upland buffer to the Traditional Replication Wetland. Photo source: Gillian Davies.

Photograph 9. June 6, 2016—Drought Rating "D0"—Abnormally Dry. Nursery stock being planted in compost-based topsoil in Traditional Replication Wetland. Photo source: Gillian Davies.

RESULTS & DISCUSSION

Construction

Intact blocks of soil/vegetation held together well during transport from the impact area to the Experimental Replication Wetland. Herbaceous and shrub vegetation was dense, with a thick root mat that contributed to cohesion of the blocks of soil. In general, the transport of the complete or almost complete O and A horizons, with intact surface vegetation, was successful. Gaps between transplanted blocks created a pit and mound topography that mimics the topography that is common in many wetlands, including the immediately adjacent Reference Wetland. Pits created in the gaps between translocated blocks were observed to hold standing water during the wetter parts of the year, similar to the pits in the adjacent Reference Wetland.

Photograph 10. June 6, 2016 – Drought Rating "D0"—Abnormally Dry. Completed Traditional Replication Wetland with plantings and mulch. Translocated shrub is in background. Photo source: Gillian Davies.

Photograph 11. June 6, 2016—Drought Rating "D0"—Abnormally Dry. Experimental Replication Wetland approximately three months after construction. Photo source: Gillian Davies.

Vegetation

At the end of the first growing season, species diversity/richness, overall vegetative cover, and percent dominance of wetland species were greater in the Experimental Replication Wetland compared to the Traditional Replication Wetland. As indicated in Table 2, the Experimental Replication Wetland:

- had a higher Margalef Index for species diversity/richness than both the Traditional Replication Wetland and the Reference Wetland, and
- had a similar Simpson's Index of species diversity to the Reference Wetland, and higher than the Traditional Replication Wetland.

The Experimental Replication Wetland had a greater percentage of dominant wetland species than both the Traditional Replication and Reference Wetlands, with 100 percent of the dominant plant species (using the Dominance Test per USACE 2012 Regional Supplement) being wetland species (four out of five were Facultative Wetland [FACW], and one out of five was Facultative [FAC]). The Traditional Replication Wetland achieved a predominance of wetland species using the Prevalence Index method per USACE 2012 Regional Supplement (three FACW species, one FAC species, and three Facultative Upland [FACU] species, and a small number of unidentifiable herbaceous species). Dominant wetland plants were 67 percent wetland species in the Reference Wetland, using the Dominance Test (two out of three were FACW, one out of three was Not Listed [NL]).

The Experimental Replication Wetland was the only wetland to meet Massachusetts state regulatory performance standards for percent cover of wetland species in wetland replication areas after the first growing season. The Massachusetts Wetlands Protection Act regulations (310 CMR

10.55[4]) require that, "…at least 75 percent of the surface area of the replacement area shall be reestablished with indigenous wetland plant species within two growing seasons…" The Experimental Replication Wetland achieved a vegetative cover that was close to that of the Reference Wetland by the end of the first growing season, whereas the Traditional Replication Wetland achieved significantly less vegetative cover than either the Experimental Replication or the Reference Wetland.

Hydrology

Hydrologic indicator data were collected from each of the three soil pits in each of the three wetlands. Despite the Severe Drought ("D2" drought rating) conditions on November 18, 2016, all soil pits in the Experimental Replication Wetland were saturated to the surface, and two exhibited standing water (at 15 cm [6 in] and at 19 cm [7.5 in]) within the pits. Two soil pits in the Traditional Replication Wetland were saturated to the surface, and one was saturated at 18 cm [7 in]) below the surface. All three pits contained standing water (at 5 cm [2 in], 23 cm [9 in], and 30 [12 in] cm below surface). All Reference Wetland soil pits were saturated to the surface, and contained standing water (at 3 cm [1 in], 19 cm [7.5 in], and 23 cm [9 in]). In the month of November 0.1 cm (0.04 in) of rainfall fell on November 4, 2016, a trace fell on November 7, 2016, 2.1 cm (0.83 in) fell on November 16, 2016, a trace fell on November 17, 2016, and none fell on November 18, 2016. Particularly in the context of the multi-month drought, the rainfall on November 16, 2016 was not considered to have a significant impact on field observations.

Photograph 12. June 6, 2016—Drought Rating "D0"—Abnormally Dry. Experimental Replication Wetland approximately 3 months after construction. Gaps between translocated blocks are holding water. Photo source: Gillian Davies.

Photograph 13. August 11, 2016—Drought Rating "D1"—Moderate Drought. Experimental Replication Wetland with dense vegetative cover, primarily native wetland species, and high species diversity/richness score. Photo source: Gillian Davies.

Soils

Existing Soils

Soils in the project area are mapped as Becket-Skerry association (Web Soil Survey). The Becket-Skerry association are well drained or moderately well drained spodosols. Spodosols are soils developed from leaching of mild organic acids created by precipitation draining through acidic plant litter at the surface of the soil. The weak acids translocate organic matter, iron, and aluminum from the surface layers deeper into the profile. This illuviation of humic materials and sesquioxides into subsurface layers often produces very distinct soil colors. The hydric component of the Becket-Skerry association catena is the Pillsbury soil (Coarse-loamy, mixed, superactive, acid, frigid Humic Endoaquepts). Pillsbury soils are poorly drained soils that formed in loamy lodgment till in glaciated uplands and lowlands. Typically, the range of characteristics are as follows: The O horizons, where present, consist of peat, mucky peat, and/or muck and is 0 to 4 cm (0 to 1.5 in) thick. The A horizon has hue of 7.5YR to 5Y, value of 2 to 3, and chroma of 1 to 3 and will typically range from 4 cm (1.5 in) to 15 cm (6 in) in depth. The Bg horizons are neutral or have hue of 10YR to 5Y, value of 4 to 6, and chroma of 0 to 2 with Bg1 to a depth of 33 cm (13 in) and Bg2 to a depth of 58 cm (23 in) from grade (NRCS 2017).

The Experimental Replication Wetland and the Traditional Replication Wetland appear to have been constructed in an area where iron-rich groundwater discharges causing at least some of the subsoil matrices to have higher than normal matrix chromas. Continued monitoring of the soil is recommended to see how soils develop with time. Direct observation of the water table becomes more important in assessing replication area success under such circumstances.

While conducting soil observations, it was noted that soil profiles retained relatively normal structure and

Photograph 14. August 11, 2016—Drought Rating "D1"—Moderate Drought. Traditional Replication Wetland approximately two months after construction. Partial vegetative cover, approximately 50:50 upland:wetland species, and lower species diversity/richness scores than Experimental Replication Wetland. Mulch has dispersed. Seeding and nursery stock have not fully covered the soil. Photo source: Gillian Davies.

Photograph 15. August 11, 2016—Drought Rating "D1"—Moderate Drought. Traditional Replication Wetland approximately two months after construction. Partial vegetative cover, approximately 50:50 upland:wetland species, and lower species diversity/richness scores than Experimental Replication Wetland. Mulch has dispersed. Seeding and nursery stock have not fully covered the soil. Photo source: Gillian Davies.

consistence in the Experimental Replication Wetland, whereas compost-based topsoil in the Traditional Replication Wetland was loose and lacking in soil structure. On August 11, 2016 (D1- Moderate Drought), it was noted that the lack of soil structure and incomplete vegetative cover in the Traditional Replication Wetland appeared to contribute to drier conditions in the top several inches of soil, compared to the Experimental Replication Wetland and the Reference Wetland.

Hydric Soil Indicators

Experimental Replication Wetland

Soil profile results should be considered preliminary given that the soil profile experienced disturbance during the translocation. Soil in Pit E1 met the USDA NRCS Hydric Soil Indicator F3, Depleted Matrix, as specified in the USDA NRCS "Field Indicators of Hydric Soils in the United States: A Guide to Identifying and Delineating Hydric Soils, Version 8.0, 2016" (USDA NRCS Field Indicators). The top 23 cm (9 in) of soil in Pit E2 meets the "Field Indicators for Hydric Soils in New England, Version 3" (New England Hydric Soil Technical Review Committee Field Indicators 2004) hydric soils criteria X.A. Soil from 23 cm to 28 cm (9 to 11 in) may be within the Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast (Version 2.0) (2012) Problematic Hydric Soil #8: "Discharge Areas for Iron-Enriched Groundwater," based on the patterning of redoximorphic features within a chroma 4 matrix, and the observation of soil saturated to the surface during a Severe Drought. Soil from Pit E3 did not appear to meet criteria for hydric soils.

Traditional Replication Wetland

Soil profile results should be considered preliminary given that the soil profile experienced disturbance during the installation process. Soil in Pit T1 may

Photograph 16. November 18, 2016—Drought Rating "D2"—Severe Drought. Experimental Replication Wetland with dense vegetative cover, primarily native wetland species, and high species diversity/richness scores. Relatively warm temperatures in fall of 2016 extended the growing season. Photo source: Gillian Davies.

Photograph 17. November 18, 2016—Drought Rating "D2"—Severe Drought. Traditional Replication Wetland vegetative cover is developing, but not as densely as Experimental Replication Wetland. Species are a mix of upland and wetland, species diversity/richness scores are lower than those of the Experimental Replication Wetland. Relatively warm temperatures in fall of 2016 extended the growing season. Photo source: Gillian Davies.

be within the Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region (Version 2.0) (2012) Problematic Hydric Soil #8: “Discharge Areas for Iron-Enriched Groundwater,” based on the patterning of redoximorphic features within a chroma 6 matrix in a loamy sand (see Photograph #21), and the observation of soil saturated to the surface, weeping at 10 cm (4 in), and standing water at 23 cm (9 in), during a Severe Drought (November 18, 2016). Soil in Pit T2 does not meet hydric soil criteria, but may also be located in a discharge area for iron-enriched groundwater. Soil in Pit T3 may be within the Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region (Version 2.0) (2012) Problematic Hydric Soil #8: “Discharge Areas for Iron-Enriched Groundwater,” based on the patterning of redoximorphic features within a chroma 8 matrix in a very gravelly loamy coarse sand, and the observation of soil saturated at 18 cm (7 in), and standing water at 30 cm (12 in) during a Severe Drought (November 18, 2016).

Reference Wetland

Soil profile results reflect relatively undisturbed conditions. However, it should be noted that the Reference Wetland, like the wetland replication wetlands, is located within a utility ROW, and thus has experienced historical disturbance and continued control of woody vegetation above a certain height (i.e., no trees are present). Based on observations, soil in Pit R1 is likely to meet hydric soil criteria, although excavation below 41 cm (16 in) was not possible, and A horizon material extended the full depth of the pit (preventing a conclusive soil evaluation). Low chroma redoximorphic features were observed throughout the soil profile, and high chroma redoximorphic features were observed from 8 to 23 cm (3 to 16 in). Oxidized rhizospheres were observed at 8 cm (3

Photograph 18 & 19. November 18, 2016—Drought Rating “D2”—Severe Drought. Ground surface in Experimental Replication Wetland (on left) and in Reference Wetland (on right) at the end of the growing season. Photo source: Gillian Davies.

Horizon [1]	P	K	Ca	Mg	Fe	Mn	% OM
	mg / L						
R2-O	0	2	47	1	0.05	0	54.8
E1-Oe	0	9	4	0	0.29	0	49
E2-Oe	1	9	1	0	0.13	0	46.8
E2-Oa	0	6	1	0	0.1	0	52.7
E2-A1	3	228	920	124	31	4	45.6

[1] Samples Identification are wetland type – Reference Wetland (R), or Experimental Replication (E); the number is the replicate, followed by the horizon designation assigned in the field

Table 1. Nutrient Concentrations and Percent Organic Matter (OM) of the Organic Horizons

WETLAND AREA	MARGALEF INDEX FOR DIVERSITY/ RICHNESS	SIMPSON’S INDEX OF DIVERSITY (RANGE 0 – 1)	% WETLAND VEGETATION - DOMINANTS[1]
Experimental Replication Wetland	2.34	0.74	100%
Traditional Replication Wetland	1.61	0.4	50%
Reference Wetland	1.7	0.76	67%
[1]USACE Dominance Test.			

Table 2. Vegetative results: First Growing Season (2016)

in). Soil in Pit R2 met the USDA NRCS Hydric Soil Indicator A1, Histosol, as specified in USDA NRCS Field Indicators. Soil in Pit R3 met the USDA NRCS Hydric Soil Indicator S7, Dark Surface, as specified in USDA NRCS Field Indicators.

Soil Lab Experimental Results

Soil properties in the Experimental Replication Wetland more closely resembled those of the Reference Wetland and retained moisture to a greater degree than the Traditional Replication Wetland during drought. Of particular note (see Figure 2), pH was noticeably higher in the Traditional Replication Wetland (5.57 to 7.73), than in either the Experimental Replication Wetland (4.14 to 5.01) or the Reference Wetland (4.20 to 4.67). The nutrient concentrations (Table 3) documented in this study suggest that the translocation of soil and intact vegetation results in a wetland replication area with soil that more closely resembles typical hydric soils than those found in traditionally constructed wetland replication areas with compost-based soil. Moreover, the addition of significant amounts of phosphorous (P) to the compost-based topsoil in the Traditional Replication Wetland may cause leaching into the adjacent natural wetland with adverse effects on overall growth in the natural wetland since P is usually limiting in freshwater wetlands. Similarly, the increased concentrations of calcium (Ca), and magnesium (Mg) will alter the pH (Table 3) and, in most wetland situations, significant pH changes will alter vegetation patterns and impact soil microbes. In general, soil microbial populations will experience stress when soil pH is lower than 4.0 or higher than 6.0. Five out of the six Traditional Replication Wetland horizons sampled

Photograph 20. Excavation (June 6, 2016) in the vicinity of Pit T1 during Traditional Replication Wetland construction. High chroma matrix (with redoximorphic patterning) is present with observable water table, under Abnormally Dry conditions (drought rating of "D0"), suggesting soils in this area are discharge areas for iron-enriched groundwater. Photo source: Gillian Davies.

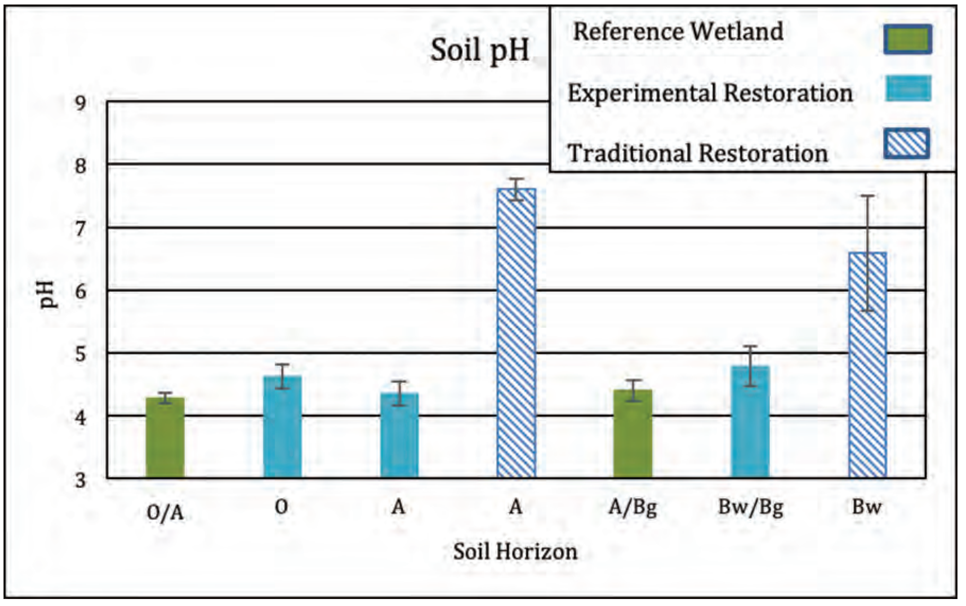

Figure 2. Mean Soil pH of the Sampled Horizons. The bar represents the mean of the soil sample replicates, and the error bars are shown. When one treatment had a single replicate, the value of that replicate is shown with no error bar.

exhibited pHs above 6.0 (from 6.85 – 7.73), with the sixth sample exhibiting a pH of 5.57. The pH in both the Experimental Replication Wetland and the Reference Wetland was found to be within acceptable soil pH range (between 4.0 and 6.0), although on the lower side (all but one sample exhibited pH below 5.0). The Experimental Replication Wetland has replicated the typical pH for this location, whereas the Traditional Replication Wetland has not.

The differences in soil pH between the Traditional Replication Wetland and the Reference and Experimental Replication Wetlands are mirrored by the percentage of organic matter in the surface soils of the same treatments (Figure 3). While there were no differences in the amount of organic matter in the first mineral horizon of all plots (A) only the Reference and Experimental Replication Wetlands had an organic horizon (O). Additionally, the Experimental Replication Wetland had more organic matter in the B horizons than the Traditional Replication pits. Organic matter (which is high in carbon) in the soil holds water longer than mineral soil (thus contributing to drought resiliency) and is responsible for the high cation exchange capacity (CEC) of the surface horizons.

Similar trends were seen in the surface horizons of the Reference and Experimental Replication Wetlands in Total Nitrogen (Figure 4) and Total Carbon (Figure 5). These trends are to be expected, since the majority of nitrogen in non-fertilized soil comes from the breakdown of plant and animal materials. The high organic matter seen in Figure 3 is not all carbon, but a large percentage of organic matter is carbon. Note that the C:N ratios (Figure 5) are not statistically different for any of the treatments, because those samples which were high in total nitrogen (Figure 4) were also high in total carbon (Figure 5). In all samples, nitrogen is the limiting factor to growth, as would be expected in natural environmental settings.

Elemental analysis of soil samples from the different replication sites (Tables A2 and A3 in Appendix 1) document the notably higher concentration of iron in the A horizons of the Reference Wetland, 30.96 and 26.31 mg/L, when compared to either replication type, all of which were less than 1 mg/L.

			P	K	Ca	Mg	Fe	Mn
Wetland	**Horizon**		**mg / L**					
Reference Wetland	O/A	mean	0.23	7.6	28	2.8	17.4	0.25
		sd	0.07	5	16.5	1.6	15.8	0.252
	B/Bg	mean	0.55	3.3	19.8	2.1	2.7	0.131
		sd	0.72	0.8	1.1	0.1	2.1	0.036
Traditional	A	mean	23.3	111.6	650.3	62.4	0.8	3.226
Replication		sd	15.3	16	392.1	10.5	0.1	1.311
Wetland								
	Bw	mean	0.26	40.3	65.6	8.8	2.2	0.688
		sd	0.04	30.4	39.2	5.3	1.2	0.651
Experiment	O	mean	0.45	8	2	0	0.173	0
Replication		sd	0.3	1.7	1.7	0	0.102	0
Wetland								
	A	mean	0.08	4	32.1	3.7	1.8	0.53
		sd	0.01	0.3	1.4	0.4	0.5	0.003
	Bw/Bg	mean	0.07	3.9	16.5	1.6	4	0.388
		sd	0.06	4.4	14.5	1.4	5.8	0.489

Note: Nutrient concentrations of the surface and subsurface horizons from the Reference Wetland and the replication sites. Numbers presented are the mean of the soil sample replicates and standard deviation (sd) from the mean.

Table 3. Nutrient Concentration of Surface and Subsurface Soil Horizons in the Three Wetland Areas

Constraints and Considerations

We were not able to control all factors in this study. It would have been preferable to plant both the Experimental and Traditional Replication Wetlands at the same time, and to monitor more parameters, such as directly measuring greenhouse gas fluxes. We only have data from the first growing season, whereas longer term monitoring data would be more informative. Our results are preliminary, due to the single season of monitoring. It would have been preferable to collect data from more than one vegetative plot per wetland type. It is likely that the replication wetlands are located at least partially within an area where iron-rich groundwater discharges, thus adding to the complexity of evaluating the soils. Additionally, the 2016 growing season included an extended drought from May onward, so typical wetland water tables were not available.

CONCLUSIONS

The results of this study, in terms of soil chemistry, vegetative richness and diversity, percentage of dominant plants that are wetland species, as well as informal observations of soil moisture during drought, vegetative cover and density, and soil structure (or lack thereof) strongly suggest that the overall function of the Experimental Replication Wetland more closely resembles that of the Reference Wetland after one growing season than does that of the Traditional Replication Wetland.

By protecting and translocating intact A and O horizons (sometimes with inclusion of underlying B horizon material) and associated rooted vegetation, the Experimental Replication Wetland maintained higher levels of soil organic matter and soil carbon than the Traditional Replication Wetland, exhibited greater soil structure and consistence, greater predominance of wetland species, greater vegetative cover, and greater species diversity and richness, while replicating Reference

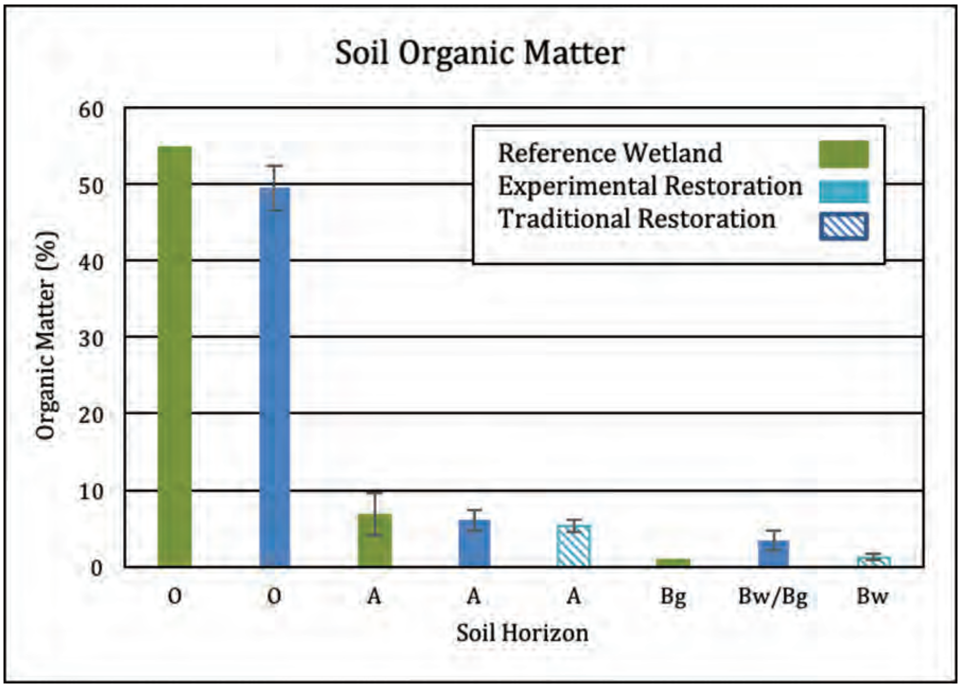

Figure 3. Mean Percent Soil Organic Matter. The bar represents the mean of the soil sample replicates, and the error bars are shown. When one treatment had a single replicate, the value of that replicate is shown with no error bar.

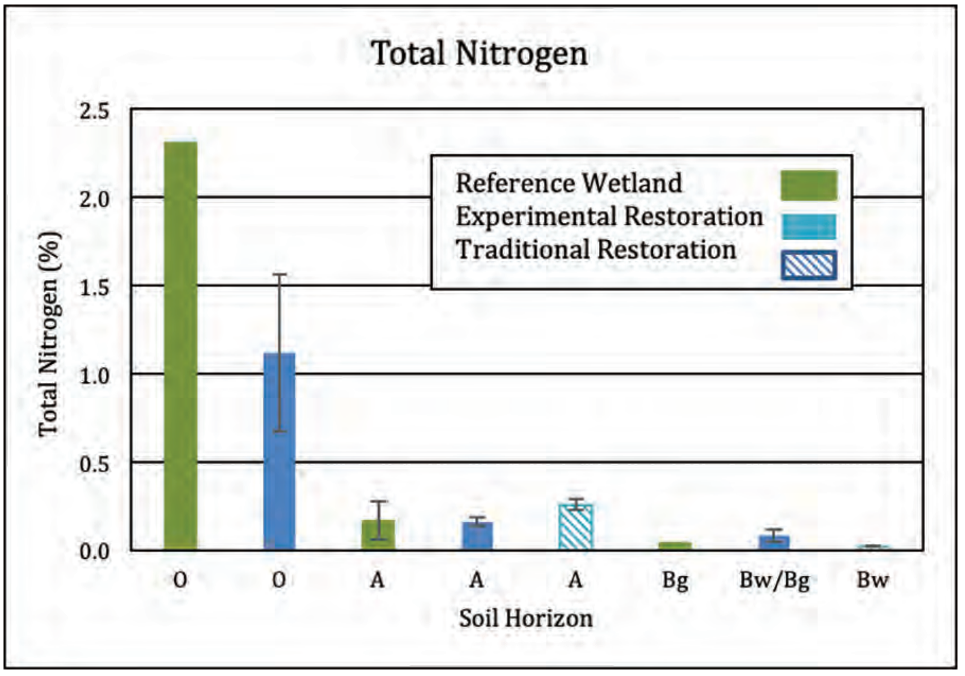

Figure 4. Percent Total Nitrogen. The bar represents the mean of the soil sample replicates, and the error bars are shown. When one treatment had a single replicate, the value of that replicate is shown with no error bar.

Wetland pH more successfully. The relatively high levels of soil organic matter/soil carbon, soil structure and consistence, and establishment of an intact, dense vegetative cover immediately upon installation of the blocks of intact soil with vegetation appeared to provide enhanced soil moisture retention capacity, compared to the Traditional Replication Wetland. Thus, the capacity of the Experimental Replication Wetland to withstand the effects of the 2016 drought, and future drought-related impacts from climate change, was likely enhanced immediately upon completion of installation of the translocated blocks of soil and vegetation. Continued monitoring would be valuable for further assessment of drought resilience.

Due to the transfer of blocks of soil and vegetation, which resulted in continued vegetative cover, the Experimental Replication Wetland likely offered fewer opportunities for invasive species to establish. Monitoring this site in a longer period of time would be helpful in determining if reduction of invasive species is a long-term result of the use of the experimental construction method. The construction method employed for the Experimental Replication Wetland resulted in microtopography that resembled the Reference Wetland to a greater extent than the Traditional Replication Wetland, thus more successfully mimicking the microtopography of adjacent undisturbed wetlands.

Laboratory soil test results document higher levels of soil organic matter and soil carbon in the Experimental and Reference Wetlands, compared to the Traditional Wetland, demonstrating that much of the impacted wetland soil organic matter and soil carbon were successfully translocated to the Experimental Replication Wetland. In the

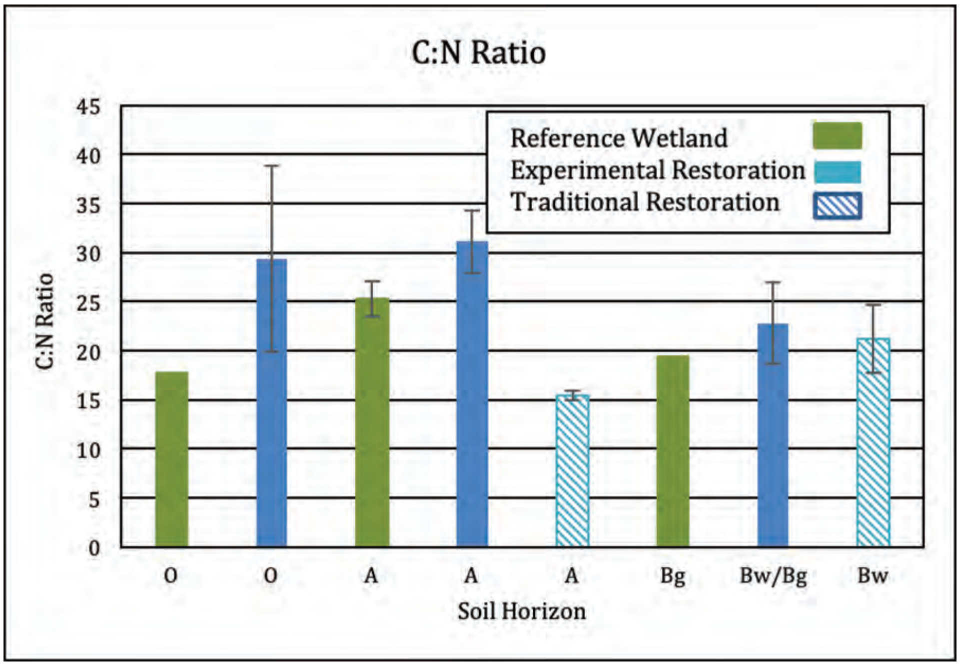

Figure 5. Percent Total Carbon. The bar represents the mean of the soil sample replicates, and the error bars are shown. When one treatment had a single replicate, the value of that replicate is shown with no error bar.

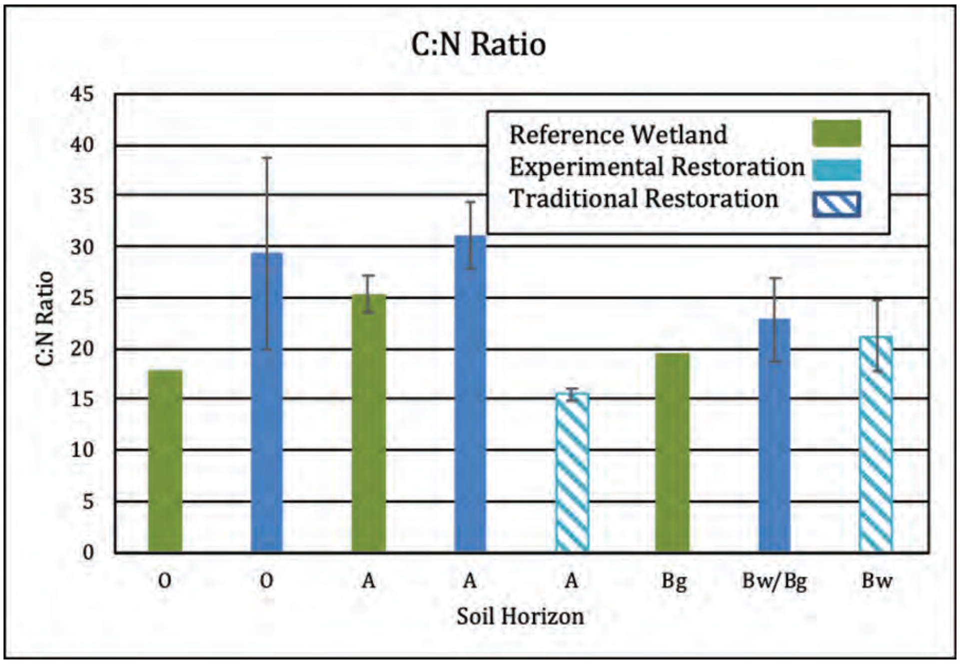

Figure 6. Ratio of Total Carbon to Total Nitrogen. The bar represents the mean of the soil sample replicates, and the error bars are shown. When one treatment had a single replicate, the value of that replicate is shown with no error bar.

Experimental Wetland, soil structure was preserved within soil blocks, although disrupted at the edges. Monitoring of greenhouse gas fluxes would enable further verification of the success (or lack thereof) in preserving soil carbon biogeochemistry and reducing greenhouse gas emissions from the Experimental Wetland. Such greenhouse gas flux monitoring is recommended to evaluate whether or not the experimental translocation of intact soil and vegetation blocks allows a newly created wetland to become a net sequesterer of carbon within a shorter timeframe than wetlands created with traditional methodologies. If the length of time that it takes for a newly created freshwater wetland to become a net sequesterer of carbon can be shortened or eliminated by implementing this experimental method, then it has the potential to reduce or prevent net greenhouse gas emissions from newly created freshwater wetlands.

Next Steps

Where site conditions allow, it is recommended that managers of ROWs (and similar) projects implement the experimental replication methodology (soil and vegetation translocation) discussed in this paper. By doing so, they are likely to:

- Achieve better ecological function (see parameters discussed in prior sections of article)
- Create wetlands with greater resilience to changes in climate, particularly drought
- Create wetlands with greater resistance to invasive species
- Realize cost savings (see prior section of article)
- Contribute to greater conservation of carbon stored in soils
- Potentially protect soil microbial communities, soil structure, and soil biogeochemical functions to a greater extent than traditional construction methods allow, and thus potentially prevent or reduce net greenhouse gas emissions from a newly created wetland. However, direct measurement of greenhouse gas fluxes is needed in order to verify this idea.

Following these preliminary results, it is recommended that further research be conducted, particularly with regard to monitoring of greenhouse gas fluxes. It is hoped that wetland restoration and creation BMPs can be developed that minimize disruption of soil biogeochemical processes and greenhouse gas emissions, in addition to more typical measures of wetland replication and creation success.

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APPENDIX – SOIL ANALYSIS

		pH	Organic Matter	Total Carbon	Nitrate	Ammonium	Total Nitrogen	C:N
Wetland Type	**Horizon**	**pH units**	**%**	**%**	**——mg/L**	**——**	**%**	**22.2**
Reference Wetland	A1	4.36	8.35	5.51	1	4	0.25	22.2
	A2	4.52	5.95	3.4	1	2	0.13	26.7
	O	4.27	54.8	40.94	5	5	2.3	17.8
	A	4.28	3.34	2.21	1	1	0.09	25.9
	A	4.2	9.59	8.36	1	6	0.35	24.2
	Bg	4.67	0.85	0.76	0	1	0.04	19.4
Traditional Replication Wetland	A	7.73	5.87	4.17	12	2	0.28	15.1
	Bw	6.85	1.65	0.63	4	9	0.03	24.1
	A	7.68	4.34	3.58	10	2	0.22	16.1
	Bw	7.35	1.23	0.41	3	1	0.02	22.1
	A	7.41	5.61	4.23	22	2	0.28	15.2
	Bw	5.57	0.95	0.37	2	1	0.02	17.4
Experimental Replication Wetland	Oe	4.42	49	28.03	0	1	0.86	32.6
	A1	4.14	45.6	28.32	2	18	1.55	18.2
	A2	4.45	6.95	5.18	9	1	0.18	28.9
	Oe	4.8	46.8	31.93	0	1	0.87	36.8
	Oa	4.65	52.7	30.55	0	3	1.63	18.7
	Bg	4.42	2.69	1.79	1	1	0.07	27.6
	Bw	5.01	2.77	1.2	1	1	0.06	20
	A	4.47	6.7	4.86	10	1	0.15	33.4
	Bw	4.92	4.8	2.54	2	1	0.12	20.8

Table A1. Soil pH, organic matter, total carbon, nitrate, ammonium, total nitrogen, and carbon-to-nitrogen ratio for all soil samples

		P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
Wetland Type	**Horizon**	——————— mg/L ———————								
Reference Wetland	A1	0.18	9.38	18.73	3.28	30.96	0.51	0.03	0.51	0.01
	A2	0.1	3.42	15.13	1.73	3.59	0.14	0.01	0.15	0
	O	0.03	0.34	7.99	0.17	0.01	0	0.01	0	0
	A	1.02	2.01	15.27	1.64	0.26	0.08	0.01	0.04	0
	A	0.39	14.42	22.59	4.99	26.31	0.29	0.03	0.34	0
	Bg	0.11	2.05	13.7	1.42	2.22	0.07	0.01	0.08	0
Traditional Replication Wetland	A	34	104	914	57	0.76	3.27	0.03	0.77	0.32
	Bw	0.15	44.5	64.7	8.5	2.2	0.88	0.02	0.06	0.03
	A	8.55	67.3	275.6	36.1	0.58	2.88	0.02	0.52	0.2
	Bw	0.2	25.5	44.1	6.3	1.29	0.34	0.03	0.05	0.05
	A	13.4	89.7	361.2	53.2	0.61	1.33	0.02	0.52	0.3
	Bw	0.13	5.92	14.4	1.78	0.66	0.07	0.01	0.04	0.01
Experimental Replication Wetland	Oe	0.05	1.53	0.68	0	0.05	0	0.02	0	0
	A1	0.54	38.7	156.4	21	5.25	0.69	0.02	0.57	0
	A2	0.08	4.04	29.49	3.27	1.37	0.5	0	0.11	0
	Oe	0.1	1.53	0.17	0	0.02	0	0.01	0	0
	Oa	0	1.02	0.17	0	0.02	0	0	0	0
	Bg	0.05	2.26	20.98	1.92	0.95	0.16	0	0.05	0
	Bw	0.05	1.69	7.44	1.03	4.15	0.38	0.02	0.04	0
	A	0.07	3.62	31.42	3.76	2.03	0.51	0.01	0.07	0
	Bw	0.11	7.5	18.28	1.99	9.23	0.81	0.04	0.11	0
* Values for Experimental replication wetland A1 are most probably not correct as it was analyzed as a mineral soil.										

Table A2. Macronutrients [phosphorous (P), potassium (K), calcium (Ca), and magnesium (Mg)] and micronutrients [iron (Fe), manganese (Mn), copper (Cu), zinc (Zn) and boron (B)] for all soil samples

		Pb	Al	Na	S	Exchangeable Acidy	CEC	Base Saturation			Soluble Salts mS/cm	Sample Density g/cc
Wetland Type	Horizon	———— mg /L ————						Ca	Mg	K		
Reference Wetland	A1	0.82	73.38	3.95	2.67	18	18.5	2.98	0.85	0.76		0.85
	A2	0.14	62.51	2.8	2.36	13	13.74	3.24	0.61	0.38		1.04
	O										0.16	
	A	0.06	40.05	2.36	1.52	16	16.8	2.67	0.47	0.18		1.15
	A	1.47	27.3	3.72	2.99	15	16.59	4.01	1.45	1.31		0.68
	Bg	0.15	6.89	2.64	0.63	5	5.19	7.77	1.32	0.59		1.25
Traditional Replication Wetland	A	0.32	1.9	21.25	15.21	0	31.17	86.21	8.78	5.02		1.02
	Bw	0.07	21.84	12.92	2.39	0	2.98	63.84	13.7	22.46		1.36
	A	0.2	1.64	16.28	2.95	0	10.86	74.65	16.02	9.33		1.19
	Bw	0.05	14.58	8.64	1.2	0	1.98	65.38	15.3	19.32		1.31
	A	0.22	1.64	26.76	3.8	0	14.54	73.08	17.64	9.28		1.1
	Bw	0.03	8.24	2.86	2.84	1	1.56	27.08	5.51	5.71		1.49
Experimental Replication Wetland	Oe										0.05	
	A1*	1.98	49.48	12.71	7.46	25	31.68	14.52	3.2	1.84		0.39
	A2	0.14	42.61	3.32	1.53	17	17.71	4.9	0.89	0.34		0.9
	Oe										0.04	
	Oa										0.08	
	Bg	0.06	42.03	2.05	0.77	16	16.47	3.75	0.56	0.21		1.14
	Bw	0.12	29.86	1.57	2.97	7	7.03	3.11	0.7	0.36		1.29
	A	0.08	36.08	3.09	2.58	15	15.86	5.83	1.14	0.34		0.89
	Bw	0.21	41.59	3.52	9.1	9	9.8	5.49	0.98	1.15		0.98

* Values for Experimental replication wetland A1 are most probably not correct as it was analyzed as a mineral soil.

Table A3. Micronutrients lead (Pb), aluminum (Al), sodium (Na), and sulfur (S) exchangeable acidity, cation exchange capacity (CEC), and percent base saturation and sample density for mineral soil samples. Soluble salts for organic samples

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Methods for Terrain and Geohazard Analysis for ROW Planning in Northern Environments

Dennis O'Leary, Anne Sommerville, and Christiane Brouwer

When planning a linear infrastructure, be it a road, pipeline, railway, or transmission line, it is imperative to evaluate the terrain conditions. Evaluating soil material, overburden thickness, slope, drainage, and on-going geomorphological processes, such as permafrost and landsliding, is critical in determining the final location of the right-of-way (ROW). This geological data provides some of the data required for engineering design, construction, and long-term maintenance. This need has never been more important with changing climate conditions—especially in northern environments where the knowledge of permafrost conditions is poor, but the need for such data is so critical moving forward. Failure to properly determine ground conditions upfront in a project can result in significant future costs that may not be included in estimating overall project costs.

This paper provides examples from two projects in Alaska and northern Alberta where detailed terrain and geohazard analysis completed at scales of 1:2,000 and larger have been used to refine road, pipeline, and rail alignments in addition to providing data for both planning and asset management purposes.

Keywords: Alaska, Alberta, Climate Change, Ecology, Groundwater Seepage, Landslides, Mapping, Northern Alberta, Permafrost, Permafrost Degradation, Pipeline Integrity Management, Pipeline Routing, PurVIEW, Rockfall, Rights-of-Way (ROWs), Slumps, Softcopy, Summit Evolution, Terrain, Terrain Mapping, Terrain Sciences, Thaw Flow Slides.

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INTRODUCTION

Terrain and geohazard analyses are a critical component of all development activities that involve any disturbance of the earth's surface. A knowledge of the soil (origin, texture, drainage), depth to bedrock (overburden thickness), slope, topography, and geomorphic processes is critical for the proper engineering design and construction of a project, as well as on-going operations, maintenance, and future reclamation activities.

In northern environments, where permafrost is found, it is extremely important to understand the type, depth, and location of the permafrost—especially in areas of discontinuous, sporadic, and isolated permafrost in which it is not continuous across the landscape and is often associated with specific terrain conditions, including aspect, soil material, soil material texture, and drainage.

Permafrost is defined as soil or rock materials that remain frozen from one year to the next. Four permafrost zones have been mapped and identified in Canada; each zone is defined by the percent of land area underlain by permafrost. The zones include:

- Continuous (90–100 percent of the land area underlain by permafrost)
- Extensive Discontinuous (50–90 percent)
- Sporadic Discontinuous (10–50 percent)
- Isolated Patches (<10 percent)

Climate warming in the past decades has caused degradation in permafrost widely and quickly. Permafrost degradation refers to a naturally or artificially caused decrease in the thickness and/or areal extent of permafrost (Lemke et al. 2007). It has the potential to significantly change soil moisture content (Yang et al. 2010), possibly resulting in (1) horizontal downslope movements due to the creep of permafrost bodies, and (2) vertical settling movements due to the melting of ice bodies and/or interstitial ice (Dall'Amico et al. 2011). The former tends to result in thaw flow slides (Figure 1) while the latter is more typical of thermokarst terrain (Figure 2).

A study by Beilman and Robinson (2003) recorded recent changes in the areal extent of permafrost at the individual peatland scale within the discontinuous permafrost zone of northern Alberta, Saskatchewan, and Manitoba. This study found that at five southern sites, between 30 and 65 percent of localized permafrost has degraded in the last 100 to 150 years and that the thaw is significantly correlated to mean annual air temperature. The same study recorded as much as 50 percent of peat plateau permafrost has thawed within the past 50 years in the discontinuous permafrost zone, and total thaw can be greater in the north than the south (Beilman and Robinson 2003). The results of the study by Beilman and Robinson (2003) suggest that localized permafrost at the southern limit of the discontinuous permafrost zone responds more directly to climate warming than peat plateaus in the north.

Forest cover also plays a role in the regulation of surface temperatures, and extensive logging is known to be a potential trigger of extensive permafrost melting. These effects can have a very high spatial variability due to the uneven ground ice distribution (ice wedges and lenses). This effect on permafrost has been documented through numerous experiences with road construction, railways, pipelines, and forest logging (Dall'Amico et al. 2011).

In the Arctic, temperature at the top of the permafrost layer has increased by up to 3o Celsius since the 1980s. The permafrost base has been thawing at a rate ranging up to 0.04 meters (m) per year (yr) yr-1 in Alaska since 1992 and 0.02 m yr-1 on the Tibetan Plateau since the 1960s. As a result, permafrost degradation is leading to changes in land surface characteristics and drainage systems (Lemke et al. 2007).

Figure 1. Thaw flow slide *(from nwtgeoscience.ca)*

Figure 2. Thermokarst terrain *(from nwtgeoscience.ca)*

Pipelines buried in soils with fluctuating water tables may be more prone to stress cracking corrosion (SCC) than when buried in well-drained soils. Pipelines buried in thick organic materials may be subject to floatation unless properly anchored. Roads, railways, transmission towers, and pipelines built in and over areas of permafrost are subject to subsidence. Transmission towers built in rugged steep terrain may be subject to upslope movements including landsliding and avalanching.

Guo and Wang (2016) suggest that the considerable impact of permafrost degradation on hydrology and water resources, ecosystems, human-engineered facilities, and climate change requires us to carry out more in-depth studies and at finer spatial scales to investigate the issue. It is with this challenge that this paper discusses a relatively new approach to obtaining more in-depth data at finer spatial scales. This conclusion by Guo and Wang (2016) is not only relevant to permafrost, but to other terrain data, including soil materials, soil textures, depth to bedrock/overburden thickness, slope, drainage, and geoprocesses including permafrost.

Smith and Riseborough (2010) found that through simulation modelling for warm, thin permafrost (mean annual ground temperature above -1o Celsius; 20 centimeters [cm] thick), the combined effects of right-of-way (ROW) disturbance and climate warming are likely to result in permafrost degradation within 20 to 40 years. These ROW-disturbance effects may extend off-ROW in the scenarios of climate warming. Based on the range in ground thermal conditions considered in their study, the results of the simulation indicate that the effects of ROW disturbance outweigh those associated with climate warming in the initial 10 to 15 years following disturbance, although climate warming becomes important during longer periods of time.

Larsen et al. (2008) estimated that permafrost degradation is projected to increase the cost of maintaining public infrastructure in Alaska by 10-20 percent ($4 billion to $6 billion) by 2030, and another 10-12 percent ($5.6 billion to $7.6 billion) by 2080.

Descriptions of the two example areas discussed in this paper are provided below. This is followed by a discussion of publicly available data for these two areas and the issues surrounding these use of these datasets for detailed terrain and geohazard purposes. The paper concludes with a discussion of new techniques to obtain the necessary detailed data as well as conclusions.

AREAS OF STUDY

Two study areas are discussed in this paper, the first area being in northwestern Alberta near Hay-Zama Lakes where permafrost degradation is occurring. The second area is the Healy Canyon area, which is southwest of Fairbanks, Alaska.

Figure 3 shows the distribution and types of permafrost within northern Alberta and the southern part of the Northwest Territories. As seen in Figure 3, a narrow band of isolated permafrost approximately 50 to 100 kilometer (km) in width runs northwestward from the Fort McMurray area to Fort Vermilion and the High Level area immediately west of Fort Vermilion; isolated permafrost accounts for less than 10 percent of this land base. This band of isolated permafrost is found primarily on near-level glaciolacustrine materials and is found south of two major upland areas, the Birch Mountains and Caribou Mountains (Pettapiece 1986). Recent work by Pawley and Utting (2018) have suggested that the zone of isolated permafrost extends further south than initially mapped by Heginbottom et al. (1995). Indications of permafrost including thermokarst lakes are found nearly 50 to 75 kilometers (km) to the south, along the Alberta/British Columbia border, near the Chinchaga River. North of this band, the extreme northern portion of Alberta is classed as having sporadic permafrost (10–50 percent of land base). This includes area such as Bistcho Lake (Figure 3a) and two lakes not shown on the map but south of Bistcho Lake, Hay, and Zama lakes. The area of interest for this paper is shown with the letter B.

Figure 4 shows the distribution and type of permafrost in the Fairbanks—Glennallen area in east central Alaska (Jorgenson et al. 2008). It would appear that the permafrost distribution in this area is related to a number of factors, including elevation and hydrology, with continuous permafrost being found at higher elevations adjacent to glaciers, and isolated permafrost being associated with river valleys.

What Terrain and Geohazard Data Is Publically Available For Our Study Areas?

Most terrain or surficial geology data is available from public websites—for

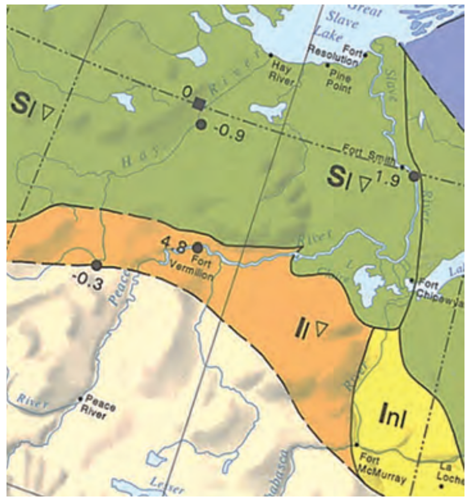


Figure 2a. Map showing distribution of permafrost zones in northern Alberta (from Heginbottom 1995). Areas in orange and yellow are classed as Isolated (<10 percent of land base has permafrost), areas in green as Sporadic (10–50 percent), and areas in blue as Extensive Discontinuous (50–90 percent) permafrost. The area of interest is shown with the letter B.

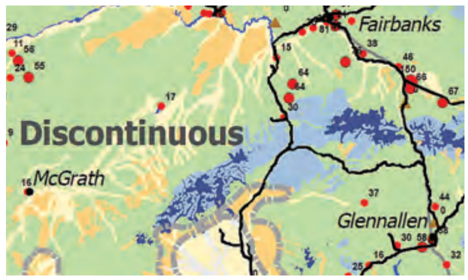


Figure 2b. Map showing distribution of permafrost in the Fairbanks—Glennallen area in east central Alaska (from Jorgenson et al. 2008). Areas in beige are classed as Isolated (<10 percent of land base has permafrost), areas in orange as Sporadic (10–50 percent) areas in green as Discontinuous (50–90 percent) and blue areas are areas of Continuous (90–100 percent) permafrost. Dark blue areas represent glaciers. Red dots represent area of known permafrost and its depth. The area of interest is Healy Canyon and is shown with the letter A.

example, the U.S. Geological Survey (*www.usgs.gov/*), the Canadian Geological Survey (*geoscan.nrcan.gc.ca*), or from state, provincial, or territorial government agencies. Maps available from these sites are generally considered to be small-scale regional maps (i.e., landscape level maps) and do not provide the detailed data required for most ROW planning and engineering.

For example, mapping at 1:100,000 scale by Paulen et al. (2005) suggests the area in northwestern Alberta near the Hay-Zama Lakes complex is comprised of recent lacustrine, glaciolacustrine, and fluvial materials, as well as large expanses of organic accumulation. The geology mapping at 1:63,360 for the Nenana River area southwest of Fairbanks suggests that the area along the Nenana River is comprised mainly of Birch Creek schist, a quartz-sericite schist and impure marble with local disseminated pyrite with areas of landslides and outwash gravel in the valley bottom (Wahrhaftig 1970). While both of these data sources provide valuable data for initial high-level planning, they are not detailed enough for proper ROW or corridor planning. While some ROWs such as those for transmission lines can avoid problematic terrain types through the spacing of towers, other ROWs such as roads, rail lines, pipelines, and fibre optic lines cannot, because the infrastructure is either on the mineral surface or buried within the soil. As a result, the location of areas exhibiting evidence of soft ground, karst topography, landslides, wetlands, areas susceptible to avulsion and channel migration, etc. is critical in the overall routing process. Many of these terrain features are too small to properly depict on small scale regional maps.

The level of information on permafrost varies significantly across the northern climes of northern North America and is generally presented in maps at scales of approximately 1:7,000,000 for countries such as Canada and states such as Alaska. Efforts are being made to develop better maps, but these maps are still considered small-scale regional maps or landscape-level maps. For example, the North Slope Science Initiative with the U.S. Geological Survey (USGS) Alaska Climate Science Center along with the University of Alaska Fairbanks, Institute of Northern Engineering developed a new permafrost map for northern Alaska by compiling existing soil and permafrost data from available sources to create a region-wide permafrost database and landscape-level (1:1,000,000 scale) map that is suitable for regional modelling and climate impact assessments. Jorgenson et al. (2015) developed a prototype map at a 1:250,000 scale to better differentiate geomorphic units because the 1:1,000,000 scale mapping typically includes complexes of geomorphic units. And similarly, in northern Alberta, work by Pauley and Utting (2018) has developed a 15-m resolution raster dataset using machine learning prediction based on establishing relationships between locations where permafrost is known to be present, and a suite of predictors consisting of topographic data, satellite imagery, and climatic factors to identify areas where permafrost may be located.

Other map products, such as soil surveys from the Natural Resources Conservation Service (NRCS) in the U.S., or from Agriculture Canada or provincial soil survey agencies in Canada, provide valuable starting data for initial routing purposes. However, these soil maps are generally at scales of 1:50,000 to 1:190,080 and only again provide what is referred to as small-scale regional map data; the soil survey of the greater Nenana area is at a scale of 1:190,080 (1 in=3 miles). And in the case of soil surveys, small-scale mapping identifies individual terrain units (polygons) with up to three soil series or components in each unit. Unfortunately, because of the small scale of mapping, the user has no idea of where the various components are to be found within the soil polygon. Is your proposed ROW going through the "*good*," the "*bad*," or the "*ugly*" components?

In most areas, a researcher is easily able to obtain landscape level, small-scale regional data; however, the user must realize the limitations of this data and develop a plan to obtain more detailed data for their needs. Guo and Wang (2016) suggest that the considerable impact of permafrost degradation on hydrology and water resources, ecosystems, human engineered facilities, and climate change requires us to carry out more in-depth studies at finer spatial scales to investigate the issue.

How Do We Get Detailed Terrain and Geohazards Data?

There are a number of readily available desktop tools available, coupled with field programs to help collect and produce detailed data to help in ROW planning and engineering design. These desktop tools include softcopy mapping coupled with digital stereo imagery, light detection and ranging (LiDAR) data, as well as Google imagery. The use of these tools allows the terrain scientist the ability to produce data at scales of 1:2,000 and larger. Data can be gathered on:

- Soil materials (e.g., till, weathered bedrock, alluvium, colluvium, etc.)
- Soil material texture (e.g., sand, silt, clay)
- Depth to bedrock/overburden thickness (e.g., bedrock at surface, within one meter of surface, between 1–3 below the surface or great than three m below the surface)
- Topography/slope (e.g., 6–5 percent slopes)
- Landform (e.g., wetlands, drumlins, eskers, outwash plain, dunes, etc.)
- Drainage (e.g., rapid, well, moderate, imperfect, poor, and very poor)
- Geomorphic processes (e.g., debris flows, thaw flow slides, thermokarst, seepage, etc.)

The use of multi-year imagery allows for the examination of changes in permafrost and landslide movement with time.

The use of these tools, especially for pipeline routing and integrity management, has been gaining acceptance and momentum in both the consulting world and in government agencies within the past decade. Scientists are increasingly using these tools to examine the ground conditions in more detail for ROW planning and site facility development (O'Leary et al. 2018; Sommerville et al. 2016; O'Leary and Isidoro 2016; Morrison et al. 2012).

The following provides a discussion of what softcopy mapping is and provides examples from the sites in northwestern Alberta and Alaska.

Softcopy Mapping

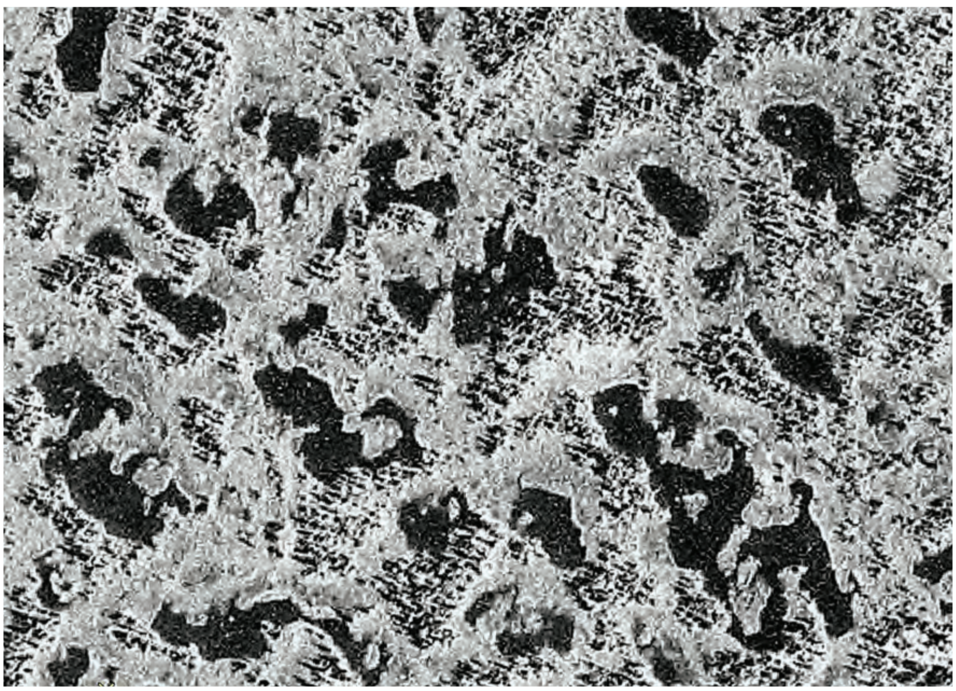
Softcopy mapping is a desktop approach that allows geologists, ecologists, engineers, or anyone looking at aerial photography the ability to zoom down into traditional black-and-white and color stereo aerial photographs on a computer monitor from their original capture scales of 1:20,000, 1:30,000, 1:40,000, etc. to scales as large as 1:1,000. Where the imagery is of good quality or has been acquired using a digital camera (e.g., 30 cm, 40 cm, 50 cm resolution), the user is able to zoom down to scales as large as 1:300 to delineate critical landscape features (e.g., permafrost, landsliding, etc.) that may affect resource development.

Softcopy incorporates 3D viewing software (e.g., PurVIEW, Summit Evolution) and ArcGIS. This combination allows the user to view the imagery in 3D and digitize linework easily. The mapper is able to zoom out of the imagery, for example, from initial capture scale of 1:30,000 to 1:50,000, etc. to view the regional context (e.g., plains, foothills, mountains, etc.) and then zoom down to very detailed scales to examine site-specific landscape features (e.g., thermokarst features, headwall scarps of landslides, groundwater seepage zones, etc.).

The results from softcopy mapping can be used directly to refine ROW planning and assist in engineering design. Locations for borehole investigations can be properly identified and executed, resulting in reduced costs for field investigations.

The following provides a number of examples of how softcopy mapping can be used to help provide not only information on soil materials,

Photograph 1. 1:60,000 scale black and white stereo image of area near Hay Zama Lakes, northwest Alberta. The area is in the discontinuous permafrost zone. Image is from June 18, 1994.



Photograph 2. The same 1:60,000 scale black and white stereo image as shown in Photograph 1 zoomed into 1:2,000 using softcopy mapping tools. Thermokarst ponds vary from less than 5 m in length to nearly 100 m.

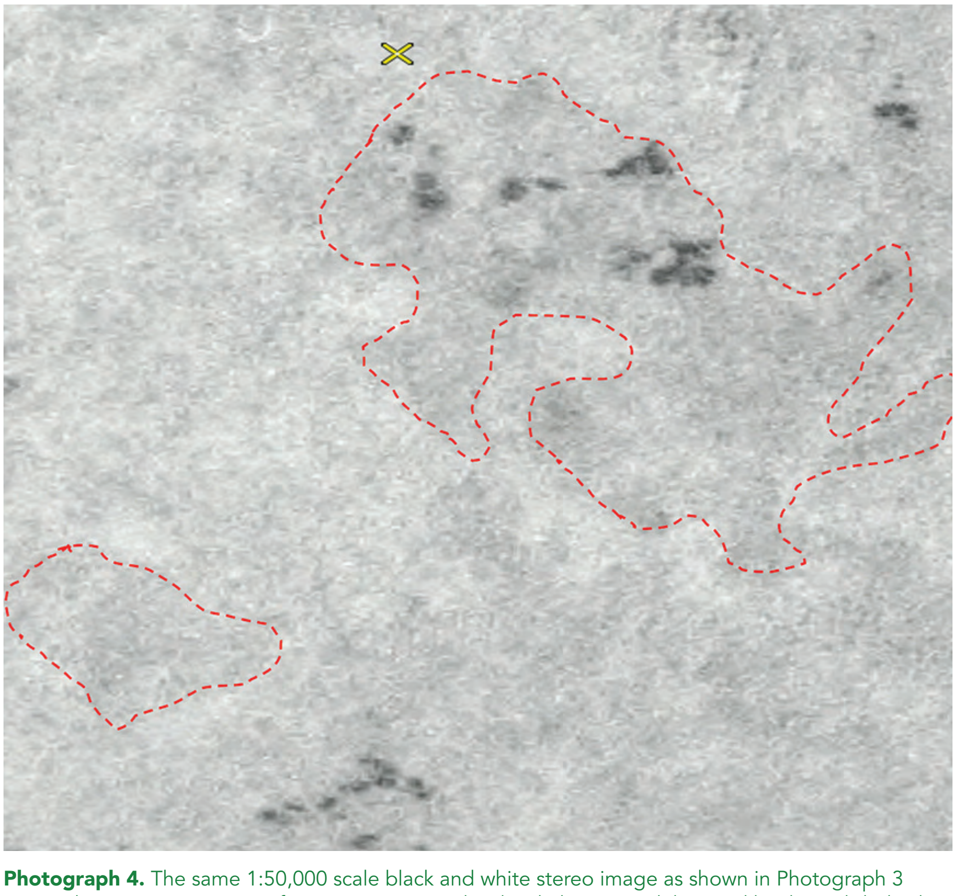
overburden thickness, slope, drainage, but also geoprocesses such as thermokarst and landsliding.

Softcopy Example 1: Photograph 1 shows an area in the Hay-Zama Lakes area of northwestern Alberta at a scale of 1:60,000. The area is crossed by a number of ROWs, including a major pipeline system, a road, and numerous seismic lines. The soils in the area are generally a silty clay, clayey silt of lacustrine, and glaciolacustrine origin. Extensive areas of shallow peat are found overlying these fine-textured materials. Fire is common within the area, thereby influencing the vegetation and the ability of an interpreter to properly interpret the landscape. At the scale of 1:60,000, an interpreter would question the area identified by the circle, wondering if the pattern is fire based, drainage based, or perhaps permafrost degradation.

Zooming down to a scale of 1:2,000 (Photograph 2) from the initial 1:60,000 scale image (Photograph 2), the mapper is easily able to see that the area identified in the circle on Photograph 2 is actually the result of permafrost degradation, thermokarst. These thermokarst lakes vary in size from less than five m in length to approximately 90 m in length. In addition to identifying the thermokarst lakes, the mapper is also able to delineate areas of thick peat materials around the lakes as well as upland black spruce areas. By drawing polygons around the features of concern, the individual is able to determine the area (hectares) and percent of the study area that has thermokarst lakes, thick peat deposits, as well as the percent upland black spruce.

Softcopy Example 2: Photograph 3 and 4 present similar examples of permafrost degradation in the Hay-Zama Lake area of northwestern Alberta. In Photograph 3 (1:50,000) an area of bright contrast is circled adjacent to a ROW. Initially, the area within the circle would be mapped as organic terrain, however, upon examination of Photograph 4 (1:2,000), the mapper is able to identify a number

Photograph 3. 1:50,000 scale black and white stereo image of area near Hay Zama Lakes, northwest Alberta. The area is in the discontinuous permafrost zone. Image is from June 18, 1994. Area highlighted in black circle is an area of possible permafrost degradation.



Photograph 4. The same 1:50,000 scale black and white stereo image as shown in Photograph 3 zoomed into 1:2,000 using softcopy mapping tools. The darker areas delineated by the red dashed lines are likely areas of permafrost degradation. The surrounding area is likely thick peat materials.

of darker areas that are likely areas of permafrost degradation.

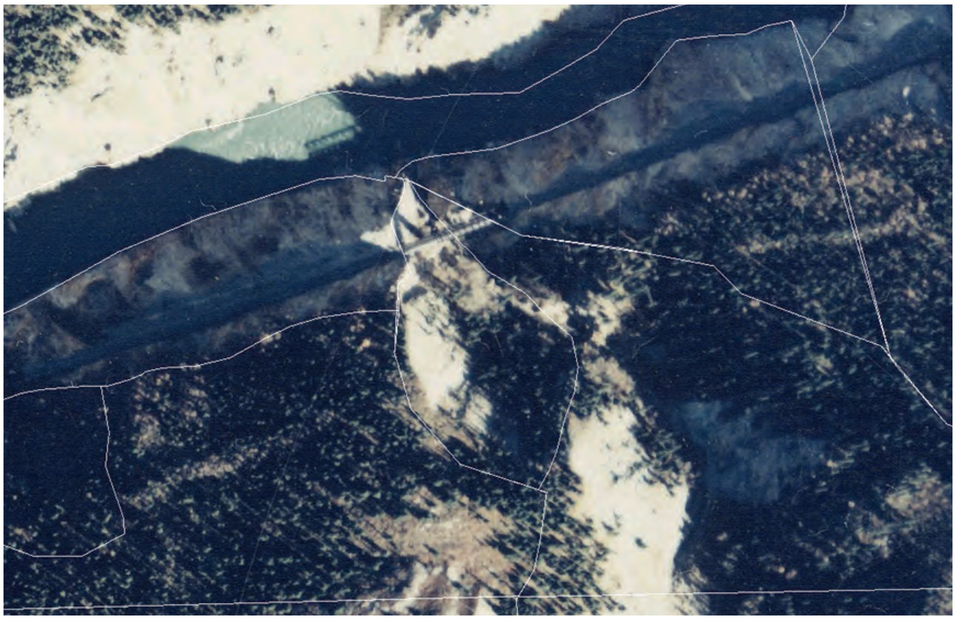
Because the imagery is rectified to either provincial DEM or LiDAR data, the user is able to quickly obtain global positioning system (GPS) coordinates for field sampling. This then allows for a more focused and less costly field program.

Softcopy Example 3: Photograph 4 and 5 are of the Healy Canyon area southwest of Fairbanks, Alaska. The Healy Canyon area has a number of ROWs, including a state highway, which includes a parallel pipeline and the Alaska Railway line; this latter ROW is not visible on Photograph 4, but can be seen on Photograph 5.

In Photograph 4 (1:31,680 scale), the mapper has identified a number of features, including a major, deeply incised, V-shaped gully system (A), a near-vertical bedrock exposure (B), and a gently to moderately sloping upland area (C). While the Nenana River can be discerned at this scale, it is too small to delineate as a separate unit, especially with the shadow effects from the steep, north-facing slope on the south side of the river near where the gully enters the river. The mapping depicted in Photograph 5 is more detailed than the landscape-level mapping of Wahrhaftig (1970), which was completed at 1:63,360 scale.

Photograph 6 shows a portion of Healy Canyon at a scale of 1:2,000. At this detailed scale, the Nenana River (A) is clearly delineated and the mapper can clearly see the Alaska railway along the south slope of the Nenana River. The mapper is also able to identify the shadow of the train trestle (B) within the Nenana River. And using ArcGIS measuring tools, the mapper is able to measure the length of the train trestle (148 m). A surficial geologist trained in geohazards mapping is able to identify three types of landsliding in this image, the first being a large debris slide (C) in thick sediment adjacent to the major gully system, the second, two areas of rockfall (D) above and below the railway, and the third, a major slump (E)

Photograph 5. 1:31,680 Scale Color Stereo Image of Healy Canyon Near Healy, Alaska. White lines delineate different terrain types. Terrain unit A is a deeply incised, V-shaped gully system; terrain unit B is a near-vertical bedrock exposure; and terrain unit C is a gently to moderately sloping upland area.



Photograph 6. The same 1:31,680 scale black and white stereo image as shown in Photograph 5 zoomed into 1:2,000 using softcopy mapping tools. The Nenana River (A) is clearly seen and is approximately 32 m in width. The shadow of the train trestle is clearly seen in the river (B). The terrain unit C is a large debris slide, Area D characterized by rock fall, and area E is a slump in the surficial materials.

in the surficial materials. Being able to identify these three kinds of slides helps in establishing a proper field program and developing proper engineering practices to safeguard the railway line.

No permafrost features are evident in the Healy Canyon imagery. This is likely due to the coarse-textured nature of the overlying materials combined with gentle-to-moderate as well as very steep slopes and bedrock being close to the surface.

CONCLUSIONS

Detailed terrain data is required for proper routing along ROWs, as well as for on-going maintenance of all infrastructure. It is well documented that the climate is changing (Beilman and Robinson 2003; Dall'Amico et al. 2011; Guo and Wang 2016), and without proper knowledge of local ground conditions, the infrastructure along a ROW may be subject to failure.

A number of conclusions can be drawn from the examples provided above. These include:

- Most publically available data pertaining to soils, terrain, surficial geology, and geohazards is of a small-scale, regional, landscape-level basis. This kind of data is of value for initial planning purposes only and does not provide sufficient detail for engineering design and construction purposes.
- Data specific to ROWs or individual sites can be produced through the use of softcopy mapping tools. This is an inexpensive desktop approach to producing detailed data that can be used for ROW planning purposes and can also be used to help identify locations of boreholes and other types of field programs.
- Softcopy mapping can be supplemented with other data including LiDAR, data from hand augers and boreholes, in addition to other field programs, including ground penetrating radar (GPR).
- The costs of obtaining proper ground condition data upfront in a project is far less than the costs associated with failures in a system.

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AUTHOR PROFILES

Dennis O'Leary

Dennis O'Leary has been working in the field of terrain and earth sciences for the past 39 years. He is a Principal of Golder Associates Ltd. in its Edmonton Alberta office. He has completed mapping for more than 60,000 km$_2$ of land across Canada, the U.S., Africa, and South America. While much of his early work focused on small-scale, landscape-level mapping in support of planning initiatives, during the past 25 years, he has focussed mainly on detailed mapping at scales of 1:5,000 to 1:350 scale in support of pipeline routing and integrity management, mineral exploration, as well as railway, road, and transmission routing. He is the leading practitioner in the application of softcopy mapping tools for natural resource inventories.

Anne Sommerville

Anne Sommerville has been completing terrain mapping projects in northern environments for the past 15 years using softcopy mapping tools. She has completed much of her work at scales of 1:5,000 to 1:1,000 in support of pipeline routing and integrity management programs. She has completed a number of terrain mapping projects in areas of continuous permafrost in support of northern mine developments.

Christiane Brouwer

Christiane Brouwer is a soil terrain scientist who regularly completed detailed terrain mapping in northern environments in support of pipeline integrity management programs. She is most familiar with area of sporadic and discontinuous permafrost in northerwestern Alberta.

Mineral Roads in *Sphagnum*-Dominated Peatlands: the Peat Inversion Technique

Kathy Pouliot, Line Rochefort, and Alexandre Beauchemin

This restoration project has been conducted on two peatlands where access roads were constructed under powerlines. A mineral road placed within a peatland changes the nature of the substrate and influences the water table level and the physicochemical characteristics of the water and peat. These changes can modify the composition of the plant communities. We examined whether burying the mineral material within the bog (Peat Inversion Technique [PIT]) is an effective method to restore the peatland conditions. The method should meet restorations goals by (1) confining the nutrients introduced with the mineral material, (2) conserving a peaty surface elevation similar to the adjacent areas, and (3) by re-establishing typical peatland vegetation. At both one and three years' post-restoration, the results of the physicochemical analyses of the water sampled at various depths and distances of the buried road presented similar nutrient concentrations to the means observed in the reference ecosystems. The small soil elevation differences observed in the restored areas between readings show that the compaction and leveling used in the PIT are appropriate to fulfill the pursued objectives. The return of peatland plant communities varied depending on the site, mainly due to local factors. Ultimately, the results of this project show that the PIT complies with restoration objectives. Furthermore, it is cost effective in comparison with another restoration technique, the complete removal of the mineral material.

Keywords: Chemistry, Decommissioning, Moss Layer Transfer Technique, Peat Inversion Technique, Peatland, Restoration, Revegetation, Roads, *Sphagnum*.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

In Canada, electrical energy is mostly produced in the northern regions, while the majority of the population lives in the southern parts of the country. In addition to large hydroelectric dams, the Canadian Shield is also known for its large peatland complexes. In the province of Quebec alone, peatlands cover a little more than 10 percent of the land area, which represent 16.1 million hectares. Thus, it is inevitable that the transmission and distribution line networks sometimes cross these environments. In opposition to the wide, undisturbed peatland complexes of the boreal and subarctic zones, peatlands of the south part of the country are largely fragmented (Pellerin et Poulin 2013). In conjunction with conservation, restoration is essential to ensure peatland sustainability in the regional landscape of the heavily inhabited part of the country.

Peatland's Important Concepts

This project studied the restoration of *Sphagnum*-dominated peatlands disturbed by a low-volume road of mineral material. At each of the two sites, a maintenance access road was installed in a right-of-way (ROW) located in a peatland. There are two types of peatlands: bogs and fens. *Sphagnum*-dominated peatlands are bogs or poor fens. Bogs are isolated from runoff and oblique drainage (bogs), as poor fens have a little water enrichment from the surrounding environment. *Sphagnum*-dominated peatlands are systems with low nutrient availability and pH because the water table is mainly fed by local rainfall. Sphagnum-dominated peatlands are characterized by an accumulation of organic matter called peat. The thickness of the organic horizon for a peatland to be considered as such is variable. It is usually appropriate to refer to peatlands when the organic layer reaches a minimum of 30 to 40 centimeters (cm) (Canada Wetlands 1988).

We find two distinct horizons in *Sphagnum*-dominated peatlands: the acrotelm and the catotelm. The acrotelm is the surface layer where water table fluctuations occur. These fluctuations lead to the alternation of aerobic and anaerobic conditions. The most intense hydrological and biogeochemical processes occur there (Ivanov 1981), including the decomposition of vegetation by fungi and microbial activity (Clymo 1992). Its thickness varies between a few millimeters to more than 50 cm, depending on the hydrogeographic context (Rydin and Jeglum 2013). The catotelm is the layer below the acrotelm. The limit between the two horizons is drawn by the lowest level reached by the water table (Holden and Burt 2003) since the catotelm is the layer defined by constant anaerobic conditions. The microbial activity and decomposition processes of peat are very slow, so there is compacted, more or less decomposed peat in which the water moves very slowly and the carbon is stocked (Quinty and Rochefort 2003).

The hydraulic conductivity of the peat is directly related to its level of decomposition. In peatlands, it increases with depth (Rydin and Jeglum 2013). In *Sphagnum*-dominated peatlands, vertical hydraulic conductivity is greater than horizontal. This phenomenon is called anisotropy, meaning that for the same volume, the water does not flow at the same speed vertically as horizontally (Beckwith et al. 2002). Thus, in peatlands, water table fluctuations, microtopography, and vegetation structure lead to heterogeneity in observed hydraulic conductivity values.

The peatland vegetation is directly related to the hydrology and physicochemistry of the site. The composition and diversity of species may change depending on nutrient concentrations, ionic forms, and ratios (Rydin and Jeglum 2013). Between peatlands, there is a gradient of richness in terms of minerotrophic species. Bogs are located at the "poor" end of the gradient in terms of species diversity, as opposed to rich fens (Payette and Rochefort 2001). The low availability of nutrients of a peatland characterizes the vegetation of this end of the gradient by a dominance of *Sphagnum* (Gignac et al. 1991).

Impacts of Roads in Peatlands

A mineral road in a peatland compromises the ecological integrity of the peatland by changing the nature of the substrate, thereby stopping the carbon accumulation function, and may affect the hydrological connectivity and physicochemical properties of the surrounding environment. Primarily, the introduction of the mineral material and the passage of the vehicles compact the underlying peat, which inevitably reduces the hydraulic conductivity. Also, the presence of a road may introduce alkaline minerals into the acid peat substrate via water as well as via air when particles are swept away by the passage of vehicles. These changes in the concentration, ionic shape, and nutrient ratio in the peatland can alter the composition and diversity of plant species that are endemic to this nutrient-poor environment (Müllerová et al. 2011). In peatlands, the water table level, the availability of nutrients, and the pH of the water and substrate control the distribution of species (Payette and Rochefort 2001). When a limiting nutrient is added, graminoid species tend to proliferate, while bryophytes (mosses) and other slow-growing species decline (Rydin and Jeglum 2013). These roads can thus modify the composition of the plant communities and favor the propagation of undesirable or invasive species.

Ecological Restoration

For this research project, the Peat Inversion Technique (PIT) was used for the restoration of two peatlands impacted by a mineral road. It has been developed following the same basic principle as the one used by the Northern Alberta Institute of Technology (NAIT) for the restoration of a peatland disturbed by a clay pad introduced in a poor fen for oil-sand extraction (Sobze et al. 2012). To avoid habitat loss, to confine nutrients, and to recover the functions of the original ecosystem, the road was buried in situ by inverting the layer of mineral material and the underlying layer of peat. This burying of the mineral material aims to restore on the surface of the disturbed area a layer of peat and acidic organic soil that can support peatland plant communities. It is also intended to restore surface water physicochemical characteristics similar to those of adjacent peatlands and, in the same way, to ensure restoration of a relative elevation similar to that of the adjacent environment, which are the portions of the ROW not disturbed by the access road.

The new organic substrate is finally revegetated using surrounding vegetation. The technique used in this project is directly inspired by the proven method of the Moss Layer Transfer Technique (MLTT; Quinty and Rochefort 2003; Graf and Rochefort 2016) used for the restoration of peatlands following the industrial extraction for horticultural purpose. The return of *Sphagnum* mosses is important in the ecological restoration of a bog since they have the capacity to modify the physicochemical conditions to the point of slowing the processes of decomposition and thus inducing a peat accumulation (Clymo 1987). The MLTT consists of harvesting the first 10 cm of the moss layer of a donor site to initiate the revegetation. For large-scale restoration post-extraction by the peat industry, the vegetation is spread in a 1:15 ratio to cover the entire surface without burying the fragments one on top of the other. A mulch layer is placed on the introduced plant material to create shading and moisture conditions necessary for the development of mosses. The donor material contains spores, seeds, and fragments from moss and vascular species.

The PIT should confine the introduced nutrients with the mineral material, conserve a peaty surface elevation similar to the adjacent areas, and re-establish typical peatland vegetation.

Sainte-Eulalie

Chénéville

Figure 1. Study Sites

METHODS

Study Sites

In the summer of 2012, an access road was built in a peatland at Sainte-Eulalie, Centre-du-Québec, QC (Figure 1 – left). The road was built in the ROW that crosses a *Sphagnum*-dominated peatland and a swamp to upgrade infrastructures (swamp results not presented). There are agricultural drainage ditches all along this wetland complex on both sides of the ROW. This access road was three kilometers (km) long and of an average of 4.5 meters (m) wide. It was composed of granular materials (crushed stone) placed on a geotextile membrane and on fascines at some places.

In 2013, an access road was built in a ROW that crosses a *Sphagnum*-dominated peatland in Chénéville, Outaouais, QC (Figure 1–right). This access road was 70 m long and, on average, five m wide and consisted of large rock with variable diameter (five to 40 cm) directly on the soil.

Restoration Techniques

In Sainte-Eulalie, restoration was completed in the fall of 2012, a few months after the construction of the road. In Chénéville, just more than a year passed between the construction of the access road and the restoration in autumn 2014.

The PIT (Figure 2a–2f) was completed using an excavator traveling exclusively on the access road to avoid disturbing the intact vegetation nearby and to prevent the machinery from getting stuck. The work was done by repeating each step on small sections of road—about five m depending on the scope of the arm of the excavator. First, the materials composing the access road (mineral material, logs, geotextile membrane) were removed and piled behind the machinery on the remaining road. The underlying peat was excavated, creating a pit, and piled up nearby. The road materials were then put into the pit and covered with previously excavated peat. The materials were covered with a thickness of at least 40 cm of peat. An average thickness of 52 cm of peat was estimated at Sainte-Eulalie following the work and 45 ± two cm at Chénéville. The surface was then profiled at the elevation of the surrounding peatland mean surface and then revegetated with an adapted version of the MLTT developed for the restoration of post-extracted peatlands.

Revegetation of the peat substrate with an adapted version of the MLTT is a step of the PIT. The restoration of each section ends with the uniform spreading of a thin layer of diaspores. The diaspores were mechanically harvested using the excavator bucket on either side of the access road in the undisturbed ROW. Thus, the seeding diaspores do not come from a natural peatland, but from peatland vegetation as found following the various vegetation maintenance treatments by Hydro-Québec. Once harvested, the plant material was broken up using the bucket teeth before being spread evenly over the former road. A ratio (area of plant material collected: revegetated area) ranging from 1:5 to 1:10 was used, depending on the availability and quality of diaspores.

Monitoring

Environmental monitoring was conducted mostly during 2015 (i.e., one year post-restoration in Chénéville and three years' post-restoration in Sainte-Eulalie).

Groundwater

The depth of the water table in relation to the surface was monitored to determine if the path was indeed buried in the catotelme, anaerobically. Self-recording pressure sensors (HOBO U20, Onset, Bourne, Massachusetts, U.S.) were installed in the spring of 2015 at each site.

Water Chemistry

In the summer and fall of 2015, water sampling was conducted to assess the physicochemical conditions of water in and around the areas formerly occupied by the road. The water samples were taken from piezometers placed at different depths and distances from the former road (Table 1). Samples were also taken in the reference ecosystem.

The pH and electrical conductivity values were measured in the field using a portable device (HANNA pH & EC Combo). The concentration of the assimilated form by the plants of the following elements and compounds was thus analyzed in the laboratory for all the samples taken: total phosphorus (P), phosphorus in phosphates (P/PO43-), nitrogen in ammoniacal nitrogen (N/NH4+), nitrogen in nitrates (N/NO3-), iron (Fe), calcium (Ca), potassium (K), sulfur in sulfates (S/SO42-), sodium (Na), calcium (Cl),

Figure 2a. Excavation and stockpilling of the underlying peat

Figure 2b. Fill of the excavation with the mineral material

Figure 2c. Covering the mineral material with the stockpilled peat (at least 40 cm)

magnesium (Mg), manganese (Mn), and aluminum (Al).

Surface Elevation

Soil elevation surveys were conducted in two stages: 1) immediately after restoration work and one year post-restoration for the Chénéville site and 2) one year and three years' post-restoration for the Sainte-Eulalie site. These data were used to verify whether there was decompression or compression of the peat profile following the PIT. The relative elevation was measured using a laser level (LP410, Sokkia, Mississauga, Ontario, Canada) on transects perpendicular to the former road of each of the sites using the nearby pylons as a benchmark. Three transects were surveyed at Chénéville and six at Sainte-Eulalie.

Vegetation

Mosses and vascular plants were identified to the species level. The cover of each species was visually estimated by vertical projection, was visually estimated in 1 m by 1 m quadrats for vascular species, and 25 cm by 25 cm quadrats for mosses. Surveys were made in the restored areas as well as the reference ecosystem.

RESULTS

Water Chemistry

From May to September 2015, the lowest level reached by the water table was 30 cm below the surface at both sites. One year post-restoration with the PIT at Chénéville, all nutrients apart from calcium and chlorine had concentrations in or near the variations of the reference ecosystem. Three years post-restoration with the PIT at Sainte-Eulalie, with water sampled at 20 cm deep, had concentrations of most nutrients in the range of the reference ecosystem. Concentrations that were at least 10 times higher than the reference ecosystem were found almost exclusively in the water sampled at 50 cm deep in the restored strip.

Figure 2d. Adapted version of the MLTT (Chénéville—left and Sainte-Eulalie—right)

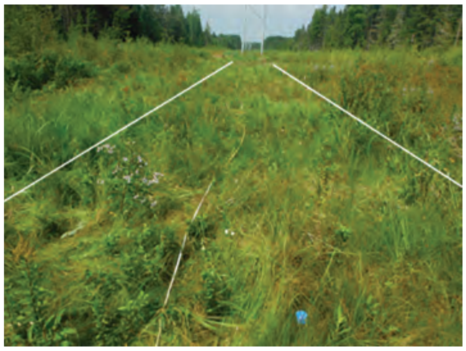

Figure 2e. Chénéville one year post-restoration

Figure 2f. Sainte-Eulalie three years post-restoration

Soil Elevation

Elevation differences between surveys are insignificant, whether it was one year or three years post-restoration. On both sites, elevation differences were similar to those observed in the reference ecosystem.

Vegetation

At Chénéville, in only one growing season post-restoration, *Sphagnum* had a cover of half that observed in the reference ecosystem (Figure 3—left). At Sainte-Eulalie, three years' post-restoration with the PIT, results were significantly different between the restored strip and the reference ecosystem apart from trees. *Sphagnum* cover was only 5 ± 3 percent in the restored strip, but herbaceous and tree cover was high (around 35 percent; Figure 3—right). Figure 4 shows the vascular plant cover in function of the preferred habitat of each species. At Chénéville, vascular cover is low in comparison to the reference ecosystem, but the repartition in each group is proportional. At Sainte-Eulalie, total

	Distance from Former Road (m)	Depth (cm)	Number of Transects
Chénéville	0* - 0.5 - 1 - 1.5 - 2 - 3 - 5	20 - 40 - 70	3
Sainte-Eulalie	0* - 0.5 - 1 - 2 - 10	20 - 50	6

* At distance « 0 », piezometers were located in the restored strip, directly in the former road localization.

Table 1. Water Sampling Depths and Distances

vascular covers are similar, but the repartition in function of the preferred habitat is totally different between the restored strip and the reference ecosystem. Most cover is represented by wetland plants, but peatland plant cover is low and there is a high cover of ruderal species.

DISCUSSION

Nutrient Containment by PIT

Ideally, the restored areas should have the same physicochemical properties as the reference ecosystem in order to favor a peatland vegetation and thus restore the characteristics of the peatland, such as the carbon accumulation function. The results clearly showed that in the first year of post-restoration (Chénéville), only a few nutrients had concentrations slightly higher in the restored strip and near it than the mean values of the reference ecosystem. In the third year post-restoration (Sainte-Eulalie), concentrations significantly higher than the reference ecosystem are restricted to the water located at 50 cm deep in the restored strip. This is no surprise, because that water is directly in contact with the buried mineral material. Knowing that the maximum depth reached by the water table is approximately 30 cm on both sites, we can say that the mineral material buried at 50 cm deep is located in the catotelm. Given the low hydraulic conductivity of the catotelm (Letts et al. 2000) and the phenomena of anisotropy found in *Sphagnum* peatlands (Beckwith et al. 2002), long lateral migration of nutrients can be considered negligible. In addition, root growth and mineral uptake is a process that requires oxygen (Bates 2009). Thus, only species in or near restored areas with specialized oxygen transport structures can take advantage of the nutrients of the buried mineral material. Consequently, the PIT (confinement under at least 40 cm of peat) makes it possible to limit the enrichment of the peatland with

Figure 3. Vegetation at Chénéville one year post-restoration (left) and at Sainte-Eulalie three years post-restoration—right. Former roads are delimited with dashed lines.

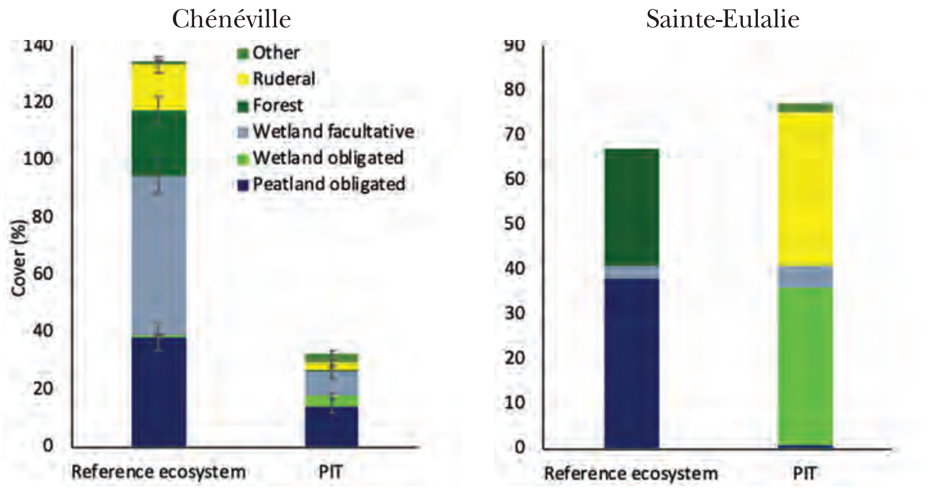

Figure 4. Cover Repartition of Vascular Plants According to Preferred Habitat

nutrients contained in the mineral material coming from the path and to restrict access to these nutrients to the wetland species.

Substrate Elevation

Whether it is one or three years' post-restoration, no significant compaction or uplift was detected following restoration with the PIT. The variations between surveys hardly exceed seven cm. However, validated models of hummocks and hollows in North Eastern America of Nungesser (2003) have shown that hummocks are pronounced (30-40 cm) in the boreal regions of Canada, and decrease more and more in amplitude to become practically zero in the more southern regions. Thus, in the respective regions of the study sites, it is common to observe amplitudes of more than 10 cm between the hummocks and hollows. This is what is observed in the reference ecosystems of the study. Thus, the slight variations between the surveys for the restored strip are similar to the normal microtopography of a *Sphagnum* peatland.

Moss Layer Transfer Technique as a step of the Peat Inversion Technique

The adapted MLTT gave extremely fast recolonization results on the restored strip at Chénéville less than one year post-restoration. The combination between an adequate substrate elevation, a high water table, good diaspore quality, and a conscientious contractor led to this success. Thus, unless there is a major anthropic perturbation, the restored strip of Chénéville should, at short term, evolve to a bog similar to the surrounding peatland.

At Sainte-Eulalie, the low colonization of the restored strip by peatland species may be caused by the low water table because of the ditching of the ROW. The addition of a layer of straw, as recommended in the original MLTT steps, could have helped the mosses to have a higher cover. Nevertheless, the restored strip at Sainte-Eulalie did have a five percent cover of mosses and 40 percent of the total vascular cover were wetland species.

CONCLUSIONS

The PIT is an effective way to restore peatlands as long as the peat is thick enough. Indeed, results have clearly proven that the PIT limits the peatland enrichment by confining the nutrients of the mineral material and establishes and maintains a peaty surface of similar elevation to the surrounding areas. The proven MLTT can give great results as long as the water table is high and the vegetation is adequate.

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AUTHOR PROFILES

Kathy Pouliot

Kathy Pouliot has a Master's degree in Plant Science at Université Laval. After a college degree in Analytical Chemistry, she worked as an analyst in environmental departments (water and soil analysis) for three years. During her bachelor's in science in Natural and Managed Environments, she joined the Peatland Ecology Research Group as a research assistant, where she participated in data collection, field work planification, and data management for two years. After her graduation in 2012, she also acted as a consultant for the peatland industry. These experiences have led her to undertake a master's specialisation in peatland restoration and ecology at the PERG in 2015. She is currently working as a research professional at the PERG and in the forest hydrology laboratory at Université Laval.

Line Rochefort

Dr. Line Rochefort is the professor in the Department of Plant Sciences at Université Laval since 1992, and graduated from Université Laval (1984), University of Alberta (1987) and University of Cambridge (1992), she is one of the pioneers and leaders in research on restoration ecology of peatlands. Dr. Rochefort founded the Peatland Ecology Research Group (PERG) in 1992-1993. This group brings together researchers from several universities, Canadian industrial peat partners, and federal and provincial government agencies. Dr. Rochefort has initiated a whole new stream of research in the peat industry in the development of techniques for restoration of mires after peat extraction. Her academic and professional career took her around the world and allowed her to become known within the international community. The technique of bog restoration is now used not only in North America, but also in South America and Europe. Since

2003, Dr. Rochefort continues her work on peatlands as the Chair holder of the NSERC Industrial Research Chair in Peatland Management. The chair continues to work closely with the Canadian peat industry. She has also expanded her activities in a new niche: rebuilding wetlands in the region of Alberta's where oil sands are exploited.

Alexandre Beauchemin
Alexandre Beauchemin holds a bachelor of science degree in Biology from McGill University and a master's degree in Environmental Sciences from Université du Québec à Montréal. Beauchemin has worked as an environmental advisor at Hydro-Québec since 2004. He has served as a large mammals and vegetation specialist on major hydroelectrical developments (Eastmain-1, Eastmain-1-A/Rupert River diversion, Romaine complex) as well as high-voltage powerlines and substations. Throughout his career, he has researched scientific and practical issues regarding impact assessment, mitigation, compensation, and follow-up, mainly in the field of large mammals and vegetation.

12th International Symposium

Environmental Concerns in Rights-of-Way Management

PART III

Planning

An Innovative Approach to Emergency Management Planning for the Trans Mountain Pipeline System

Jamie Kereliuk and
Jason Smith

Keywords: Consultation, Emergency Management (EM), Geographic Response Plans (GRP), Indigenous Groups, Stakeholders.

The Trans Mountain pipeline system located in western Canada currently transports approximately 300,000 barrels per day (bpd) of crude oil and refined petroleum products from Sherwood Park, Alberta to Burnaby, British Columbia (BC) and Washington State. The pipeline traverses through several high consequence areas (HCAs) such as Indigenous communities, urban centers, parks and protected areas, watercourses, and sensitive ecosystems. Due to the complex nature of the HCAs, a multi-stage approach to developing geographic response plans (GRPs) was undertaken to enhance Trans Mountain's spill response regime. GRPs pre-identify key locations from which to deploy response equipment to expedite response actions within the first few hours of a spill. These plans also identify ecologically and culturally sensitive areas that can be prioritized in a response situation. This multi-stage approach to GRP development began with a desktop review of current and proposed pipeline operations using hydrological data and spill modelling/tracing. This was followed by an extensive field program that involved a multi-disciplinary team that travelled the pipeline and collaboratively verified proposed control points (CPs). This paper presents the innovative and progressive consultation program and discusses the outcomes of this effort that has led to significant enhancements to Trans Mountain's emergency management program.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

The Trans Mountain pipeline system located in western Canada currently transports approximately 300,000 barrels per day (bpd) of crude oil and refined petroleum products from Sherwood Park, Alberta to Burnaby, British Columbia (BC) and Washington State. The original Trans Mountain pipeline was built in 1952–1953 and is the only crude oil export pipeline to the west coast of Canada. The Trans Mountain Expansion Project (TMEP) is a twinning of the existing 1,150-kilometer (km) pipeline, and once in service, will create a pipeline system with a nominal capacity of 890,000 bpd. The National Energy Board (NEB) regulates the ongoing operations of the Trans Mountain Pipeline system.

Trans Mountain is required to have an emergency management (EM) program (in accordance with regulations) that includes, but is not limited to, emergency contacts, spill detection and notification, incident command system, community awareness and education, hazard identification and response planning, emergency response plans, marine response, and spill liability.

This paper focuses on one key component of the EM program, which is referred to as the geographic response plans (or GRPs). This component of the program helps guide and direct emergency response actions in the first 48 hours following an incident. The GRPs are designed to expedite response times and enhance capabilities.

The development of the GRPs used an innovative and inclusive consultation approach that involved local Indigenous community members, municipalities, and other interested stakeholders to maximize the amount of traditional and local knowledge and on-the-ground experience (which was incorporated into the GRPs). This approach allowed Trans Mountain to gather information and improve upon the existing EM program. These plans were made public on an interactive web-mapping application, allowing for communities and agencies to benefit from the work. This is the first time a pipeline company in North America has publicly disclosed this data to a wider response community in a very open and transparent manner.

APPROACH

The goal of the EM consultation program, and the GRPs in particular, was to take into consideration the unique and varying input of stakeholders, Indigenous communities, and landowners in a transparent way. It was a fully inclusive approach, which focused on municipal and regional governments, corresponding first responders, provincial agencies, and Indigenous communities with Traditional Territory that overlaps the pipeline corridor as well as landowners and tenants.

Traditional consultation methods for EM have a tendency to be more passive, with a draft of the procedure or plan being provided to stakeholders and those stakeholders providing comment to the company. This results in the company either incorporating or rejecting the feedback. During the development of the GRPs, consultation was designed to be inclusive,

STEP	ENGAGEMENT PROCESS	DURATION
1	**EM Regional Workshops** Participants included Indigenous communities and stakeholders	½ day workshops
2	**One-on-One Community Visits** Participants included communities with existing or future CPs. Engagement discussion topics: • EM Program and its operation • Cultural protocols and sensitivities • Possible dates and contacts for future GRP work	three-hour meetings
3	**Conduct Field Work with Communities on GRP** Participants included Indigenous communities within the GRP. Field work objectives: • Gather community input and identify HCAs • Gather input on ERP components and procedures • Ground truth existing and possible CPs	1 to 1.5 days

Table 1. Steps in stakeholder and Indigenous engagement process

progressive, and open to interested participants throughout all phases of the pre-operations consultation period to facilitate and promote positive dialogue, open communication, and meaningful input. The approach included awareness of the goal, scope of the plan and process, engagement, and partnering in data collection and review—in addition to the traditional methods of sharing the draft plan for comment—and consistent and regular communications. It was Trans Mountain's belief that Indigenous communities and local stakeholders are in the best position to identify the resources that are most important to them, and they typically have ideas and experience protecting those resources. By developing relationships locally, Trans Mountain was able to optimize and enhance the GRPs by relying heavily on local knowledge holders.

Consultation on the plans predicated each phase of the stakeholder engagement to build on the preceding. The phased approach consisted of:

Part i. Awareness

Part ii. Engagement

Part iii. Partnering

Part iv. Review and Communicate

Part v. Continuous Improvement

Once the awareness and engagement phases were complete, the development of the GRPs aimed to build on the relationships in a more focused and integrated manner. A combination of platforms was used to engage and partner with the stakeholders, Indigenous communities, and landowners. Table 1 outlines the different platforms included in the engagement process.

Workshops

During these workshops, participants were presented with an overview of the Project and a series of presentations which informed attendees of the seven primary topics of consultation for enhancement:

i. EM Program

ii. Planning Standard

iii. Emergency Response Plans

iv. GRPs

v. Fire Pre-Plans and Fire Safety Plans

vi. Equipment Availability

vii. Exercises and Training

The agenda included strategically timed breakout sessions, which were designed to enable participants to identify opportunities for enhancement, as well as help establish closer collaboration and partnership with the Trans Mountain EM team and other participants. The breakout sessions acted as discussion forums for attendees to talk about the topics presented in a particular session. This, in addition to small group sizes, supported an inclusive environment to discuss the issues of most concern to them, which in turn led to constructive communication and meaningful input. Engaging in this manner enabled Trans Mountain to…

- …identify components and explore adjustments that could be made to enhance external response procedures and plans.
- …detail any proposed adjustments to the ERP and GRP that should be considered.
- …fortify external notification processes and the safety information to be communicated to stakeholders if an incident were to occur.
- …inform and augment the GRPs through identification of potential CPs, HCAs, and mapping sessions.
- …collect local knowledge and expertise to enhance the EM program.

Throughout the workshop, Trans Mountain EM representatives documented areas of interest and opportunities to further explore enhancements to the program. Capturing ideas and feedback from EM specialists and first responders who participated was important in facilitating a consultative process that was both adaptive and responsive to input. Trans Mountain offered participants the opportunity to complete a survey at the end of each workshop. The survey allowed for additional opportunity for attendees to provide feedback and make specific requests for one-on-one meetings with Trans Mountain.

One-on-One Meetings

The workshops generated numerous requests for subsequent one-on-one meetings. The agendas for these meetings included topics that attendees wished to further consult on. This sequential step in the consultation process allowed Trans Mountain to:

- Consult with subject matter experts.
- Gather detailed local knowledge.
- Enable stakeholders and indigenous communities to provide input as to how the trans mountain ERP can integrate with their plans, to optimize synergies.
- Have more focused and detailed discussions on topics of specific interest to stakeholders and indigenous communities.

Trans Mountain followed a similar process for both stakeholders and Indigenous communities and set up meetings which included an agenda that was tailored to their respective areas of interest. These issues were extracted from workshop meeting notes and participant surveys. The one-on-one meetings yielded further information to support enhancements to the EM program. Additional results from these individual meetings included requests to attend exercises and training with Trans Mountain, participation in GRP fieldwork, and exploration on mutual aid.

One-on-one meetings maximized the benefits of this engagement platform for attendees to communicate their concerns, ask questions, and have constructive dialogue with Trans Mountain members.

GRP Field Work

Partnering with community participants encompassed direct participation in GRPs. The starting point for GRP development were a series of workshops where participants were asked to review, ask questions, and provide local feedback on:

- Oil Spill Plume Modelling
- HCAs
- CP Selection Criteria
- Identification of Potential CPs, Boat Launches, and Staging Areas

A presentation on the GRPs was delivered at the workshop and attendees were encouraged to participate in the upcoming fieldwork. The GRP development provided an opportunity for Trans Mountain to build relationships and collect input to enhance the plan, and for attendees to act in an advisory capacity and provide direct input on HCAs, resources at risk, and potential CPs for the GRP.

Permission was sought from landowners or tenants wherever GRP fieldwork was conducted on their land. During the site visits, landowners were offered the opportunity to attend and provide feedback, as well as insight through detailed local knowledge that could enhance the EM program with regard to the selection of CPs, staging areas, and boat launches.

When the fieldwork was completed and the GRPs produced, they were shared with Indigenous communities for review and afforded another opportunity to provide feedback or request additional information. The GRPs were also shared with those attendees who, during consultation, expressed an interest in reviewing the completed plans. All feedback was reviewed and where enhancements could be made, the information was incorporated into the plans. Traditional knowledge provided by Indigenous communities also helped identify CPs and access trails—while helping Trans Mountain avoid culturally sensitive areas.

The field work, combined with the meetings and workshops, yielded information that would further improve the GRPs. These enhancements were often related to new information for access to the right-of-way (ROW), CPs, and boat launches, all of which helped improve response times for deployment of equipment and personnel.

Review and Communicate

GRP fieldwork formed a large part of the input. The information and data gathered for CP selection, identification of HCAs, and areas of cultural sensitivity played an important part in the enhancement process. CPs were selected based on several criteria encompassing certain geographical, ecological, cultural, and logistical considerations. It is this shared, detailed local knowledge which helped develop the GRPs and enhance the EM program. Input regarding GRPs was analyzed with a desktop review and subsequent site assessment for potential CPs, boat launches, and staging areas. The desktop review allowed the investigation of the data, analysis, and cross referencing against various geographical information system (GIS) mapping data, such as topography and elevation mapping, and other references, such as environmental assessments (EAs), and supporting documentation. For culturally sensitive areas, mechanisms to denote the information in the Trans Mountain GIS mapping system, while honoring confidentiality and sensitivity, were implemented. For example, a feature point was inserted into the GIS system noting "sensitive areas," which included the contact information for the community representative, so that if an incident should occur, the information would be exchanged to better understand and protect the feature. The data collected was captured in tabular form and uploaded to the GIS system, assessed, and then incorporated where appropriate.

RESULTS & DISCUSSION

The GRPs that evolved from the fieldwork conducted with the participation of stakeholders, Indigenous communities, and landowners helped enhance the EM program via the addition of expanded CPs, boat launches and staging areas, and the identification of HCAs. Stakeholders and Indigenous communities who expressed an interest in reviewing the final versions were presented with the opportunity to review the GRP and accompanying strategies.

This approach resulted in a more robust EM program that maximized local knowledge and input, as well as mitigated risk and potential impacts from a pipeline incident affecting the safety of people and the environment. More specifically, the GRPs set out actions to be taken at specific sites along the pipeline ROWs, such as a municipal water intake, sensitive environmental feature, coastline area, river crossing, or place of cultural or environmental significance to an Indigenous community.

The GRPs located and documented CPs. These are predetermined locations along the ROW, either on land or in watercourses, where responders could intercept spilled product in order to establish a spill response strategy and deploy spill response equipment. Identifying CP locations ahead of time enables Trans Mountain to respond more effectively, limiting potential impacts to sensitive areas downstream of a release point. Site photographs were captured of land and water features using a small unmanned aerial vehicle (UAV) or "drone" to provide a high-level overhead shot.

GRPs contain the operational

district's CPs and describe natural and cultural resources and other geographically specific information relevant to emergency response. CPs are locations where responders can set up equipment to intercept, contain, and recover spilled product. A data sheet was created for each point. CPs were selected and were based on spring freshet conditions. There are approximately five to seven CPs and four to five boat launches for every 50-km (31.2 miles) to 70-km (43.8 miles) reach to match oil spill models. The CP data sheets document the site-specific tactics and the resources and equipment needed to implement the tactic. GIS data layers provide responders with additional information on HCAs, water wells, water sources, and hazards. Individual GRP data sheets were created for waterbody CPs, land-based CPs, and boat launches. The GRPs captured and depicted the required information for a rapid response, including:

- Details of location
- Waterbody information
- Shoreline information
- Logistical information
- Decontamination areas
- Resources at risk
- Safety concerns
- Access and driving directions for crews
- Spill implementation strategy and resources
- Equipment resources
- Support technical services
- Wildlife at risk and wildlife mitigation tactics

Each of the GRPs along the pipeline system (i.e., four districts in total) were a standalone plan for their respective operational district, complementing and supporting the ERP with geographically specific response information for each CP along the pipeline.

Table 2 shows the number of data points provided directly by stakeholders and Indigenous communities during the workshops. Data points were then classified into one of four different elements.

Eight Workshops spanning 1,500 km	Feature of Interest*	Potential Access	Potential CP	Water Intake Wells	HCA
Totals	124	17	120	52	1

*Feature of Interest – natural, environmental or culturally sensitive area

Table 2. Number of Data Points Provided in the Workshops

Consultation and engagement with stakeholder and Indigenous communities were significant and of key importance in the enhancement of the GRPs. The development of the GRPs provided an opportunity for local Indigenous communities and stakeholders to act in an advisory role, and provide direct and valuable input on HCAs, resources at risk, and potential CPs for the GRP. The detailed local knowledge they provided has been used to inform, and thereby enhance, the response to a potential incident. In one of the four districts along the system, approximately 200 potential CPs, staging areas, and/or boat launches were evaluated.

Input from stakeholders, Indigenous communities, and landowners generated approximately 885 data points for assessment. These data points informed a host of GRP aspects, including water CPs, land CPs, boat launches, and work staging areas. The identified areas were assessed against factors such as:

- Accessibility to site
- Responder safety
- Equipment deployment
- Implementation of tactics

Of the 885 data points, approximately 600 CPs were confirmed as viable and GRP CP Data Sheets were generated for each. The GRPs captured the required information on boat launches, staging areas, and CP sheets in an easily accessible manner to allow field responders to carry out a rapid, aggressive response to an incident. The GRP Data Sheet denotes the valve location in relation to the CP, shoreline information, logistical information, map, resources at risk, directions, and includes a photograph of the staging area. The reverse side of the data sheet provides responders with information on the implementation strategy, implementation resources, equipment resources, support/technical services, wildlife at risk, and wildlife mitigation tactics.

The data was collected during a multi-year program that included spill modelling, data analysis, and field verification. The information has been uploaded to a new CP Map website that can be accessed by communities, other industries and emergency response personnel along the ROW. All EM and GRP data is also available in a GIS platform and web interface. Due to the remoteness of some locations along the pipeline system, as well as potential system outages during critical times, hard copy manuals continue to serve as a valuable resource to response crews.

Based on emergency response simulations and field drills, the detailed information provided in the GRPs have proven to enhance the effectiveness of the response and outcome. In addition, and as part of the GRP development, these plans were made public and available to communities and first responders along the pipeline route to allow communities and agencies to benefit from the work.

CONCLUSIONS

As a result of this approach to consultation and development of the GRPs, and ultimately to the overall EM program, Trans Mountain has incorporated significant enhancements that are making it more robust and increasing its ability to prepare for, respond to, and recover product from a pipeline incident. An extensive and robust regulatory review process has facilitated the comprehensive review and assessment of Trans Mountain's EM program, and has led to material enhancements and consideration of new facets of the program, including, but not limited to:

- ERPs
- GRPs
- Fire Pre-Plans and Fire Plans
- ERP Supplements
- Equipment Availability
- Exercise and Training Program

This inclusive and transparent approach to engagement and consultation has benefitted Trans Mountain and could be considered by other pipeline operators looking to optimize and enhance their EM program. It has also provided for stronger working relationships with external entities and communities.

The enhancements to these EM program elements will continue to be incorporated as dialogue with stakeholders, Indigenous communities, municipal, provincial, and federal agencies remains ongoing through the life cycle of the pipeline. As technology, regulations, industry-recommended practices, operational need, and relationships continue to evolve, so too will Trans Mountain's EM program. The GRPs set out a process for how this information can be gathered, validated, and applied to strengthen the EM program, as well as opportunities to regularly re-visit the information.

It was noted that not all stakeholders, Indigenous communities, and landowners wished to participate; however, the open design of this approach provided all parties with the ability to engage at their discretion and at any point in the process. There are examples whereby stakeholders, Indigenous communities, and landowners chose not to participate at the start of the process, but later participated as they saw value in the process.

One measurement of the success of this approach is demonstrated through feedback incorporated into the EM program. The approach facilitated the delivery of an enhanced EM program, not only because of the solid working relationships that were built, but through a greater understanding of EM and controls put in place to respond and mitigate the impacts of spills. The EM program was built on the fundamental principle that those who respond together should plan together, and as a result, this approach facilitated the sharing of information between individuals and communities, thus simultaneously enhancing other EM capabilities and capacities.

ACKNOWLEDGMENTS

Mr. Jamie Kereliuk would like to sincerely thank the members of the Trans Mountain EM team, consultants, stakeholders, and Indigenous communities who dedicated their time and knowledge in the development of the GRPs and helped enhance the Trans Mountain EM program. The EM program is stronger and more robust with your involvement. In addition, thank you to the Trans Mountain team for their ongoing dedication and commitment to pipeline safety and spill prevention, as well as all the operations staff who come to work every day to ensure the integrity of the pipeline system is maintained and to educate the public about the importance of pipelines in our energy infrastructure network.

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Case Study: Use of High-Resolution Imagery and LiDAR in ROW Planning and Design

Sarah Allen and Adele Fiorillo

Keywords: High-Resolution Aerial Imagery, Land Change, Light Detection and Ranging (LiDAR), Natural Resources, Remote Data, Right-Of-Way (ROW) Wetland Delineation.

A combination of high-resolution aerial imagery and light detection and ranging (LiDAR) can provide valuable information on topography, natural resources, land use, and other features for planning, permitting, and designing for existing, new, or expanded right-of-way (ROW) work. The materials include georeferenced, true-color, near-infrared, stereo, high-resolution imagery, and high-density LiDAR. During project planning, the benefits of collecting such a data set include: documentation of baseline conditions, preliminary delineation of natural resource features (wetlands, streams, rare species habitats), mapping of some historical and archeological resources, visual impact assessments using a digital terrain model, and determining the type and dimensions of existing infrastructure. This remote data can be collected and analyzed during early project planning phases, or in situations where foot access to a ROW is unavailable.

Flying a corridor several times wider than the proposed ROW provides flexibility during design. As sensitive features or engineering constraints are encountered, the imagery can be revisited to re-route a ROW without additional field work. This is a cost-effective planning tool and results in a demonstrable alternatives analysis process.

We have achieved more than 90 percent concurrence in acreage between mapped wetland resources using the high-resolution imagery and field delineations. On large projects, some regulatory agencies have agreed that high-resolution mapping can be used in place of field delineations in the permit application, followed by permit conditions that require jurisdictional field delineation prior to construction. Limiting field work to a well-defined and narrow final project area has associated cost savings.

In the lifetime of the project, the imagery and LiDAR provide a permanent record to compare with future changes and act as an evidence base for land changes or disputes with landowners and abutters. Planners and engineers can refer to the imagery to extract new datasets and gather additional information without the need to re-deploy a ground team.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Understanding land use, natural resources, and existing infrastructure are key aspects in the preliminary stages of development for new or expanded rights-of-way (ROW). Aerial imagery used in conjunction with light detection and ranging (LiDAR) is commonly used to identify features within the landscape for planning purposes (Reutebuch et al., 2005; Corcoran et al. 2011; Mason 2016). We have taken that concept a step further using high-resolution aerial imagery to map wetlands and streams for permitting purposes. This paper looks at a comparison of wetland mapping results between the photo-interpreted wetland boundaries with ground delineated wetland boundaries. The ground-delineated wetlands were considered to accurately represent jurisdictional wetlands, and served as the boundaries against which the photointerpretation results were compared. The purpose of this exercise was to demonstrate the effectiveness of photointerpretation for preliminary estimates of jurisdictional wetland boundaries, and to use the results for state and federal wetland permit applications.

METHODS

The preliminary study corridor was approximately 640 kilometers (km) in length, and approximately 1.6 km in width. Although some data was acquired in November 2014, the large majority of the digital full-spectrum (RBGN) stereo aerial imagery was acquired in April through May of 2015 for the full width of the study corridor, at five-centimeter (cm) resolution. Leaf-off and snow-free conditions were targeted for the flights, although late snows and early warmth resulted in a compressed spring flying season. As a result, the later imagery showed partial leaf-out, which obscured ground conditions in some areas. The imagery was post-processed to five-cm resolution, although the resolution was later decreased to 10 cm after analysis indicated little lost accuracy and improved file management. Even at 10-cm resolution, the image files were terrabytes in size.

LiDAR data was collected in October 2014 after leaf drop and April 2015 before bud burst. The LiDAR data were estimated to have accuracy to 10 cm horizontal and one cm vertical after corrections. For photointerpretation purposes, the LiDAR points were processed to produce 0.3 m (one foot) contours.

Traditional photointerpretation tools were also used to supplement the imagery during mapping, including georeferenced U.S. Geologic Survey (USGS) maps, Natural Resource Conservation Service (NRCS) soil survey data, National Wetland Inventory maps, hydrography maps, Natural Heritage atlas data, and local/county/state data, if available digitally.

A subset of the full study corridor was photo-interpreted along the ROW, the width of which depending on the presence or absence of existing ROWs. In sections with an existing cleared ROW, the photointerpreted corridor was 120 meters (m) wide. In sections with no existing cleared ROW, the photointerpreted corridor was 450 m wide. Mapped features included wetlands, streams, waterbodies, vernal pools, and broad upland cover types, as well as categories of land use, including infrastructure and development.

Jurisdictional ground delineations of wetlands were performed by qualified wetland scientists on public land and parcels where landowners allowed access. These were sporadic throughout the length of the project and were generally more prevalent in the western portion of the corridor. All ground-delineated wetlands were surveyed with global positioning system (GPS) capable of submeter accuracy, and a subset of those were surveyed by a licensed land surveyor and provided to the project team as georeferenced polygons.

The wetland comparison evaluated the acres and numbers of wetland resources (wetlands, streams, water bodies, and vernal pools) and cover type polygons for both the photo-interpreted and ground delineation methods. The analysis was performed only within the parcels for which land survey data was collected. This subset of the corridor, termed "Study Area" for this report, represented approximately 2,100 hectares (ha), or 22 percent of the total corridor area.

RESULTS

Approximately 255 ha of ground-delineated wetland resources occurred within the comparison study area (Table 1). Normandeau identified 245.8 ha of wetlands via photogrammetry, which captured approximately 96 percent of the total ground-delineated area of wetlands within the Study Area. The majority of the discrepancies between methods were associated with small wetlands. Normandeau's specified map unit was 0.2 ha (0.5 acres) in our work scope; however, the quality of the high resolution stereo imagery was such that wetlands as small as 0.1 ha (0.25 acres) could routinely be observed. If wetlands less than 0.1 ha are removed from the analysis, the ground-delineated and photo-interpreted acreages are almost identical by 100 percent.

Wetlands	Ground-Delineated (hectares)	Photo-Interpreted (hectares)	% Concurrence
All Wetlands	255	245.8	96
>0.1 hectares in size	217	217.4	100
<0.1 hectares in size	38	28.4	75

Table 1. Comparison of Acreage Between Ground Delineated and Photo-Interpreted Wetlands

This result, while very encouraging, does not reflect the delineation accuracy on an individual wetland basis. A graphic comparison of the wetland mapping, including those smaller than 0.1 ha, indicated that there was 58 percent (146.9 ha) agreement for individual wetlands delineated by the two methods within the Study Area.

The photo-interpreted delineation misidentified 42 percent (108.1 ha) of ground-delineated wetlands as upland, and an additional 98.7 ha of upland as wetland. Most of the differences in delineations occurred along the edges of the wetlands and, given the two different methods of delineation, are to be expected. Some of the difference is an artifact of discrepancies in the ground survey area, which did not consistently cover the full extent of all parcels identified as ground surveyed. This results in an overestimate of misidentified wetlands in the photointerpretation process. The extent of this issue was not quantified, but appears to be relatively minor. Examples in Figures 1-3 show sections of the corridor where the delineations concur well (Figure 1), with only moderate overlap (Figure 2), and a mix of good concurrence except for some small (<0.1 ha) wetlands and where ground survey did not cover the entire survey parcel (Figure 3).

Wetland size also affected mapping accuracy; wetlands that were smaller than 0.1 hectare (the de facto minimum map unit) accounted for approximately 81 percent of the number of wetlands missed in photointerpretation. Increasing the map unit size to 0.2 hectare (the specified minimum map unit) accounted for 92 percent of the number of wetlands missed in photointerpretation.

Cover type also contributed to photointerpretation error, with the most mapping discrepancies occurring in forested wetlands (approximately 50 percent). This is a common condition with photointerpretation in general, and appeared due to the ground being obscured by shadows and woody clutter (branches, twigs, and buds/early leaves), combined with the relatively minor

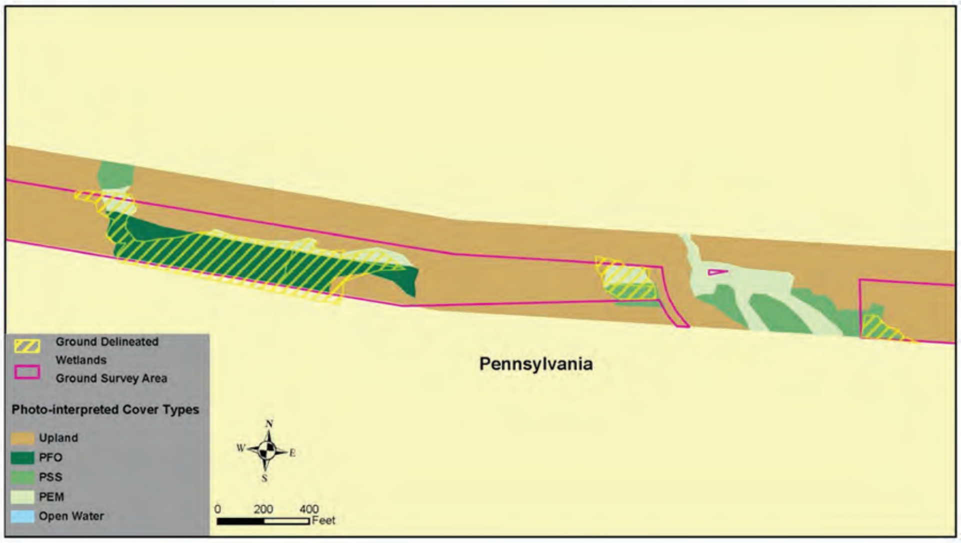

Figure 1. NED PI-ground comparison figure demonstrating concurrence between photo-interpreted and ground-delineated wetlands

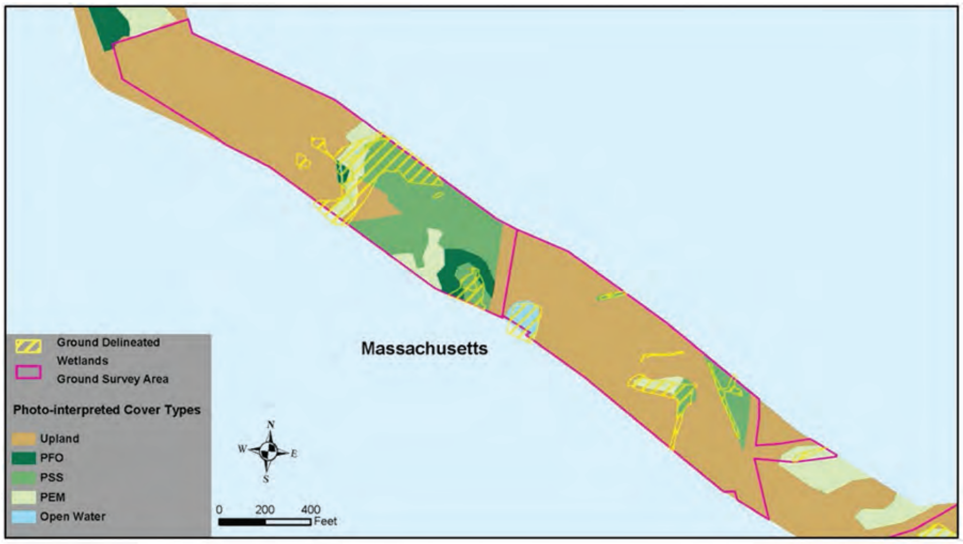

Figure 2. NED PI-ground comparison figure demonstrating moderate concurrence between photo-interpreted and ground-delineated wetlands

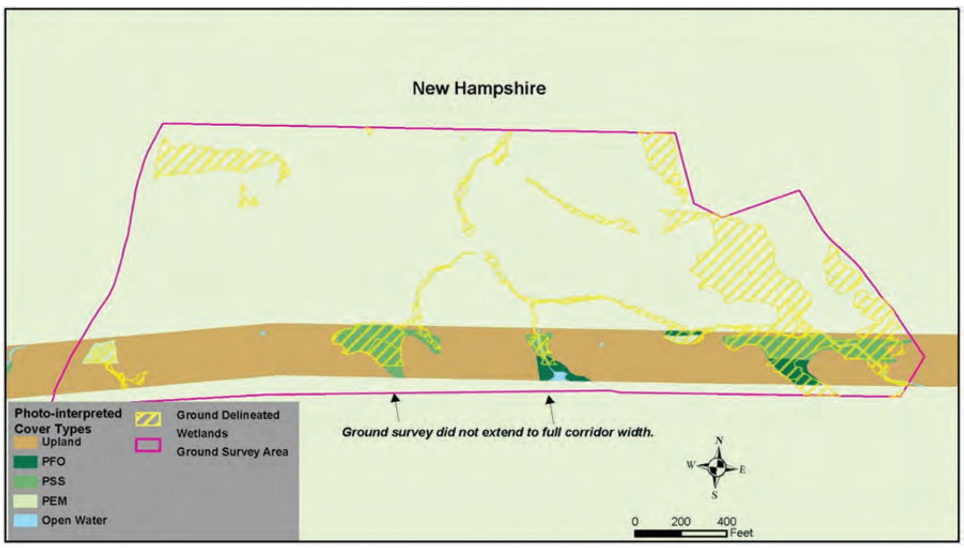

Figure 3. NED PI-ground comparison figure demonstrating moderate concurrence between photo-interpreted and ground-delineated wetlands

differences in topographic relief common in many forested wetlands.

Woodland vernal pools could not reliably be delineated using this method. Those that occurred in cleared ROW or otherwise open habitat could be distinguished and mapped, but in forested cover, the smaller pools were difficult to distinguish from shadows cast by trees and boulders. This was particularly true in mixed and conifer-dominated forests. The LiDAR was used to define large pools, but was too coarse to pick out the smaller ones.

The final map product included all of the wetland mapping, topographic contours, and additional data pulled from the high-resolution imagery: detailed building and infrastructure locations, general land use cover types for commercial/industrial, urban, surburban, and rural residential, and natural land cover, and unique features important to construction—beaver dams, informal trails and ATV use, active pasture, and logging activities. On top of this was layered the typical planning features for a permit application, including sensitive rare species and cultural sites (generalized), hydrographics, roads, floodplains, and floodways, municipalities, and property lines where digitally available, etc.

DISCUSSION

This map product was used in several ways that were beneficial to the project. During the design process, a preliminary engineering plan was developed and natural resource impacts were calculated within the original 120-450-m wide corridor. As additional information was gathered, and agencies, states, and municipalities began to provide review and comments on the design, changes to the pipeline route, and, in some cases, changes to the entire corridor were necessary. Because high-resolution imagery had been collected for the full 1.6-km wide corridor, but not processed, the Project team could go back to the unprocessed photographs for the area in question and photo-interpret the new locations quickly. In several areas, the changes extended outside of the original corridor and thus required acquisition of new data. Georeferenced LiDAR outside of the original corridor was collected, but because full leaf-out had occurred by then, high-resolution stereo photoimagery could not be acquired. In these locations, the wetland mapping was done using the LiDAR data in conjunction with standard publicly available orthophotos, and distinguished as such on the maps.

In the preliminary stages of permitting, the Project team met with state and federal regulators to discuss the feasibility of using high-quality photoimages to remotely map jurisdictional wetland resources for permitting purposes. The agencies were initially skeptical, but were willing to consider the product after a percentage of the wetlands were ground verified for comparison purposes. After completion, the findings from the exercise described above were presented to the agencies along with the proposed design. Regulatory reviewers attended a demonstration of the stereo mapping equipment and data, where they could manipulate and review the imagery and data for both photo-interpreted ground-surveyed delineations. After the demonstration, several state agencies recommended accepting the photo-interpreted mapping for preliminary permitting, with the condition that the project would be required to ground delineate all wetlands within the work corridor prior to construction. This resulted in a greatly reduced field delineation footprint.

This method also supported the development of strong alternatives analysis for permitting. The aerial imagery made it easy to track the incremental route and design changes as the project progressed, which in turn allowed the project to demonstrate the optimal route that had been selected, and to quantify avoidance and minimization during design.

An additional benefit of the three-dimensional (3D), highly detailed photos and LiDAR is the permanent record they provide of existing conditions. This data set has value in documenting baseline conditions to protect the project against injury claims from abutters during construction and operation, and to monitor changes in habitat and surrounding land uses.

CONCLUSIONS

High-resolution aerial imagery and LiDAR were used to photo-interpret preliminary estimates of jurisdictional wetland boundaries, and state and federal wetland regulators generally agreed to accept these delineations for permit applications. Flying a corridor several times wider than the proposed ROW and initially delineating only the area needed is an economic and efficient way to advance the design. As sensitive features or engineering constraints are encountered, the imagery can be revisited to re-route a ROW without additional field work. This is a cost-effective planning tool and results in a demonstrable alternatives analysis process.

The final product showed more than 90 percent concurrence in acreage between mapped wetland resources using the high-resolution imagery and jurisdictional ground delineations. On large projects, some regulatory agencies have agreed that high-resolution mapping can be used in place of field delineations in the permit application, followed by permit conditions that require jurisdictional field delineation prior to construction. Limiting field work to a well-defined and narrow final project area has associated cost savings.

In the lifetime of the project, the 3D imagery and LiDAR provide a permanent record to compare with future changes, and act as an evidence base for land changes or disputes with abutters. Planners and engineers can refer to the imagery to extract new datasets and gather additional information without the need to re-deploy a ground team.

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Creating Route Optionality and Defensibility: A Case Study of the Aurora Pipeline

Kevin Seel and Adam Phillips

Keywords: Decision-Support, Optionality, Non-Technical Risk Assessment, Pipeline Routing, Spatial Multi-Criteria Analysis.

Major linear infrastructure projects—pipelines in particular—are becoming increasingly difficult to develop in North America. The root causes of this are complex, but arise from interrelated factors such as environmental opposition, Indigenous rights, regulatory and investor indecision, as well as rapidly evolving energy and emissions policy. In the face of these challenges, developers are advised to consider a route development methodology that balances the consideration of technical as well as non-technical drivers, and which provides transparency, defensibility, and enhances optionality. This can be achieved through an approach that represents the landscape based on the level of routing suitability related to environmental and social factors, construction and operational considerations, as well as strategic business drivers and cost.

A recent example of demonstrating this approach is the Aurora Pipeline, which undertook a preliminary routing study conducted within the paradigm of creating maximum optionality, transparency, and defensibility in assessing potential pipeline routes across northern British Columbia (BC), Canada. By implementing an automated, multi-criteria routing decision support system called GoldSET, the team was able to perform a robust options analysis of potential routing corridors spanning approximately 400,000 kilometers^2 (km), or nearly one-third (1/3) of the province. The extensive use of computer automation to map pipeline routing suitability resulted in 72 different potential routes comprising more than 50,000 linear km. The potential routes were merged to create an interconnected network of route options which had been pre-screened for technical and non-technical risk and opportunity.

The combination of subject matter, expert participation, and automation provided efficiencies a clear and defensible rationale as to why routes were considered feasible, and how potential impacts to sensitive features might be addressed. This routing study was accomplished in less time and with less cost than could otherwise be possible with traditional methods.

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INTRODUCTION

The Aurora liquefied natural gas (LNG) joint venture was majority led by Nexen Energy ULC (Nexen) and proposed to construct and operate an LNG facility and marine terminal on the southeastern corner of Digby Island, near Prince Rupert, British Columbia (BC). The LNG process envisioned the supply of natural gas by a number of potential sources in northeastern BC, including assets based in the Horn River basin as well as market gas. A high-pressure natural gas pipeline connecting the source areas to the LNG facility was considered, including strategic options such as a direct route to tidewater, routing through selected interconnection points at gas plants, market hubs, and other related infrastructure. Potential pipeline routes were examined by Nexen and Golder Associates Ltd. (Golder) in July 2016 to determine the most feasible and suitable options.

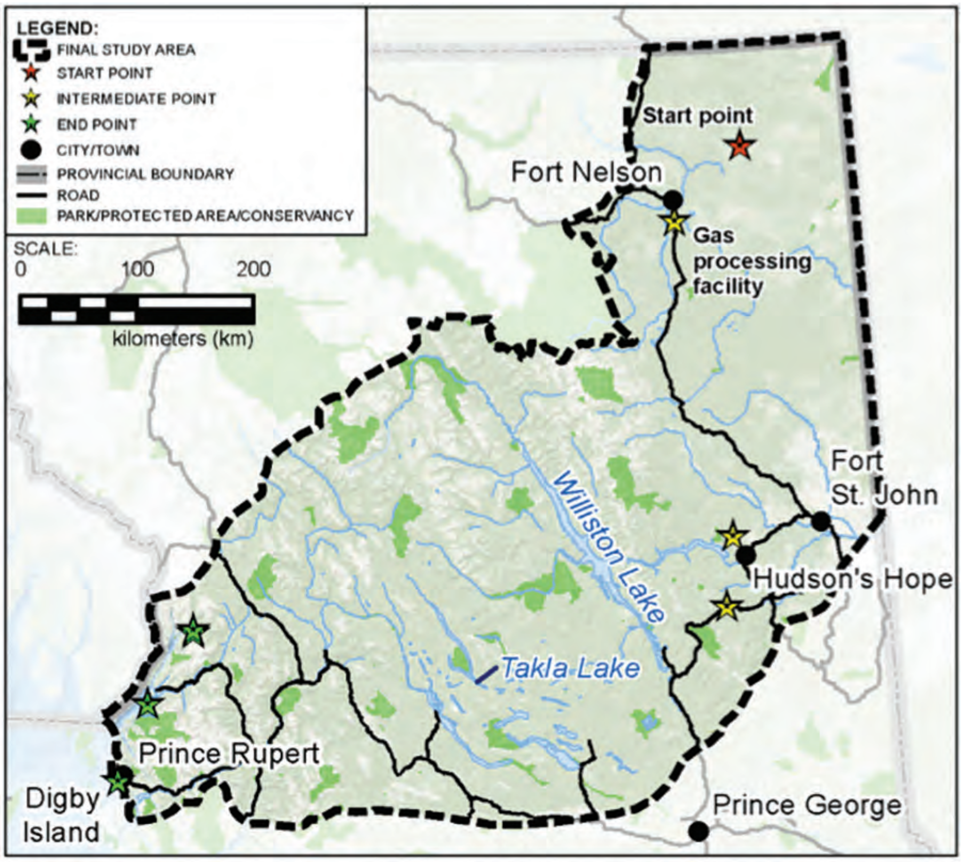

Figure 1. Aurora LNG Study Area, Northern BC, Canada

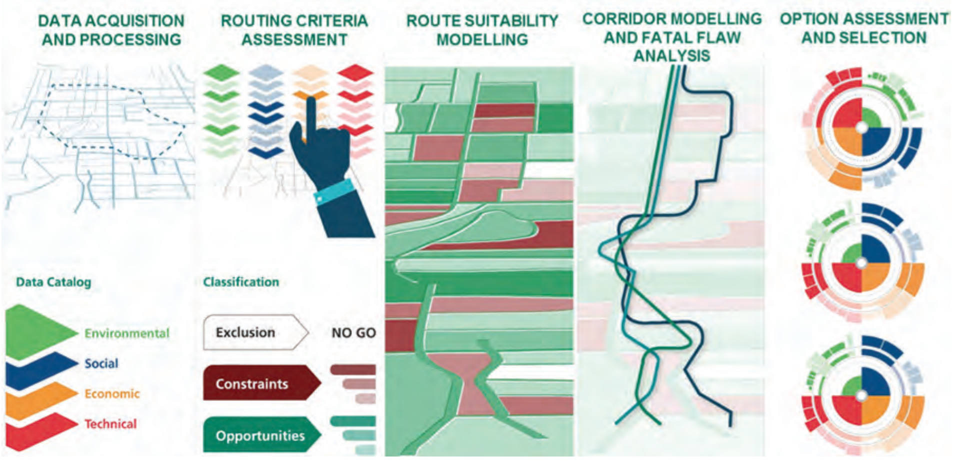

Figure 2. Methodology Work Flow

Study Area

A large portion of northern BC was included in the boundaries of the Study Area, which extended from the Horn River basin to Canadian tidewater. An initial screening process defined the perimeter boundary of a study area where possible pipeline routes would be practical, considering the start and end points. This included a total area of approximately 470,000 kilometers^2 (km) (Figure 1).

METHODS

The method used in the Study was an advancement on the Spatial Multi-criteria Approach (SMCA) used in previous studies (Seel and Dragan 2016; Seel et al. 2014) and is called GoldSET. GoldSET is a structured process and routing tool which employs ESRI's™ geographical information system (GIS) software called ArcGIS™. The tool is used to capture consensus-based routing decisions made by SMEs based on spatial data. Routing calculations are performed automatically, and outputs are evaluated by SMEs for logical consistency. Refinements to routing decisions are made iteratively as new insights are encountered or additional information becomes uncovered throughout the process. Transparency and defensibility are enhanced by fully documenting all data and data processing steps, as well as all decisions, priorities, and the underlying rationale for each route option and iteration.

The first step in the methodology is the acquisition and processing of spatial data into GIS layers to visualize and classify areas into categories of high, moderate, and low suitability for pipeline routing using the GIS-based tool (Figure 2). At this early stage, the various GIS layers are sorted into respective themes including environmental data, such as vegetation, land cover, sensitive habitat, and surface waterbodies. Social data corresponds to the human and cultural footprint on the landscape, such as populated areas, historical and cultural resources, legal boundaries, and other economic activities. In the case of the Aurora Study (the Study), the technical and economic perspectives were combined because the economic factors influencing pipeline design, such as constructability and operability, were highly correlated with technical factors, such as terrain challenges and complexity, water body crossings, and proximity to exiting linear infrastructure, for example.

This process was led by guidance and input from a team of multidisciplinary SMEs acquired during facilitated workshops conducted at key steps in the process. SMEs at various stages included regulatory and legal experts, social and cultural scientists, First Nations advisors, pipeline and facility engineers, construction and operations experts, terrain scientists, biologists, as well as geomatics and information management specialists.

Based on the specific requirements of the Aurora project, SMEs jointly assessed and rated the data layers representing the decision criteria (known as indicators in GoldSET) into three categories: exclusion, constraint, and opportunity areas. Exclusion Areas occur where pipelines are prohibited for social, legal, or regulatory reasons, or where they cannot be constructed or operated for physical or technical reasons (e.g., fatal flaw conditions). Examples include national parks, hazardous terrain features, or very large water bodies. Exclusion areas must be avoided by pipeline routes.

Constraint areas are locations that have sensitivities, limitations, or require special mitigations should a pipeline be constructed and/or operated in their vicinity. Examples include conservation areas, sensitive wildlife habitat, culturally or historically significant areas, and parks or protected places. Constraint areas are rated by SMEs based on the level of suitability as high, medium, or low (high being most constrained).

Opportunity areas are landscape features considered to be highly suitable or advantageous for pipeline routing. Examples include co-location with existing pipelines, roads and transportation infrastructure, and existing disturbance areas such as seismic lines or cut blocks. Like constraint areas, opportunity areas are rated by SMEs based on the level of suitability as high, medium, or low (high being most suitable).

Opportunities, constraints, and exclusion areas are cumulative in GoldSET, thereby allowing tradeoffs to be explored and balanced by SMEs. For example, several constraint indicators (e.g., a high, medium, and low constraint) can combine to form a higher level of constraint at a particular location. Likewise, several opportunity indicators combine to form a greater opportunity; however, each subsequent constraint or opportunity layer is decremented to the degree that several together will not add up to the value of the next higher ranking in the sequence. In other words, several low opportunities combined will not add up to a moderate opportunity, and several moderate opportunities would not add up to a high opportunity. The same is true for constraints.

The exception is for exclusion areas, which override all other considerations regardless of whether they are opportunities or constraints. Several high constraints together will not add up to an exclusion, and may still permit pipeline routing, albeit under very limited circumstances. Such areas are referred to in the Study as pinch points, which characterize an area of very poor suitability combined with extremely limited optionality. Using this relatively simple system, the GoldSET algorithm assembles a picture of suitability for pipeline routing expressed simultaneously across the landscape of the Study Area.

The Study Team used best available data and information obtained through public sources, commercial license, or were proprietary to Nexen. The raw spatial data used in the Study were selected at a regional or landscape scale (greater than 1:50,000). Consequently, smaller local features such as minor streams, wetlands, and small terrain variations may not have been detectable. Data quality was also likely variable due to differences in the baseline mapping methods used, the age of the data with respect to landscape changes with time, and variability in the level of ground-truthing, surveys, or field sampling intensity. Overall, the quality of data was an unknown, and thus the data were not intended to be relied upon solely for detailed, engineering level decisions without further detailed investigation or validation at later stages.

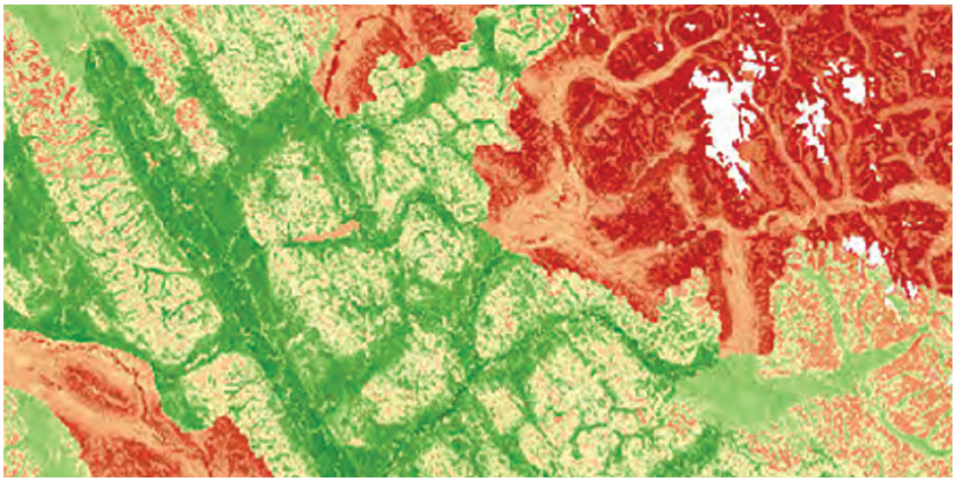

Figure 3. Sample Suitability Surface for Pipeline Routing

Pipeline Routing Model

GoldSET uses the indicators configured in previous steps to create a representation of the landscape, called a pipeline routing suitability surface, for particular model scenarios. A suitability surface (Figure 3) is the cumulative expression of all opportunities, constraints, and exclusions combined together across the Study Area for a given scenario, and has the appearance of a heat map where "hot" areas (shown in red) are more constrained and "cold' areas (shown in green) are less constrained. The highest levels of constraint and opportunity occur where the color is most intense. Exclusion areas appear as white.

Suitability surfaces are the foundations for modelling pipeline corridors and routes based on the various model scenarios, and configurations of start, intermediate, and end points. Corridors are modelled using a custom algorithm using ESRI's™ ArcGIS™ software that follows the shortest mathematical path of highest suitability. The algorithm balances the consideration of achieving the shortest pathway with lowest overall constraint and is similar to standard GIS "least-cost-path" analysis, but uses a much higher degree of automation and refinement based on corridor spatial statistics to efficiently process multiple options. The geometric centerline of the modelled corridor is used as an approximation of the route for the purposes of the Study. In practice, this information is often used to identify a narrow corridor of interest for further detailed terrain, geohazard, and routing studies done at local scales (<1:20,000).

Multi-Option Analysis

The application and use of different routing model configurations or scenarios have been addressed widely in the literature (Seel et al. 2014; Yildirim 2010; EPRI-GTC 2006; Malczewski 1999, 2006; Berry et al. 2004; Humber 2004). In the GoldSET methodology, alternative routing scenarios are generated by altering the indicator configuration for a specific model run.

Model Scenario	Description:
Base Case	A logical and defensible balance of competing environmental, social and technical trade-offs, as determined through consensus by a diverse group of SMEs.
Environmental	Minimized impact to environmentally sensitive areas and utilized existing linear disturbance wherever possible.
Technical	Emphasized constructability, reduced length and materials, and avoided geological and terrain hazards.
Social	Minimized route impact and proximity to populations, land use areas, and cultural and historical resources.

(Seel et al. 2014)

Table 1. Aurora Model Scenarios

The indicators are typically revised by SMEs at a workshop intended to explore and evaluate the multiple "what if?" options to be considered in the routing Study. The table of modified indicators is then input to the GIS tool, and the process of generating a new suitability surface and routes is repeated. Developers are therefore able to explore the sensitivity and potential implications of multiple scenarios on the results, and thereby maximizing the potential optionality of the analysis to the desired extent.

The Aurora SME team chose to explore four different, high-level routing scenarios representing thematic perspectives on the proposed pipeline project (Table 1). The first scenario undertaken was called the Base Case, and was intended to represent the most balanced case between the various environmental, social, and technical tradeoffs expressed by the different indicators. With the Base Case as a reference, three additional alternative scenarios were configured, which represented options that were intentionally predisposed towards the related theme: e.g., environmental, social, and technical. This allowed SMEs to more fully explore and understand the possible key drivers affecting routing outcomes might be.

This practice enhances defensibility and robustness by showing where route options show concordance between different scenarios (robustness), or where there are obvious differences, and the underlying conditions for each (defensibility).

In addition to using different model scenarios to provide routing optionality, a variety of strategic terminus and intermediate connection points were provided by the Aurora Program, which represent different commercial strategic options. By combining different logical sequences of start, intermediate, and end points, an additional 18 model cases were developed. The 18 model cases were run for each of the four scenarios (Base Case, Environmental, Social, and Technical), resulting in a total of 72 pipeline routing model runs producing approximately 50,000 km of potential routes for evaluation by the Study Team.

To simplify the decision-making process, all the route centerlines were merged into a single interconnected network of potential route segments and nodes. As many of the route segments were spatially similar and—in some cases—identical between model runs, these were merged together such that only unique route segments were retained in the analysis. This refinement process resulted in an interconnected network of approximately 180 route segments, totaling more than 12,000 km of potential routes. The capability of considering many route segment combinations at the early stages of planning, as well as clearly being able to explain the underlying rationale for each, is considered a strength of this approach.

Metric Name	Description
3-Dimensional (D) Length	Measures the vertical elevation as well as the horizontal distance of a route centerline.
2D Length	Measures the horizontal distance of a centerline only.
Terrain Complexity	Measures the variation of elevation at the 1km slope level. Highly varied terrain is usually comprised of a cascading series of peaks and valleys.
Impacted Indicators	Includes all contextually-relevant indicators that are crossed by either the 1km route or the centerline of a route segment. Impact was measured by intensity (distance travelled through) and variation (standard of deviation between comparable options). In instances where there were large differences between impact at a centerline and route level (i.e., route is more constrained) these indicators were highlighted.
Infrastructure Crossings	Measured as points where the centerline crosses existing infrastructure. Facilities included: • Large pipelines >19” • Smaller pipelines <19” • Highways of 2 lanes or greater • High voltage transmission lines • Active rail lines
Watercourse/Waterbody Crossings	Include the number of individual crossings and distance based on centerline intersections with named rivers, streams and lakes.
Road Distance to Towns	Measured as the minimum driving distance along any connected road to any point on the potential centerline.
Distance Through Gas Fields	Measured as distance through areas with known gas reserves and gas exploration.
Pinch Points and Route Constraints	Measured as areas along the route where there is significant variance in total suitability and highlights narrow areas of higher suitability sandwiched between lower suitability zones. Measurements include: • Count; • Distance through pinch point; and • % of line pinched

Table 2. Sample Metrics for Option Comparison

Fatal Flaw Analysis

Given the large number of potential options available, it was desirable to refine and reduce the number of route options to only those that were considered feasible (i.e., not subject to possible fatal flaw conditions). Towards that end, the Study Team conducted a fatal flaw analysis at a facilitated workshop based on the combined route segment options. This task consisted of performing a coarse-scale evaluation of each route option to identify results that were not feasible due to total length or other considerations (e.g., crossing of wide waterbodies or proximity to densely populated areas).

The Study Team also identified potential challenges along routes and route segments from the perspective of the environmental, social, and technical themes that were not captured in the spatial data and models due to a lack of existing information. Some examples included:

- Understanding of local First Nations, and other community and stakeholder concerns
- Identified archaeological or heritage sites
- Critical habitat identified in a federally listed species Recovery Plan under the Species at Risk Act (SARA) (e.g., woodland caribou and marbled murrelet)
- Time to market, including anticipated issues that may incur delays as a result of obtaining regulatory approvals, permits, and/or social license
- Regulatory complexity that could add cost, timeline, and difficulty to obtain approvals
- So-called pinch points (narrow areas of high constraint less than 200 m wide) and areas of potential geo-hazard, terrain, or other technical concerns
- Known areas of concern for engineering, design, construction, or operational

Based on the above, the SMEs determined whether each concern could be mitigated either through detailed routing, engineering design, consultation and engagement, or by some other means in later development.

Concerns that were identified as unmitigatable were considered to be fatal flaws to a route or segment. Fatally flawed routes and segments were removed from further study, but were retained for documentation purposes and future consideration.

Routes or segments that lacked serious concerns or had concerns that could be mitigated were considered feasible and retained for further study. Through this approach, approximately 12 of the original model cases were determined to have fatal flaws, and the remaining six short-listed cases were considered feasible and proceeded to the next stage of the analysis.

Option Assessment and Selection

Based on the six short-listed candidate routes resulting from the fatal flaw analysis, a set of descriptive metrics were calculated to provide a standardized, systematic, and quantitative basis for selection of final preferred and alternate routes (Table 2).

The metrics were evaluated by the Study Team, a final route selection workshop. In this workshop, SMEs evaluated each candidate route option for key concerns and impacted indicators, and compared the metrics for each short-listed option. Detailed steps included:

- Determination of which metrics were most important and discriminating between routes
- Elimination of non-discerning metrics between route options (e.g., metrics that were close or identical in value between all options and therefore not useful in selection)
- Pairwise comparison between corresponding segment along routes to remove the least preferable options based on an assessment of metrics and trade-offs
- Determination of which routes were preferred versus alternate and why
- Results recording and documentation including notations on GIS electronic metadata files

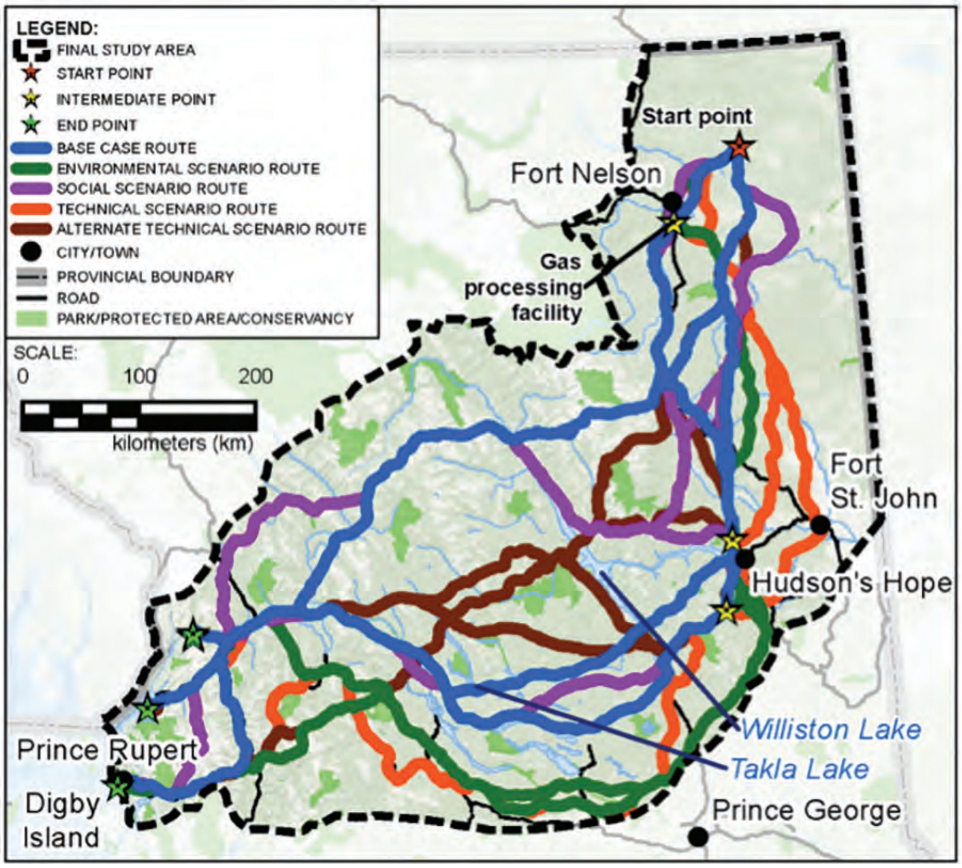

Figure 4. Combined Model Scenario and Case Results

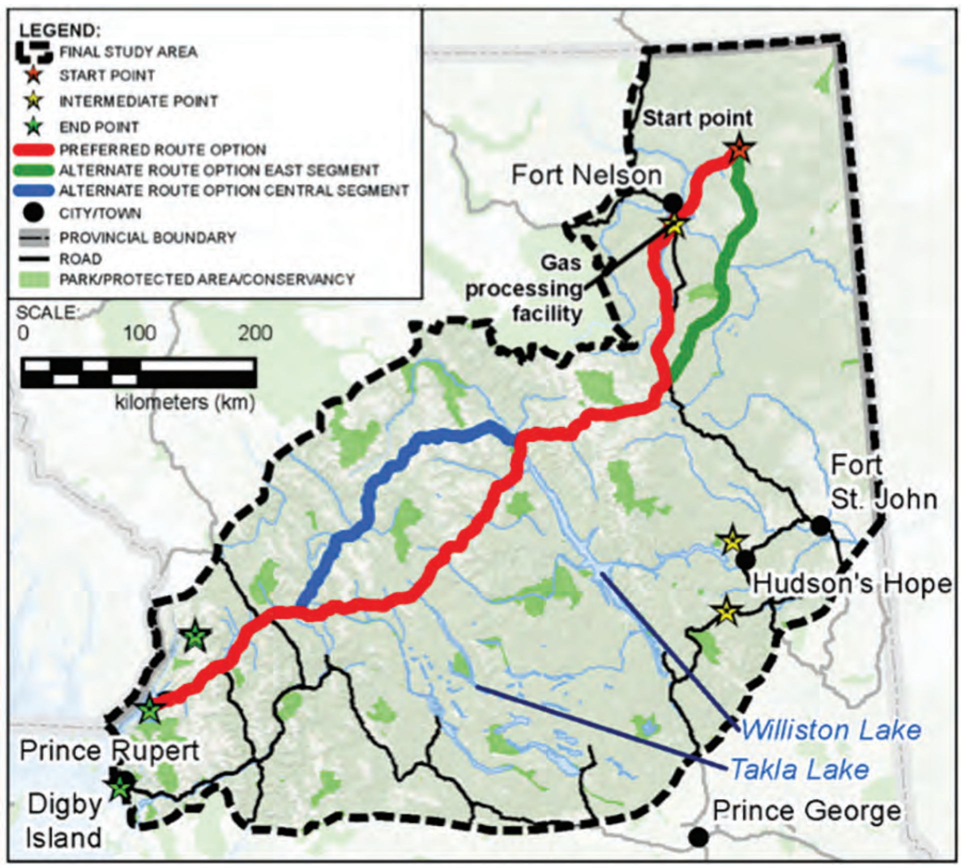

Figure 5. Bullet Line Route Options

Based on the results of the final option selection workshop, Aurora SME's were able to identify and short-list three different complete sets of preferred and alternative route segments. These were named as the Bullet Line, Full Interconnects, and Partial Interconnects options, respectively.

RESULTS

Figure 4 provides the combined results of the route modelling exercise for the 72 individual runs, and shows the interconnected network of potential routes for further study and refinement. The results illustrate some of the key differences between the various themed perspectives. For example, the environmental scenario runs tended to be longest because of diverting further south to avoid proximity to more highly weighted, environmentally sensitive indicators in the north. The Base Case and Technical runs tended to be shorter by taking advantage of higher suitability pathways more central to the core of the Study Area. Social scenario runs tended

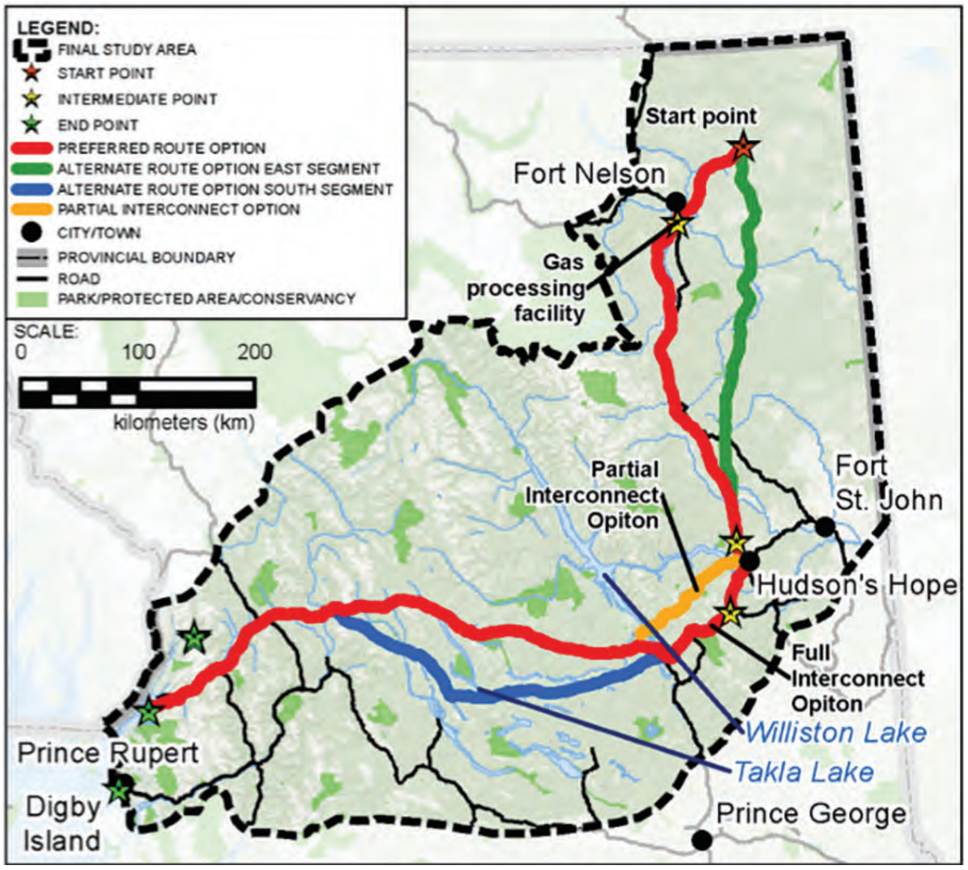

Figure 6. Full and Partial Interconnect Route Options

Route Name	2D Length (km)	Infrastructure Crossings (No.)[(a)]	Water Crossing Length (km)	Pinch Point Length (km)	Possible Challenges[(b)]
Bullet Line - Preferred Option (AW)	865	10	23 (2.8km)	63.7 km 6.50%	Moderate Slopes Caribou Muskwa-Kechika Resource Management Zone (MKRMZ) Wetlands Steep Slopes
Full Interconnect - Preferred Option (AIMW)	1063	37	30 (4.9 km)	72.8 km -6.80%	Caribou Wetlands Moderate Slopes Populated Places Steep Slopes
Partial Interconnect - Preferred Option (AIW)	1027	15	25 (3.9 km)	64.5 km -6.30%	Moderates Slopes Caribou Wetlands Steep Slopes

[(a)]Includes Highways, HV Transmission Lines, Rail Lines, and large Pipeline.
[(b)]Includes all high or moderate constraint impacted indicators with a presence of more than five percent along the potential route.

Table 3. Summary of Metrics for Selected Routes

to be longer and more convoluted as they tended to avoid or minimize areas of higher social sensitivity.

Figure 5 provides an overview of the Bullet Line (i.e., directly overland) route options, including both preferred and alternate segments.

Figure 6 provides the results for the Full Interconnects route options, which joins to the Spectra CS2 Hub, and the Partial Interconnects route, which avoids the CS2 Hub and takes advantage of a shorter route to the north.

Table 3 summarizes the key metrics describing the Bullet Line, Full, and Partial Interconnects route options, including the primary concerns which could not be avoided or mitigated through the route development and selection process. It was assumed in the study that these factors would be addressed in detail at a later stage of the Aurora Program.

DISCUSSION

Bullet Line Options

The Bullet Line (Figure 5) provided the most direct route options between the gas supply in northeast BC and tidewater that was produced by the Aurora LNG study. The preferred route has the shortest length of all the routes studied, and it has the added business benefit of being connected to gas processing facilities. It also has the least number of infrastructure crossings, shortest distance through pinch points, and the fewest water course crossings. Primary concerns for this option were the distance traversed through non-critical caribou habitat, moderate to steep slopes, and proximity to wetlands that cannot be avoided. There is also limited access across nearly a quarter of the route.

An alternate route on the east side (Alternate Route Option East Segment) parallels existing infrastructure associated with gas field development. However, this route crosses more wetlands, and excludes connectivity to gas processing facilities. A second alternate route (Alternate Route Option Central Segment), which is north of the Omineca Mountains, minimizes interaction with caribou habitat, but is more remote and traverses more complex terrain.

Full Interconnect Options

The Full Interconnects option (Figure 6) includes a preferred option that is longer than the Bullet Line, but has the business advantage of connecting with additional gas processing facilities and market hubs. This route has the largest number of infrastructure crossings, water crossings, and distance through pinch points. The major concerns are the distance this option has—traversing moderate slopes through non-critical caribou habitat and wetlands. These factors can likely be partially mitigated through more detailed routing studies and/or through engineering design and construction practices. Sections of this route have been previously validated through the successful Westcoast Connector Gas Transmission regulatory approval process.

There is an alternate route for the east segment which is shorter, but loses connectivity with the gas processing facilities, and an alternate route for the central segment which could be potentially easier to construct, but is longer than the preferred segment. This southern alternate route traverses south of Takla Lake and has more locations of narrow higher suitability surrounded by lower suitability (pinching).

Partial Interconnect Options

The preferred route for the Partial Interconnects option (Figure 6) is approximately 40 km shorter than the Full Interconnects route. This route has resulted mainly from eliminating the connection with a market hub. It differs from the Full Interconnects option only in the segment between Hudson's Hope and the use of the northernmost crossing at Williston Lake.

Metrics for the Partial Interconnects option indicate that it has fewer constraints than the Full Interconnect preferred option, but more than the Bullet Line. Primary concerns are moderate slopes, non-critical caribou habitat, wetlands, and steep slopes, which can likely be partially mitigated through more detailed routing studies and/or through engineering design and construction practices. The preferred option is the second longest route option; however, it does tie into the gas processing facilities, which provided an advantage.

CONCLUSIONS

The GoldSET decision analysis process successfully generated and analyzed 72 separate model runs, producing a total of approximately 50,000 km of potential routes for evaluation by the Study Team. Further refinement guided by a multidisciplinary group of SMEs through a consensus-based, workshop-driven process resulted in an interconnected network of approximately 180 route segments, totaling more than 12,000 km of potential routes. Subsequent fatal-flaw analysis narrowed the field to the most feasible options, resulting in three different route option groups including the Bullet, Partial, and Full Interconnect route options. Optionality within each grouping was demonstrated by having preferred and alternate segments in each case.

The inclusion of multiple options at the early stage of project development allowed the Study Team to efficiently and effectively maximize the exploration of potential routes and manage subsequent risk by eliminating fatally flawed and other non-feasible routes at appropriate stages. This approach contrasts with previous, traditional methods, which are laborious, costly, and limited to producing fewer routes. The work was also completed at a fraction of the cost and time required for traditional routing studies.

In addition to including technical considerations, the study was able to integrate environmental and social themes into the analysis and provide a platform to explore tradeoffs and different "what if?" scenarios. The ability to incorporate these value components directly and transparently into the routing analysis is considered critical for supporting the regulatory approval process and gaining social license.

Although the Aurora LNG Program was ultimately cancelled, the work performed at this preliminary stage provided a robust foundation that enhanced further routing studies that were undertaken. It can be surmised that this would have similarly supported consultation and regulatory processes had the project proceeded to that stage.

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AUTHOR PROFILES

Kevin Seel

Dr. Kevin Seel has more than 25 years of consulting and modelling experience with a focus on decision support and optimization of linear infrastructure routing and industrial facility siting. Seel leads the North American routing and siting practice at Golder Associates Ltd. and has been involved in more than 50 large infrastructure projects. Seel is currently involved in several routing studies for pipeline and power infrastructure, as well as optimizing centralized facilities and water use for unconventional oil and gas development in both Canada and the U.S.

Adam Phillips

Adam Phillips has a Bachelor of Science degree in Mechanical Engineering from the University of Calgary and holds a certificate in professional engineering. He has more than a decade of experience in system planning and execution of pipeline projects, and has supported projects throughout various stages of evolution. A mechanical engineer by training, Phillip's role for Nexen Energy ULC within the Aurora LNG Program involved managing the technical development of a pipeline solution to transport natural gas more than 1,000 km from supply fields in northeast BC to a liquefaction site near Prince Rupert, BC.

Prior to joining Nexen Energy ULC, Phillips worked for TransCanada Corp, developing and executing pipeline projects in western Canada and Mexico. This experience on large projects facing technical, environmental, social, and political challenges proved invaluable in progressing the Aurora Pipeline.

EAs: In Search of the Right Level of Detail at the Right Stage of the Game

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Keywords: Footprint, Impact Assessment, Pipeline, Stakeholders, Study Corridor.

Indigenous groups, regulators, landowners, and other stakeholders crave detailed information at the early onset of a project. Meanwhile, proponents require time to gather the information and seek feedback from the various groups and their teams in order to build their project concept. The "corridor approach" to environmental assessment (EA) provides the proponent with some flexibility in the planning and design of a project. However, this approach has its limitations. The sequencing and timing of gathering the environmental information has varied for pipeline projects, especially as the level of Indigenous and public engagement has increased. The cost for upfront EAs and studies in Canada has only grown, while project certainty has waned, and legal challenges have increased. This paper explores the different considerations proponents need to evaluate prior to conducting EAs and surveys, including the level of detail required, and anticipation of potential concerns interested parties may have while still advancing the project. The diversity of concerns has grown and now pipeline proponents are faced with the challenges of addressing these concerns in a timely manner. Lessons learned on major pipeline projects in Canada will help us understand the different levels of information needed at various stages of the regulatory review process.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Impacts of a project on the environmental and socioeconomic valued components are some of the key considerations in regulatory decision-making when issuing project approvals and conditions. In the early planning stages of a new pipeline project, the project team assesses the certainty of the project route and decides on the general width of the study corridor to allow for flexibility in the final route selection. The study corridor can be described as the general area in which the project construction footprint will be located between source and end points (i.e., existing above ground facilities), while several control points throughout the route (e.g., tie-in locations, pump stations / compressor stations, power needs, operational access, pinch points on the landscape, and crossings of major watercourses) will often drive the general route location.

The study corridor width decision is important to help frame a project and provide a foundation for the project team to start with, as it drives the appropriate scoping of the project programs and associated costs and schedule. Assessing a corridor allows for the collection of data in a greater study area, which helps inform project decision-making along the way and allows for better balancing of potential impacts. However, collection of baseline data across a broad or expanded study corridor may potentially increase the overall uncertainty of the project impacts. The study corridor provides the aerial extent for collection of information and baseline studies (e.g., geotechnical, environmental, cultural, archeological, and engineering studies), assessment of the potential impacts of the project, as well as have bearing on the extensiveness of the Indigenous and stakeholder engagement programs, landowner consultation, and the need for survey consents. The study corridor has an influence on all aspects of the project and is different from resource-specific spatial boundaries as set out in an environmental assessment (EA). The width of the study corridor can vary throughout the entire length of the pipeline and is often expressed as an average width by the proponent. Table 1 provides a summary of some of the limitations and benefits to a wider versus a narrower study corridor.

CORRIDOR WIDTH	BENEFITS	LIMITATIONS
Narrower **< 200m (656 ft)**	• Keeps the survey focused and reduces overall time and cost • Reduces the number of survey consents needed from landowners • Provides more certainty to stakeholders and Indigenous groups on the location of the pipeline • More certainty on the project-specific impacts • More certainty on the project-specific impacts	• Any route adjustments or deviations may require proponent to file supplemental reports to the regulator or complete additional studies for review and approval • Perceptions from Indigenous groups or stakeholders that the route has been determined and there is no opportunity for input or change
Wider **> 200m (656 ft)**	• Allows for flexibility to accommodate re-routes and deviations as well as additional workspaces • A wider corridor typically will capture storage areas, work camps, access roads, powerlines, etc. in the overall survey • Provides stakeholders and Indigenous groups with opportunities for input • Provides a broader study area for environmental surveys	• More time is required to survey larger areas • Higher cost for surveys • Additional survey consents or approvals may be required • Alternative access vehicles may be needed (i.e., helicopter) • Increased logistical and safety arrangements • May introduce stakeholders and Indigenous groups that otherwise would be outside of the project construction footprint • Greater uncertainty regarding specific project impacts

Table 1. Benefits and limitations typically associated with wide and narrow study corridors

The width of a study corridor may depend on whether the pipeline is a "greenfield" or "brownfield" pipeline project. A "greenfield" pipeline crosses new landscapes for a majority of its length where there is little anthropogenic disturbance. A "brownfield pipeline" may parallel other existing linear disturbances or traverse a landscape that has already been altered. The risk of the pipeline alignment needing adjustment or the need to consider alternate routes for a regulatory application, combined with regulatory requirements for an EA, will help inform a decision on the appropriate width of a study corridor.

Throughout the regulatory review process, proponents generally seek approval from a regulator for the entire study corridor, and as such, distinction between the study corridor for which approval is sought and the project construction footprint has to be clearly communicated in the proponent's EA. A typical project construction footprint for a large diameter pipeline (i.e., 30 to 48-inch O.D.) can range from 45 (148 ft) to 55 m (180 ft) in width depending on the terrain, land use, and site conditions. Where special construction techniques are warranted (e.g., rock outcrops, urban settings), the project construction footprint can be narrowed down to an approximately 10 m (33 ft) for very short lengths.

The objective of this paper is to provide a general set of considerations to help guide proponents on evaluating an appropriate width for a study corridor. For the purposes of this paper, the term EA is synonymous with environmental and socio-economic assessment (ESA), environmental impact statement (EIS), environmental impact assessment (EIA) or impact statement (IS). Furthermore, the term "environment" in this context includes all biophysical factors as well as socio-economic matters related to air quality, greenhouse gases (GHG), climate change, archaeological resources, traditional land use, social and cultural well-being, human health and ecological risk, human resource and land use occupancy, employment and economy, infrastructure and services, and aesthetics.

METHODS

For determining the appropriate width of a study corridor for a project, this paper examined select pipeline projects in western Canada in combination with the author's professional experience and knowledge. The projects considered in this review are included in Table 2.

The benefits and limitations of each project approach to selecting a study corridor width was assessed at key decision points in the project lifecycle up until construction. These key decision points in a project lifecycle that influence the consideration of a study corridor width include:

- Project Initiation
- Project Description
- Engagement of Indigenous Groups and Completion of Traditional Land Use Studies
- Application to Regulator

PROJECT	CORRIDOR WIDTH (m) (ft)	RATIONALE
Trans Mountain Expansion Project	150 m (492 ft)	Parallels an existing pipeline system owned and operated by the proponent (Trans Mountain Pipeline ULC 2013).
NGTL North Montney Mainline	100 m (328 ft)	If there was an area of interest, disciplines would expand their survey beyond the 100 m centered over the pipeline (NOVA Gas Transmission Limited 2006).
TMX-Anchor Loop	100 m (328)	Pipeline through a World Heritage UNESCO site warranted special consideration including the study of route alternatives to the same level of detail as the proposed route (Terasen Pipelines Inc. 2006).
Georgia Strait Crossing Pipelines	200 m (terrestrial) (656 ft) 600 m (marine) (1,958 ft)	A marine and terrestrial pipeline through major shipping route and populated rural areas on Vancouver Island (Georgia Strait Crossing Pipeline Limited 2000).
Enbridge Line 3 Pipe Replacement	50 m (164 ft)	The project was located adjacent to a well-defined pipeline corridor containing multiple pipelines that had been extensively studied in the past. The general area and the potential impacts were previously well known and understood. Studies generally focused on the project footprint, however, where potential for impacts to extend beyond the project construction footprint (e.g., a raptor nest 1,000 m away), surveyors would expand their survey effort (Enbridge Pipelines Inc. 2014).
Enbridge Northern Gateway	1,000 m (3,280 ft)	A greenfield oil pipeline with very difficult terrain through multiple mountain ranges and river valleys (Enbridge Pipelines Inc. 2004)

Table 2. Study corridor widths for major pipeline applications in Canada

- Regulatory Review Process
- Public and Detailed Route Hearings
- Contractor Engagement
- Final Investment Decision
- Environmental Protection and Management Plans and Alignment Sheets

In addition to these key decision points for a project, and reaching consensus on a study corridor width for all project activities, there are needs for each environmental discipline to help ascertain the appropriate study corridor width. Table 3 lists the common spatial boundaries that inform corridor selection and form part of the EA approach. The project construction footprint and the local study area are most likely to overlap with the selected study corridor.

RESULTS

Project Timeline

A project will typically encounter a series of stage gates where review and decisions need to happen. Project initiation, project description, application to the Regulator, Regulatory review, Indigenous engagement and completion of TLU Studies, final investment decision, Contractor engagement, mitigation development, detailed route and regulatory hearings, and construction are just a few of the more common stages in a project.

Once the feasibility of the project has been determined and following project commencement, the costs of the project planning typically increase with time as the need for decision-making

Spatial Boundary	Description
Project Construction Footprint	The area directly disturbed by surveying, construction and clean-up of the pipeline and associated physical works and activities (including, where appropriate, the permanent right-of-way, aboveground facilities, temporary construction workspace, temporary stockpile sites, temporary staging sites, construction camps, access roads, powerlines).
Local Study Area	The zone of influence (ZOI) or area where the element and associated indicators are most likely to be affected by Project construction and operations. This generally represents a buffer from the centre of the proposed pipeline corridor or edge of a facility site.
Regional Study Area	The area extending beyond the LSA boundary where the direct and indirect influence of other activities could overlap with Project-specific effects and cause cumulative effects on the environmental indicator. This varies for each element.
Provincial / Territory / State	The area extending beyond regional or administrative boundaries but confined to provincial or state (e.g., provincial permitting boundaries).
National	The area extending beyond a province or state but confined to a country.
International	The area extending beyond a country or nation.

Table 3. Spatial Boundary - Location of Residual Effect

Stage	Limitations	Benefits
Application to the Regulator	Less certainty of specific effects and mitigation	More knowledge, speedier timeline
Regulatory Review	Uncertainty of direct effects	Greater rationale for route choice
Contractor Engagement	Difficulty in costing; claims	Options for reroutes and temporary workspace
Indigenous engagement and completion of TLU studies	Uncertainty of specific effects; unnecessary sites	Inclusive of areas not traditionally considered
Final Investment Decision	Time consuming and costly	Greater project certainty
Mitigation Development	Costly, need for decision making frameworks	Very inclusive suite of mitigation options
Detailed Route and Regulatory Hearings	Detailed knowledge is limited	Flexibility with need for new lands
Construction	Supplemental Studies needed	Flexibility with need for new lands

Table 4. Limitations and benefits associated with each stage of the Project timeline

often drives the spend on the environmental studies and the EA. The investment into gathering data to inform the routing decisions will often increase confidence in the route selection for the regulatory application and potentially decrease the risk of regulatory updates prior to construction, which may negatively impact schedule and jeopardize the in-service date. Each stage comes with a cost and a benefit that need to be weighed and this is largely a function of fulfilling the project details required for the next step (for example, conducting environmental studies to submit an application to the regulator). Some of the benefits and limitations for each stage are presented in Table 4.

Routing and Corridor Definition

As workers for engineering, land, environment, and construction examine their maps, complete their initial field observations, and the proponent engages with Indigenous groups, stakeholders, landowners, and government agency representatives, a corridor width can be established to help guide decision-making. Analysis of the route selection process and determination of a study corridor for proponents resulted in a similar hierarchy. In descending order of preference, these were:

- Where practicable, co-locate or install a new pipeline within or adjacent to any existing owned facility or easement to:
  - o …reduce land use fragmentation
  - o …reduce the use of unencumbered lands by utilizing the existing easement for location of the pipeline and construction workspace
  - o …leverage the existing operations and maintenance programs and landowner knowledge of the location to optimize pipeline integrity and safety
- Where co-location with an existing easement is not practical, minimizing the creation of new linear corridors by installing the pipeline adjacent to existing easements or ROWs of other linear facilities including other pipelines, powerlines, highways, roads, railways, fiber-optic cables, and other utilities.
- If co-location of the pipeline with an existing linear facility is not feasible, install the pipeline segments in a new easement selected to balance safety, engineering, construction, environmental, cultural, and socio-economic factors.
- in the event a new easement was necessary, minimize the length of the new easement before returning to an existing owned easement or other ROWs.

These routing criteria not only helps establish the pipe centerline, but also provides guidance to the selection of a study corridor width. For a proponent where an existing easement is owned and there is enough space to install a second pipe or use the easement for construction workspace, then the study corridor can be adjusted as well to avoid environmental studies on lands that will not be impacted. Alternatively, if there are no disturbed lands or existing easements to parallel and there is a new crossing of a waterbody, the study corridor may be widened until further engineering and geotechnical data is gathered.

DISCUSSION

Corridor Selection

The importance of careful selection of a study corridor at key project development stages cannot be emphasized enough. A study corridor chosen with the appropriate routing considerations and criteria will help minimize environmental impacts. However, it is important to note that although a proponent may have a set of routing criteria, this does not imply that all criteria must be met as the overall balance of safety of the workers, integrity of the pipeline, and environmental, socio-economic, land, and Indigenous matters needs to be maintained. In addition to corridor and route selection, potential impacts of a pipeline can be further reduced or avoided through the implementation of timing of construction and construction techniques.

Typical features crossed by a pipeline that may warrant a wider study corridor include areas of excessive grade, watercourse crossings, wetlands, foreign lines, roads, urban infrastructure, and highways. Not to mention, alternative construction methods or alternative routing may require a wider corridor. For example, the use of a horizontal directional drill may minimize your above-ground footprint; however, the entry and exit points typically require additional workspace and a place to weld up the pipe segment (i.e., false ROW) may be needed.

In the early stages of a pipeline project, a proponent does not typically have knowledge of site-specific environmental features to be avoided. Furthermore, the timing of when a project kicks off will often dictate when site-specific detail for routing will be known. Whether it is through the stakeholder and Indigenous engagement programs or the collection of site-specific data from the field, even a pipeline that is <40 kilometers (km) (24 miles [mi]) may need additional time to complete its routing feasibility. Timing is also important from a seasonal perspective. If a project in Canada commences in fall or winter, then the field programs will have to commence the next growing season, which could be six to eight months away. On one hand, this would allow engineering, landowner, stakeholder, and Indigenous engagement programs to commence. It will often leave a project team advancing a study corridor with limited information until studies are completed. For some wildlife or vegetation species, the timing of these surveys is important to help inform the routing. Wildlife species at risk surveys are subject to timing, as well as certain vegetation surveys require a spring and or a late summer survey. In addition, engagement with Indigenous groups takes time and often the traditional land use studies follow a common seasonal round or require an agreement before commencing.

The study corridor approach is designed to create some flexibility to adjust the route where required. This may require the avoidance of important environmental, cultural, or archaeological features or to allow for input from landowners, Indigenous groups, stakeholders, or government agencies. Any changes to the route that would deviate outside the study corridor would typically warrant additional study and undergo a more rigorous regulatory review that would require any new project input. Table 5 outlines some of the factors that may warrant a change in the study corridor, or alternatively may provide guidance to proponents where a wider corridor may be needed in the early planning stage.

Environmental Effects Assessment

The description of the environmental setting (current state of the environment) within the study corridor is typically compared against the project description to assess potential

FACTOR	RATIONALE
Safety	Minimize areas posing hazards to: a. construction/operations workers – workspace, overhead hazards, geotechnical hazards b. public – traffic interaction, proximity to excavations and heavy equipment
Pipeline Integrity	Minimize crossing areas with geotechnical hazards, high potential for third-party contact, and poor maintenance access
Environment	Minimize environmental impacts by attempting to reduce the following where practical: a. the total number of watercourse crossings b. length in the riparian areas c. difficult reclamation areas and unstable terrain d. length within designated protected areas e. the total number of wetland crossings f. creating new access in areas considered to be ecologically important
Constructability	Avoid factors negatively affecting construction efficiency
Terrain	Minimize crossing side slopes, geohazards, rock, water bodies, wetlands, and high water table areas
Infrastructure	Minimize encroachment on existing and planned infrastructure
Access	Avoid limited or difficult existing access roads (stability, turn radius, local interference)
Stakeholders and Socio-economic requirements	Minimize socio-economic impacts by attempting to reduce the following as much as is practical: a. review and be consistent with land use policy documents b. landowner – consider landowner concerns c. parks – avoid where practical d. recreational areas – avoid where practical e. infrastructure – dependent on meetings with representatives of applicable utility f. residential density - reduce length in high density areas where other options are available
Indigenous Impact	Minimize Indigenous impacts by attempting to reduce the following where practical: a. reserve Lands dependent on consultations; provide alternate routing for planning b. traditional lands – dependent on engagement
Cost and Schedule	Reduced length is preferred; schedule reduction due to improved constructability over a longer distance should be considered.

Table 5. Factors that could result in a deviation from the study corridor or change in project construction footprint

environmental effects that might be caused by the Project. The environmental effects assessment uses the information provided in the environmental setting and Project description to:

- …evaluate the environmental elements of importance in the project area
- …identify and evaluate potential Project effects associated with each environmental element of importance
- …develop appropriate technically and economically feasible, site-specific mitigation. In addition, the environmental effects assessment determines the significance of potential residual effects resulting from construction and operations activities after taking into consideration proposed mitigation measures.

In contrast to the selection of a study corridor, the spatial boundaries often cited in an EA to identify the location of residual effects are provided in Table 3.

The study corridor and the spatial boundaries of the assessment are sometimes overlapping, yet different. The study corridor often refers to the actual area of "boots on the ground" or integration of site-specific data that informs the assessment. The spatial boundaries of the impact assessment will vary from as large as "international" to "project construction footprint" boundaries, while general study areas for site-specific biophysical resources will often drive the overall width of a study corridor.

Choosing a study corridor width allows for appropriate consideration and assessment of potentially impacted resources by the Project during baseline studies and preparation of the application. Setback distances can also be accommodated through route refinements within the corridor, since often the knowledge on presence of specific resources within certain distance of the project is not available early in the project timeline.

Any application to a regulator needs to be complete. That is, it needs to contain sufficient information and understanding of the project area and potential impacts in order to enable the regulator to make an informed decision. The amount and type of information needed by each regulator may vary at different stages of a project; therefore, it is important for proponents to have ongoing discussions with regulators to ensure alignment in their respective information needs.

During the preparation and filing of a regulatory application, there is a stage in the game where a study corridor and project construction footprint need to be "frozen" to ensure that all the information captured in the application is based on a well-understood study corridor and the EA has considered the appropriate spatial boundaries and impacts. The study corridor and project construction footprint shapefiles are critical to informing the technical data reports and the EA. It allows for calculations to be completed, maps to be generated, and the assessment to be finalized and submitted to the regulator. It is common practice that the project construction footprint continues to be refined while aiming to keep the footprint within the applied for study corridor and to allow the regulatory review to proceed unhindered, and with minimal routing changes.

CONCLUSIONS

The study corridor selection recommendations provided herein should be considered, as well as the factors that may warrant a wider or narrower study corridor to help balance schedule, cost, and information requirements at various project stages. It is important that a study corridor be developed based on a standard set of corridor selection hierarchy to enable the pipeline to be installed safely and reinforce the protection and integrity of the pipeline while minimizing the adverse effects of pipeline installation and operation. As a practice, determination of study corridor width for pipeline project should contemplate a range of factors including constructability, long-term geotechnical stability, environmental, cultural, and socio-economic suitability.

The selection of a study corridor and project schedule are vital for meeting critical project milestones. The advancement of the project through the planning and permitting cycle relies heavily on navigating each stage with a thorough understanding of the drivers behind decisions and associated risks. Selection of an appropriate study corridor width can set the stage for well-balanced decision-making, while allowing flexibility for re-routes and decreasing risks of regulatory updates, schedule delays, and higher costs. A variable study corridor width that accommodates route alternatives, workspace needs, and alternative construction methods combined with narrow study corridors where there is certainty (i.e., paralleling existing linear infrastructure) was found to be the most reasonable approach taken by pipeline proponents.

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Environmental DNA: Real-Time Results in the Field to Confirm the Presence of Target Species

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Keywords: Evaluation, Invasive, Mitigation.

Environmental managers require rapid, reliable, and cost-effective methods to monitor for the presence of rare, keystone, or invasive species. Sampling for environmental DNA (eDNA) has emerged as a reliable and cost-effective approach to biomonitoring that does not require the capture, or even visual confirmation, of the target species. This approach involves sampling for DNA that has been shed by the target species into their environment (i.e., water, soil, or sediment). Compared to conventional surveys, sampling for eDNA is proven to be a rapid, sensitive, objective, and reliable way to confirm species presence that is less labor intensive.

A promising field-based eDNA sampling point-of-need tool has recently been developed that puts the power of the laboratory into a hand-held unit to provide real-time results in the field. This means no searching for an appropriate laboratory and no prolonged wait for results. Additionally, since samples can be collected from shore without entering a waterbody, safety risks, the potential to spread invasive species, and eDNA cross-contamination between sites are all significantly reduced. This paper reviews a successful field eDNA methodology that has been implemented at sites across North America to detect the presence of aquatic species and preliminary results from those studies.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

All living organisms expel genetic material (i.e., DNA) into their environment from their skin, feces, urine, blood, decaying body, or gametes (i.e., eggs or sperm) (Wilson and Wright 2013). This genetic material is called "environmental DNA" or eDNA. Fish and other aquatic organisms imprint their environment with their eDNA, which is being used in an emerging method to detect the presence of target species by sampling the environment for this shed DNA. Using eDNA technology provides the ability to quickly assess the environment for the presence of both invasive, rare, threatened, and endangered (T&E) species in their habitats. This paper focuses on the application of eDNA approaches to detect the presence of target species in aquatic environments.

The persistence of eDNA in the aquatic environment and its rate of decay relative to environmental interactions is an active area of research. There have been studies indicating that eDNA of a species can be detected in water for one to 58 days after removal, with slower rates of degradation in colder waters that are more alkaline and have less ultraviolet radiation exposure (Dejean et al. 2011; Thomsen et al. 2012a and 2012b; Barnes et al. 2014; Strickler et al. 2015, as cited in Evans et al. 2017). In addition to the water chemistry and other abiotic factors, the persistence and strength of the eDNA signal in the aquatic environment depends on how recent a target species was present, their residency time, stage of their life cycle (i.e., more eDNA during external fertilization), the density of the target species population, how much DNA is being shed, and the volume and flow rate of the water body.

However, using eDNA has been demonstrated as reliable and effective for detecting rare species at low densities in aquatic environments, including stream, riverine, and lacustrine systems (Evans et al. 2017; Jerde et al. 2011; Ficetola et al. 2008; Nevers et al. 2018). Studies introducing caged fish at densities as low as seven individuals have detected eDNA of those species up to 400 meters downstream of the cage after just two days of residence time (Dysthe et al. 2018). Because of the inherent challenges of observing rare transient fish underwater and low capture probabilities through conventional methods (e.g., electrofishing, netting), sampling for a species using eDNA provides a potentially more sensitive method for rapidly assessing the presence of rare fish species across large spatial scales (Wilson and Wright 2013; Evans et al. 2017). Furthermore, the limited window of eDNA persistence in water versus other environments (e.g., lake sediments) provides a useful "here and now" reference point to the detection date that can be beneficial in guiding management and conservation decisions (Pikitch 2018).

In recent years, eDNA analysis has become an accepted research methodology to complement conventional methods used to detect the presence of aquatic organisms (Evans et al. 2017). Although capture-based sampling techniques can provide information on metrics such as species abundance, condition, and population structure, eDNA provides a cost-effective, safer, less invasive, and less labor-intensive alternative for detecting rare species in aquatic environments (Evans et al. 2017; Wilson and Wright 2016) (Figure 1). Water can be sampled for the presence of eDNA without having to capture or disturb the target species, habitat, or potentially spreading invasive species that can be attached to wading boots or waders. Furthermore, for similar aquatic species of the same genus that cannot be distinguished morphologically, eDNA can be more accurate at confirming presence of a specific target species compared to conventional methods with visual identification by different observers (Figure 1).

Working in partnership, Stantec Consulting Limited (Stantec), University of Guelph, and Precision Biomonitoring have developed a point-of-need method to sample, extract, and analyze eDNA samples for the presence of target species in the field in less than two hours. This point-of-need tool, described below, is being demonstrated in 2018 and 2019 for more than 20 test species, and validated using parallel eDNA testing in a laboratory. There are several advantages of real-time eDNA analysis in the field versus collecting water to later be analyzed for eDNA, including the following: 1) faster turn-around time for results, 2) prevention of

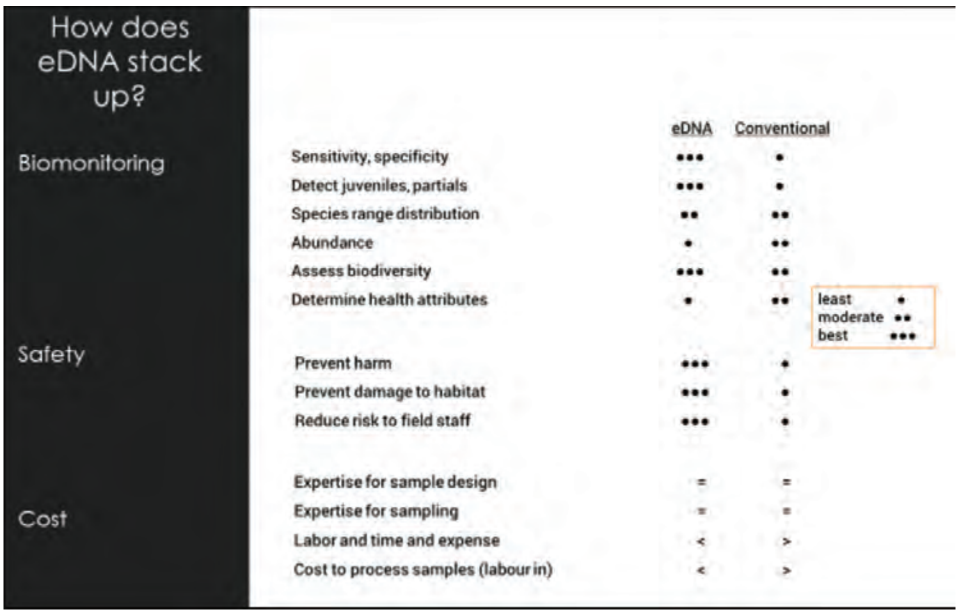

Figure 1. A comparison of the advantages and disadvantages of using eDNA versus conventional methods for detecting aquatic species adopted from Pikitch, 2018

potential contamination during sample handling, transport, or in the laboratory, 3) avoidance of DNA break-down between the time of sampling and the time of analysis, 4) avoidance of sample custody issues with transport to a laboratory, and 4) allowance for adaptive sampling decisions in the field on where/when to sample based on results received in hand, as opposed to re-mobilizing to the field after waiting for results from a laboratory. This paper reviews the field eDNA methodology and tools that have been developed and are being applied across North America to confirm the presence of aquatic species and presents the preliminary results of some of those studies. We also review the quality control measures that have been built into this real-time procedure to provide reliable results.

METHODS

Stantec has been using DNA-based tools with partner laboratories for the past five years to address biomonitoring questions for clients. The results of these pilot studies were promising. In 2017, Stantec partnered with the University of Guelph and a commercial partner, Precision Biomonitoring, to develop a point-of-need, field-based tool to sample and analyze eDNA in the field. The field work to apply these tests is occurring in 2018 in a variety of applied field programs across North America. Through this partnership, eDNA-sensitive assays were designed and validated for more than 20 different species for rapid field verification of the presence of eDNA in aquatic environments. Through this collaboration, test kits and assays were made available and an eDNA procedure was implemented by Stantec in the 2018 field season for accurately testing the presence of eDNA of target species. The point-of-need eDNA tool provides confirmation of the presence of eDNA from target species within two hours, including the water sampling, filtering, and eDNA extraction process.

To filter and extract eDNA from the target water body, Stantec uses the ANDe® sampling backpack pump system (Austen et al. 2018) to sample a fixed volume of water through a filter to collect eDNA from the environment (Photograph 1). In the example shown in Photograph 1, water was pumped from a composite water sample taken from various aquatic microhabitat features present at the individual sampling sites (e.g., depth profiles, pelagic, littoral riffles, runs, and pools). The eDNA collected on the filter was then extracted and processed using a molecular test kit (Figure 2). The extraction process involves four steps: lysis buffer, protein wash, wash buffer, drying wash, and elution buffer (Biomeme, Inc.). After this, tests for the specific target species are conducted by pipetting 20 µL of the extracted eDNA into a tube containing DNA primers and a fluorescent dye-labelled TaqmanTM probe specific for the target species, alongside other reagents necessary to perform a quantitative Polymerase Chain Reaction (qPCR) amplification test. The tests are then placed in a Biomeme Two/3 ® thermocycler to allow target DNA to amplify for 60 to 70 minutes, during which fluorescence from the probe is captured by the instrument's camera, after which the results (amplification curves) are graphically displayed on a screen to show presence (curve positive) or absence (curve negative) of the target DNA (Figure 2).

Photograph 1. Using the ANDe Sampling backpack system to pump a set volume of water through a filter to collect eDNA

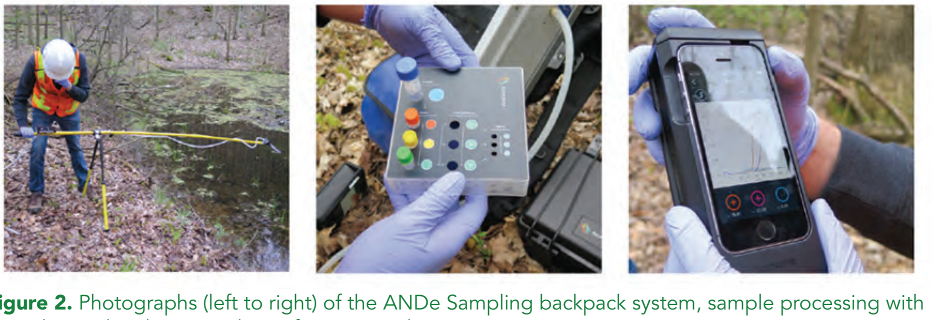

Figure 2. Photographs (left to right) of the ANDe Sampling backpack system, sample processing with a test kit, and real-time analysis of eDNA results

Typically, five replicates of qPCR are run with extracted eDNA from the field at each sample site alongside the DNA species-specific assay. The number of sampling sites and their location are developed in the sampling design process prior to the field sampling. To maximize the probability of detecting the eDNA from a target species in an environment, it is critical that the sampling design take into consideration the ecology and life history of the target species, abiotic factors within the aquatic environment, and the objective of sampling. Once the sampling program has been designed and eDNA samples have been collected, here is some guidance on sample analysis to maximize the likelihood of detecting the DNA of the target species, if it is in the sample collected.

- Analyzing at least five qPCR replicates of each eDNA extract; each replicate sub-samples the extract and replication is required to detect DNA that is at low concentration in the extract. Piggot (2016) has shown that five replicates should result in greater than 95 percent confidence of detection of the target DNA if it is present in the sample.
- Field positive and field negative samples should be included in the sampling design. A positive field control sample should be collected where the target is expected to be present or known to be recently present. Conversely, a negative field control sample should be collected where the target species eDNA is not expected to be present.
- Five qPCR replicates should also be run of samples taken at field negative and field positive sites to guard against the potential for false positives and false negatives, respectively. These field tests quantify, if any, the influence of Types I and II hypothesis errors.
- Internal positive control (IPC) should be included with each test, along with the target species assay—this will determine if there is any inhibition of the priming of DNA during the reaction; if the IPC fails to prime by the end of the thermocycling timeframe, then there may be substances in the water sample that inhibit priming. In this case, the remaining DNA extract may be submitted to a laboratory for additional treatment to remove inhibitors and be tested again.
- No template control (NTC) should be included as a sample test; this should be a sample of distilled or deionized water that is added to a reaction instead of the usual unknown or positive eDNA extract aliquot and is used to test if there is potential for contamination by target DNA during handling of samples. There should be no target DNA primed in this sample.
- Between each sampling site, decontamination procedures must be followed to avoid carry-over of target DNA from one sample to the next. Decontamination includes changing nitrile gloves frequently, wiping down the ANDe pump (Photograph 1), and soaking the pump hoses in 10 percent bleach (with distilled water) and pumping one percent bleach through the pump. Testing efficacy of decontamination could include sampling of rinse water off cleaned equipment and testing for the presence of target DNA; if present, then the decontamination procedure may not be fully effective and there is a potential that site samples may be contaminated with target DNA, resulting in false positives.

Primers have been designed for running in a handheld thermocycler developed by Biomeme® that have high specificity to discriminate between genetically closely-related species and high sensitivity to detect eDNA in very low concentrations, indicative of low population densities.

With a handheld thermocycler, extracted eDNA samples from the field will be processed and amplified during the qPCR and compared to the species-specific DNA primers for three field replicates at a time (Figure 3). The resulting Cq value indicates the PCR cycle at which the fluorescence generated during amplification becomes detectable; therefore, the lower the Cq value, the more target DNA is present in a given field sample. The Biomeme displays the Cq value and plots the curve of the florescence graphically as the qPCR progresses in real-time (Figure 3). The plotting of the red exponential lines in Figure 3 for all three IPC illustrates amplification of that DNA primer and the one green exponential line with a Cq value of 37.99 indicates a positive field sample for that species' eDNA in the water sample.

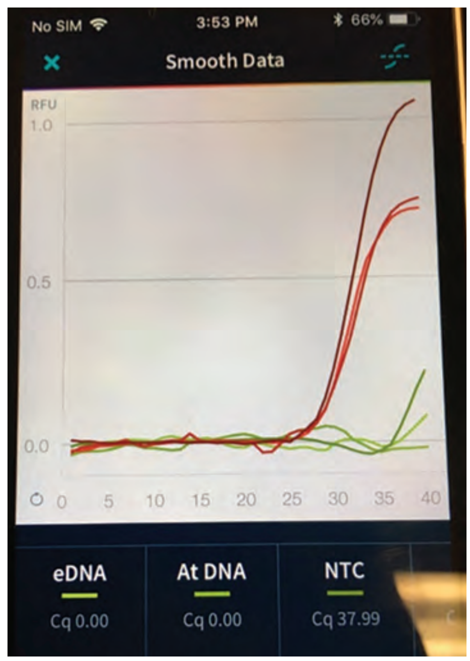

Figure 3. Example of plotting the florescence and amplification of sample eDNA (green), DNA in the primer (red), and Cq values for the DNA in the samples. The Cq value of 37.99 in the 3rd replicate (labeled "NTC") indicates a positive hit for the target DNA being present in the water sample. Conversely, the Cq values of 0.0 in the 1st and 2nd replicates (labeled "eDNA" and "At DNA") indicates that no target eDNA is present in the sample.

Stantec's Field Based Case Studies and Preliminary Results

Stantec has multiple on-going field eDNA projects across North America (Figure 3), implementing the above methodology to detect for the presence/absence of multiple sensitive and/or rare aquatic species, including both fish and amphibians, in habitats ranging from vernal pools to large rivers. eDNA sampling for the select five case studies, presented below by species, will be conducted in summer and fall 2018 and those with preliminary results are summarized below.

Shortnose Sturgeon

The Saint John River, in New Brunswick, Canada, is the most northern extent of the Shortnose Sturgeon's (*Acipenser brevirostrum*) range along the Atlantic seaboard and represents one of 16 large rivers in which they are found. The shortnose sturgeon is listed as endangered under the Endangered Species Act and under Schedule 1 in Canada's Species at Risk Act (SARA), which both provide legal protection for this species. Hydrologic dams have been one of the most significant factors that have adverse effects to this ancient, long-lived species. To better understand their seasonal habitat use of Shortnose Sturgeon relative to the first dam in the Saint John River and traditional aboriginal knowledge, Stantec is sampling eDNA from the St. Johns River with the point-of-need eDNA tool for real-time confirmation of the presence of DNA from shortnose sturgeon. During late summer 2018, water samples will be taken at six to eight study sites across the main stem of the Saint John River with composite samples from various depths. The primer for this species is currently being developed and sampling will include both running real-time results in the Biomeme with lab verification post-field collection.

Bull Trout

Bull trout (*Salvelinus confluentus*) spawn in small groundwater-fed tributaries and are classified as a "blue-listed" species in British Columbia (BC), Canada. Bull trout are a species of special concern due to their sensitivity to human activities and disturbances, including logging. In north-central BC, there is a remote headwater lake that is fed by Philip Creek within the Nation River watershed. Philip Lake is proposed for water withdraws, which could ecologically affect fish species utilizing the lake as lacustrine habitat. Stantec is conducted eDNA sampling in fall 2018, to determine if bull trout were present in Philip Lake either as a resident population or if they migrate into or through Philip Lake in the fall months to spawn. Sampling for eDNA will be a supplemental methodology to conventional summer and fall surveys with gillnets in the lake and fyke nets in Philip Creek. eDNA will be sampled in the fall during the bull trout spawning period with four total composite samples from Philip Lake and the creek. Each composite sample will be comprised of three to five liters of water pumped from various depths in the lake and locations across the stream channel. From each composite sample, there will be three replicates analyzed for the presence of bull trout eDNA using the point-of-need eDNA tool for real-time results. Water from a confirmed bull trout spawning site in an adjacent watershed will be sampled as a positive field control, and an adjacent lake that only supports rainbow trout (*Oncorhynchus mykiss*) will provide a negative field control. Extracted eDNA in the field will be sent back to a laboratory for lab verification of the real-time results from the Biomeme.

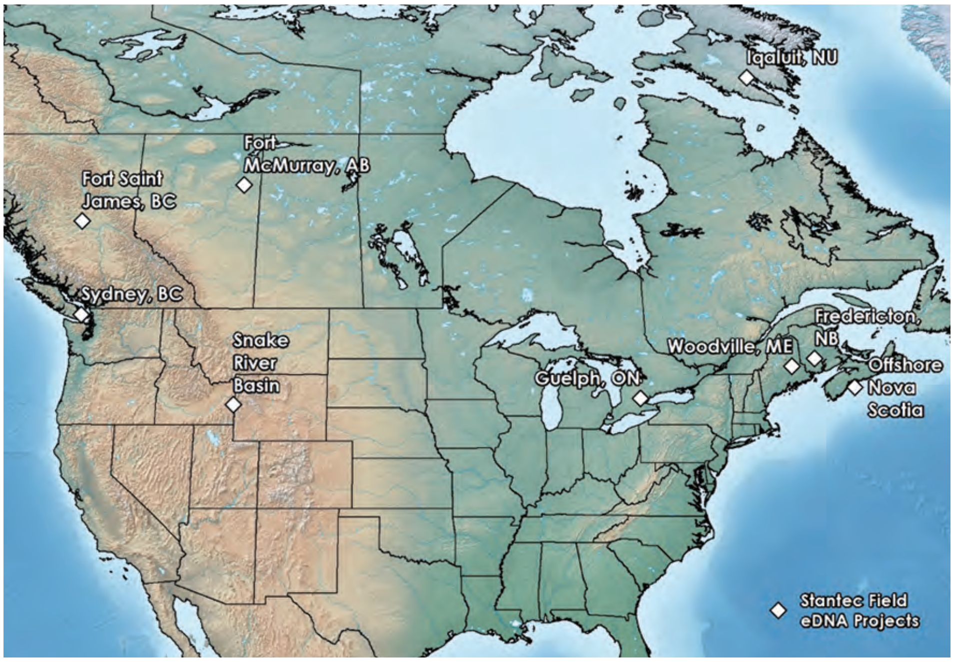

Figure 4. Locations of field-based projects that are utilizing eDNA sampling to test for the presence/absence of aquatic species

Artic Grayling and Burbot

Stantec will be conducting eDNA sampling this fall in a lake created as part of compensation for habitat loss authorized as part of the Fisheries Act, an effort for ongoing mitigation monitoring projects associated with an adjacent mine. The objective of the case study is to determine if certain sensitive species, which can be difficult to catch with conventual sampling techniques, are utilizing the lake. The two study species of this case study include:

- Artic grayling (*Thymallus arcticus*) is provincially designated as a "species of special concern"
- Burbot (*Lota lota*)

There is a river inlet to the lake and this will be sampled in addition to six lake sites that include both littoral and pelagic habitat. At each site, a composite water sample from a vertical depth profile will be collected from each site in one sampling round this fall. Positive and negative field controls will also be sampled and analyzed in the field with the handheld Biomeme. Extracted eDNA in the field will be sent back to a laboratory for lab verification of the real-time results from the Biomeme.

Jefferson Salamander

Jefferson salamander (*Ambystoma jeffersonianum*) is listed as Endangered under the SARA and are distributed across northeastern U.S. and southern Ontario. During the spring, adult Jefferson salamanders breed in vernal pools. The Jefferson salamander is known to co-occur with other species of salamanders in the same genus that are morphologically indistinguishable from one another, making conventional observation methods difficult and less accurate. An assay primer was specifically developed by Precision Biomonitoring to discriminate between Jefferson salamander and closely genetically related co-occurring species.

In spring 2017, 10 vernal pools were sampled for eDNA, including five that had confirmed Jefferson salamanders from previous observational methods, and five control vernal pools without Jefferson salamanders according to historic records. Three water samples were collected from each vernal pool. In the vernal pools with a documented historical presence, there was a 100 percent detection rate (five out of five) for the presence of Jefferson salamander eDNA (Table 1). Furthermore, at one vernal pool that was only thought to have had the other closely related species, eDNA sampling resulted in the detection of Jefferson salamander, while the other five vernal pools had no positive detections (consistent with historical records) (Table 1). These preliminary results highlight the sensitivity and accuracy of these eDNA procedures implemented for Jefferson salamander in vernal pools.

Collection site		Jefferson salamander status	
Authority	Pool	Historical	eDNA
1	A	YES	YES
1	B	NO	NO
1	C	NO	NO
1	D	NO	NO
2	E*	YES	YES
2	F	YES	YES
2	G	NO	NO
2	H	NO	NO
2	I	YES	YES
2	J	NO	YES

Table 1. Results of the Edna Sampling for Jefferson Salamander in 10 Vernal Pools with Historic Records of Presence from Previous Conventional Surveys

Atlantic Salmon

The landowner of a 1,213-hectare (ha) (3,000-acre) property is conducting planning-level aquatic resource surveys at a site located in Northern Maine. The site includes three tributaries of a stream, which flows into the Penobscot River in Chester, Maine—approximately eight miles downstream. The site is located within designated critical habitat for the endangered Gulf of Maine Distinct Population Segment of Atlantic salmon (*Salmo salar*) (Federal Register Vol. 74, p. 29, 344-29, 387) and the Penobscot River has small run of hatchery supported Atlantic Salmon, which are listed as Endangered under the Endangered Species Act.

In summer 2018, Stantec sampled three stream sites, one positive control site, and one negative control site for the presence of Atlantic salmon eDNA. The positive sample site was downstream of a caged single landlock salmon yearling (also *Salmo salar*), placed in a small stream for 17 hours (Photograph 2). At each sampling site, one to two liters of water were filtered at five distinct habitats (i.e., pools) evenly spread out across a 60- to 92-meter reach (Photograph 2). The 7-10 liter composite samples were processed and six replicates of the extracted eDNA were processed in the Biomeme. At the three stream samples in the Project Site, there were no Atlantic salmon eDNA detected in the field; however, the internal positive control of the primer was detected in all six replicates at each sample site, indicating that there were no inhibitors present in the sample water. The positive field sample (i.e., downstream of the caged salmon) had a positive detection for Atlantic salmon eDNA for two out of the six replicates. These preliminary results indicate the importance of multiple replicates and sensitivity of the sampling methodology to successfully detect the eDNA of single fish after only 17 hours in the aquatic environment. A second round of sampling will occur in September 2018.

The extracted DNA will be sent back to the laboratory for both the summer and fall samples for verification.

DISCUSSION

The case studies herein demonstrate how eDNA sampling can be used to meet multiple project objectives in aquatic environments across North America. Stantec is planning or has sampled for the eDNA of seven different rare or sensitive aquatic species, including both fish and amphibians. This paper demonstrates how eDNA sampling procedures can be implemented for a diverse target species list across multiple aquatic habitat types. Preliminary results from two of Stantec's case studies have proven that this method of real-time species-specific detection for presence/absence is accurate, reliable, and saves time/money compared to conventional sampling methods. Lessons learned from preliminary sampling includes the importance of having multiple replicates at each sampling site and a robust sampling design with field negative and positive samples to confirm our eDNA sampling protocols and procedures are working effectively. In both case studies with preliminary results, the field positive sample sites detected the presence of field extracted eDNA with no observations of false positives. In the case of species that have low densities or species that aren't morphologically indistinguishable, the results presented in this paper indicate that using eDNA is more accurate for detecting the presence/absence of target species than conventional sampling methods.

CONCLUSIONS

Using eDNA to detect the presence of species can be a beneficial management tool to answer project questions about a diverse of fish and amphibian species present in multiple types of aquatic environments across North America.

Photograph 2. Using the ANDe pump to filter water from the last habitat downstream of the caged landlock salmon (center of photograph)

Through preliminary testing, this eDNA sampling procedure has proven to be a fast, cost-effective, repeatable, reliable, and sensitive tool for detecting the presence of rare, threatened, and endangered species at low densities with short residence time. The forthcoming results in Fall 2018 will provide further conclusions and observations of eDNA as a tool for environmental managers.

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In-Field Routing a Path to Success: A Case Study of the Atlantic Sunrise Pipeline Project

Jeffrey Mason, Zack Fink, and Greg Netti

Keywords: Alternatives Analysis, Avoidance and Minimization (A&M), Centerline Siting, Cloud-Based Technology, Environmental Systems Research Institute (ESRI), Linear Projects Mobile Collector, Permitting, Regulatory.

Numerous automated methodologies exist to identify the least impactful corridor to locate a new green-field right-of-way (ROW) project. Once a preferred corridor is identified, methodologies that rely primarily on desktop tools and available geospatial data to site a centerline for the linear infrastructure within the corridor are much less effective despite new high-resolution data such as LiDAR and multispectral imagery. As a result, the proposed centerline often needs to be re-aligned in multiple locations to address concerns from landowners, agencies, and other stakeholders, as well as for engineering and constructability issues. Frequent centerline adjustments negatively affect project development by adding time to the required environmental, geologic, cultural field surveys, and to the overall permitting process, thereby increasing project costs and negatively affecting schedules. This paper discusses the in-field siting of a pipeline centerline within approximately 320.3 kilometers (km) (199 miles [mi]) of a greenfield routing corridor in Pennsylvania associated with the Transcontinental Gas Pipeline Company (Transco) Atlantic Sunrise (ASR) Project. Multidisciplinary teams of pipeline engineers, biologists, and ROW agents conducted in-field centerline siting surveys using an iPad connected to an external Bluetooth global positioning system (GPS) that was running a secure, cloud-based, and customized ArcGIS Collector mobile data collection application. The siting teams' efforts increased the overall efficiency of the ASR project development schedule by targeting specific and viable centerline locations earlier in the environmental field data collection task, which facilitated pipeline siting, design, permitting, and construction, which resulted in an effective in-service date for the new ASR pipeline Project.

Environmental Concerns in Rights-of-Way Management
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INTRODUCTION

There are myriad methods and automated algorithms used to determine preferred routing corridors for large-scale linear projects (Seel and Dragan 2016; Husenynli 2015; Yildirim and Yomralioglu 2011; Thomaidis 2000). However, efficient methods for refining routing corridors derived through desktop analytical methods into viable project centerlines are lacking. Moving from a preferred corridor to both a permittable and constructible project centerline is often a costly, lengthy, and inefficient stage in the life of a large-scale linear project. This paper presents comprehensive in-field centerline siting surveys as the missing piece of a successful large-scale linear project routing plan. It illustrates the use and benefits derived from a customized cloud-based mobile data collection technology to support these siting surveys on the Transcontinental Gas Pipeline Company's (Transco) Atlantic Sunrise Project (Project and/or ASR).

The personnel, methods, and technology comprising the ASR centerline siting surveys proved to be extremely beneficial to the development of the Project overall. This paper will provide the context by presenting an overview of the Project and discussing the details of the centerline siting surveys, the data collection technology deployed, and several examples of the data collected during the Project. The paper will also highlight the numerous benefits of conducting the centerline siting effort with a cloud-based mobile data collection platform using multi-disciplinary teams and the effects this approach had on the overall success of the ASR Project design, permitting, and construction.

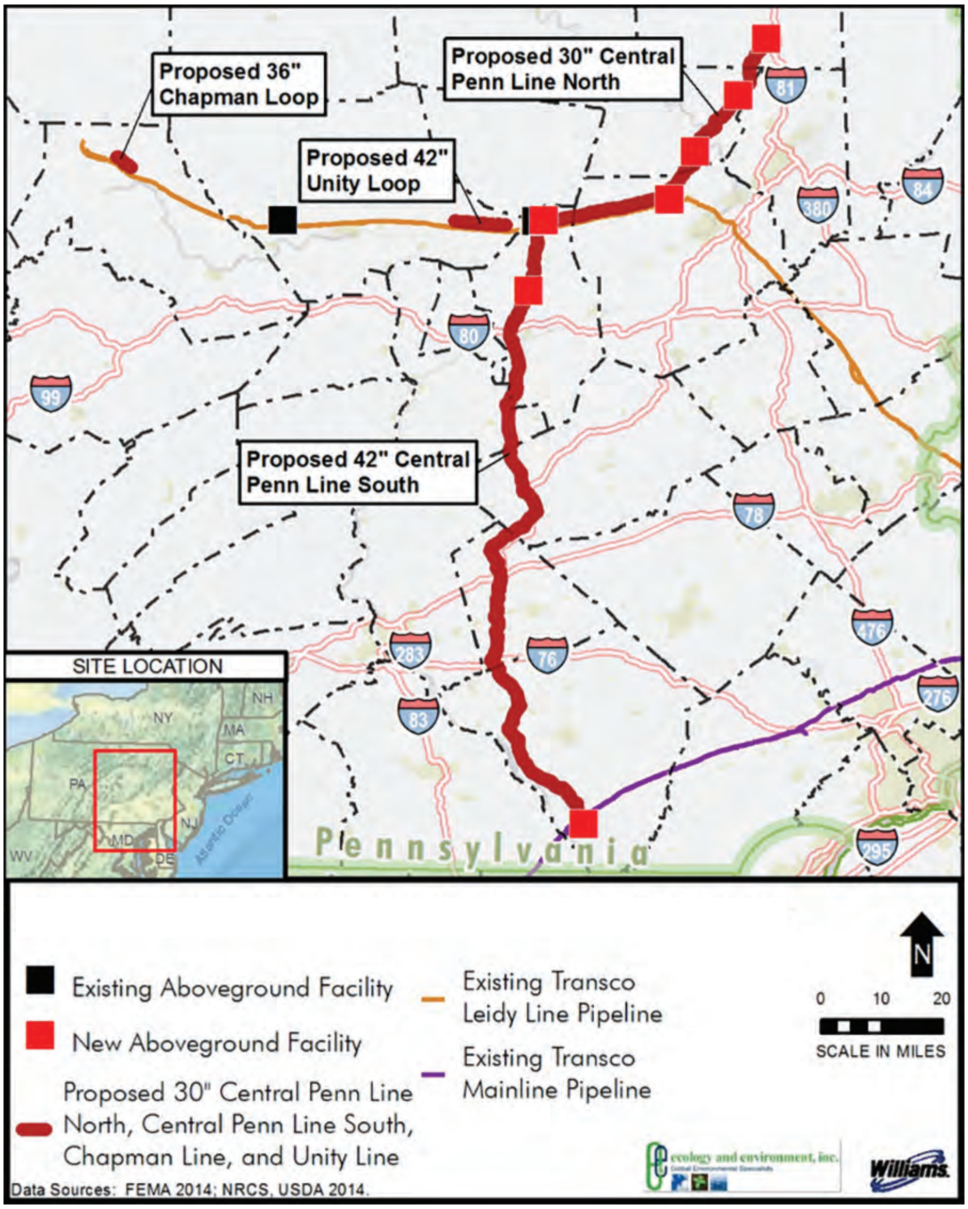

Figure 1. Atlantic Sunrise Project Location Map

PROJECT BACKGROUND & OVERVIEW

ASR is currently in construction by Transco, a subsidiary of Williams Partners L.P. (Williams), to expand their existing natural gas transmission pipeline system in Pennsylvania, Maryland, Virginia, North Carolina, and South Carolina. The Project includes about 320.3 kilometers (km) (199 miles [mi]) of pipeline, of which approximately 317 km (197 mi) are located in Pennsylvania, as well as a variety of aboveground facilities, temporary and permanent contractor yards, staging areas, and access roads (Figure 1). The Project will enable Transco to provide 1.7 million dekatherms per day (MMDth/d) of incremental firm transportation of natural gas from the Marcellus Shale production areas in northern Pennsylvania to Transco's existing market areas in the East, Southeast, and Gulf Coast regions of the U.S.

Transco filed an application for a Certificate of Public Convenience and Necessity (Certificate) with the Federal Energy Regulatory Commission (FERC) on March 31, 2015. On February 3, 2017, the FERC issued an Order granting the Certificate for ASR, concluding that the Project is environmentally acceptable and in the public's interest. Transco also applied for various other federal and state permits during the FERC certification process. All required federal and state approvals for the Project were issued and Transco began construction of the pipeline Project in 2017. Transco is currently on track to complete the 320.3 km (199 mi) of pipeline construction and to place all ASR Project facilities in service in the fall of 2018.

Comprehensive In-Field Centerline Surveys

The goal of the Project's in-field centerline siting surveys was to efficiently identify a viable pipeline centerline within a 182.9-meter (m) (600-foot [ft]) wide preferred corridor that had been generated via a geographic information system (GIS)-based desktop routing method. With almost the entire proposed ASR route as "green-field" and located in dominantly agricultural and forested land use conditions in eastern Pennsylvania, Transco identified the Project as an excellent opportunity to employ the in-field centerline siting approach. Additionally, the ASR pipeline is situated in an area of Pennsylvania that is a virtual checkerboard of land parcels, which traverses the Amish and Mennonite agricultural communities typical of eastern and central Pennsylvania. This region is currently seeing a large uptick in pipeline and energy infrastructure projects due to the Marcellus shale play, which has led to a significant increase in public awareness and opposition to industrial energy development within the region. As such, Transco was acutely aware of the need to identify a permittable and constructible pipeline alignment that would withstand public scrutiny and potential legal opposition as early as possible in the ASR Project lifecycle.

The comprehensive centerline siting surveys were identified by Transco as a means to collect multi-disciplinary, high-resolution, boots-on-the-ground centerline siting data and were conducted on as much of the preferred routing corridor as possible (approximately 83 percent of the 320.3 km [199 mi] at the start of the Project). These centerline surveys were specifically conducted prior to the more comprehensive environmental field surveys (i.e., engineering, environmental, cultural, and geologic).

The purpose of these surveys was to streamline the overall siting, design, and permitting of the ASR pipeline Project. To achieve these goals, the centerline-siting surveys were designed to accomplish the following objectives:

i) Provide multi-disciplinary expertise and field-based input as early as possible in the siting and design of the centerline of the proposed pipeline.

ii) Quickly generate a cloud-based geo-spatial dataset sufficient to facilitate Project centerline siting decisions, data sharing, and communication among the Project's team members and various disciplines.

iii) Document centerline siting decisions for later use in avoidance and minimization documentation and the Project's alternatives analyses during permitting.

iv) Occur ahead of more comprehensive field surveys to better plan and prevent surveys from being conducted along non-viable sections of the 182.9-m (600-ft) routing corridor.

v) Reduce the amount of centerline re-alignments/deviations required within the preferred routing corridor during the design, permitting, and construction phases of the Project.

Centerline Siting Methods and Data Collection Technology

Multi-Disciplinary Siting Teams

The makeup of each centerline siting team (four teams total) was critical to accomplishing Project objectives. Accordingly, siting survey teams consisted of several experienced individuals from different subject matter disciplines. Each siting team was led by a pipeline engineer with the authority and responsibility to locate a constructible centerline within the 182.9-m (600-ft) routing corridor. These individuals were supported by biologists, archaeologists, and ROW land agents responsible for advising the pipeline engineers as well as documenting and justifying any changes in the proposed centerline. The interdisciplinary makeup of these siting teams allowed the engineers to make informed design decisions in real-time by relying on the other team members to provide expert advice and observations relevant to their specific subject matter disciplines. In addition, the biologists, ROW agents, and archaeologists on the siting teams all worked for companies responsible for various other surveys and reports specific to their disciplines on the Project. Involving these individuals in the siting of the Project centerline greatly increased communication concerning where the pipeline would be located and allowed the more comprehensive environmental field surveys to be better targeted and conducted only along the viable sections of the routing corridor—and in a more timely and efficient manner.

Routing Criteria Hierarchy and Approach

The centerline siting teams evaluated the existing Project centerline in all "green-field" areas of the Project as well as within narrower survey corridors in areas of centerline collocation with existing pipeline infrastructure. The teams conducted the siting assessments on foot for the accessible portions (approximately 83 percent at the Project at start) of the preferred corridor as well as in portions of alternative corridors that were under route consideration. The siting teams adjusted the location of the centerline as necessary to avoid significant engineering, environmental, cultural, and land use issues. When determining if the existing centerline needed to be realigned, the following centerline siting criteria were considered and discussed by the multi-disciplinary siting team:

- Engineering Siting Criteria
    - o Centerline collocation
    - o Slope, side slope, stability issues, construction considerations
    - o Roads/utilities/stream crossings
    - o Horizontal directional drill requirements
    - o Coal mining caverns/potential karst locations

- Environmental Siting Criteria
    - o Wetlands (greater than one acre)
    - o Waterbodies and stream crossings
    - o Groundwater seeps and springs
    - o Water reservoirs/livestock impoundments
    - o Public/private groundwater well locations
    - o Threatened or endangered species' presence and/or habitats
    - o Upland forests and forest patch preservation
    - o Game reserves, conservation easements, farmland preserves, and organic farming locations
    - o Coal mining caverns/potential karst locations
    - o Active vineyard/orchard/livestock operations

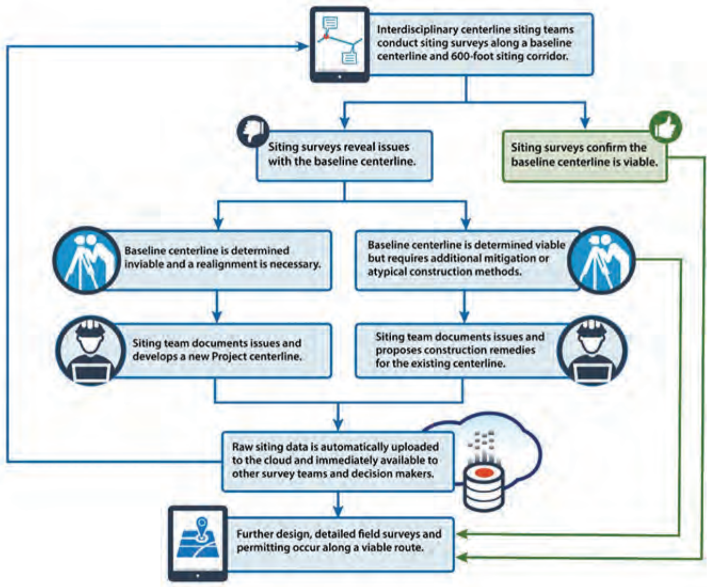

Figure 2. Centerline Siting & Data Collection Workflow

Figure 3. IPad/IPhone & External GPS Receiver with Custom ARCGIS Mobile Data Collector Application

- Land Ownership, ROW, and Land Agent Criteria
  - o Ownership/deed restrictions
  - o Amish and Mennonite cultural values
  - o Specific landowner/stake-holder input
  - o Ongoing or active landowner negotiations with Transco
  - o Locations of landowners not supportive of the Project

Centerline siting rationales were generated by the siting team for each centerline realignment/deviation and recorded both manually in field notebooks and by using the cloud-based, geospatial data collection technology and workflow developed and deployed specifically for the ASR Project (Figure 2).

Cloud-Based Geospatial Data Collection Technology

Mobile and cloud-based data collection technology was another key to the success of the centerline siting surveys. Each siting team was equipped with a ruggedized iPad Pro with 64 gigabytes of memory with Wi-Fi and cellular connection capability that allowed the teams to run a cloud-based and Project-customized Environmental Systems Research Institute (ESRI) ArcGIS Collector mobile data collection application (Collector App). The team iPads were all connected via Bluetooth to an external iSXBlue or BadElf external GPS unit that gave them approximately two-m accurate mobile data collection capabilities, geo-spatially tagged field photographs, and allowed for display all Project geospatial data collected by the four siting teams on high-resolution Project imagery in real time (Figure 3).

With both a Wi-Fi and cellular connectivity capability on the iPads, centerline siting teams were able to collect data in the field in more rural areas of the Project regardless of cellular connectivity status. The Collector App can operate in a "connected" mode with imagery and geospatial data pulling directly from the cloud to the iPad via the local cellular connection, or in a "dis-connected" mode with selected imagery and datasets for the area of centerline siting that day cached onto the tablets using the Apple iTunes application. This allowed the four siting teams to collect data and document the centerline siting process regardless of the status of cellular connectivity at any point along the 320.3 km (199 mi) of routing corridor. All data collected in a disconnected mode were automatically synced back up to the secure Project cloud the moment the iPad was back in cellular service range ensuring data sharing, back-up, and security protocols.

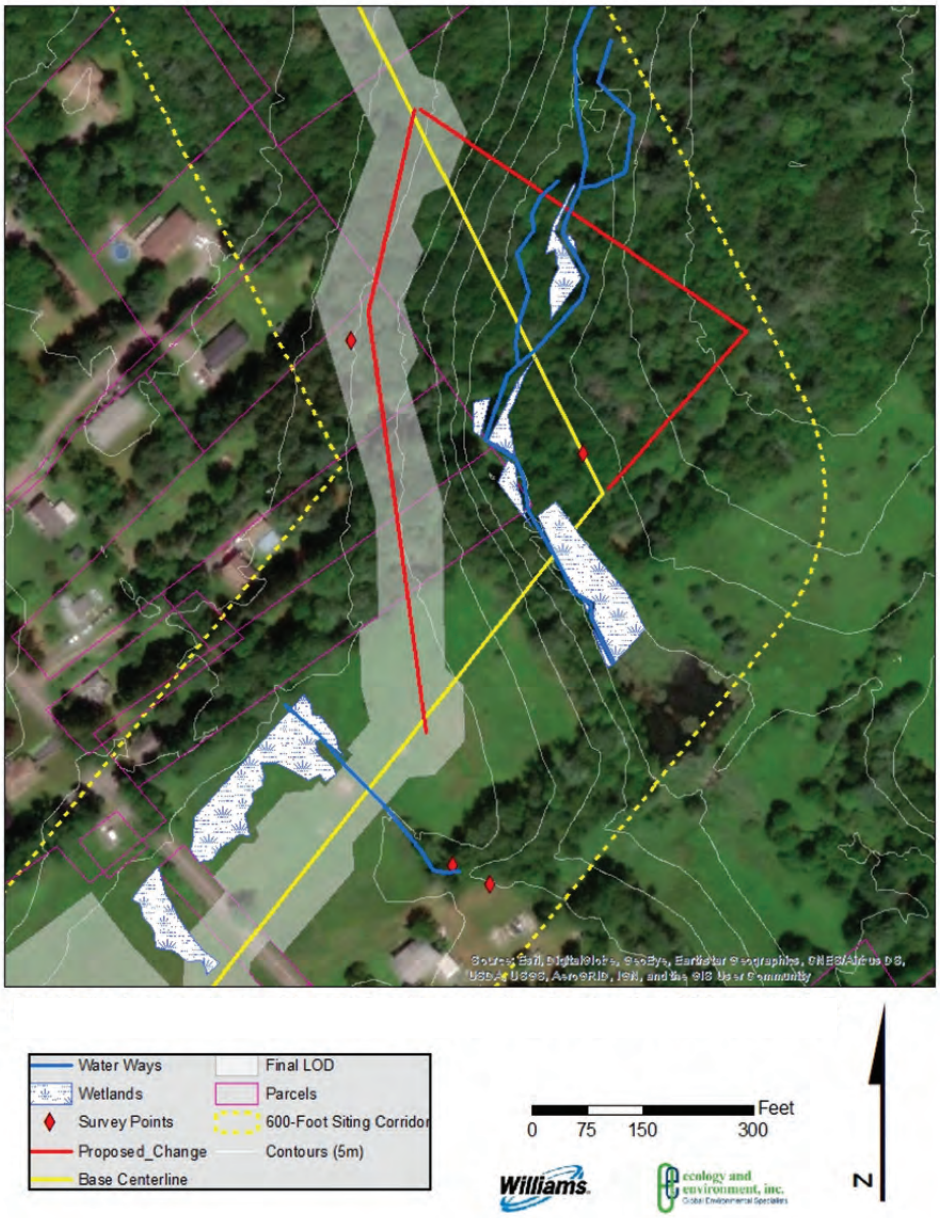

Figure 4. Raw Centerline Siting Data (ASR Milepost 21.8)

In addition to the high-resolution, cloud-served imagery, the teams loaded local elevation data and contours, Pennsylvania county land parcels, National Wetland Inventory (NWI) data, the National Hydrography Dataset (NHD), and National Historic Preservation (NHP) Threatened and Endangered (T&E) databases, as well as other Project-specific base layers and engineering data onto the iPads, allowing for a simultaneous and detailed overview of the larger Project design and centerline feasibility. The Collector App also supported additional geospatial data collection capabilities, allowing teams to digitize points, lines, and polygons, collect survey points with geospatially tagged photographs specific for each newly collected feature of interest, as well as document and justify new centerlines when site-specific problems with the original centerline were encountered in the field (Figure 4). As the entire mobile data collection system is cloud based, potential changes in the centerline made by any one siting team were instantaneously depicted across the Project's preferred routing corridor and viewable in real time by the other siting teams on their iPads. In addition, cloud-based and cellular-connected data collection allowed for the Project team members not in the field to be able to see the four teams' siting progress along the preferred pipeline corridor and to view the geospatial data, tagged photos, and ancillary centerline siting data they had collected.

Mobile Data Collection, Documentation, and Discussion

Navigation/Property Access & No Trespassing/Stakeholder Input

The iPad and mobile Collector App technology provided the centerline siting teams with the ability to either stream high-resolution imagery and data from the cloud or pre-load Project imagery and data onto the iPads for the area of interest they were going to survey that day. Since the iPads were connected to high-accuracy external GPS units, the siting teams were able to precisely view their locations in real time. This proved particularly useful to the teams when navigating roads in rural areas with difficult access to sections of the routing corridor and poor cellular connectivity. The Collector App also allowed the teams to tag locations for parking, property access, or no-access areas/parcels where trespassing along the routing corridor was an issue. These types of field logistical data were then immediately available to the other centerline siting teams through the cloud and were also recorded in the Collector App for later use by the subsequent comprehensive environmental survey teams that followed the centerline siting teams weeks and months later.

This technology proved to be an invaluable asset to ASR overall as property access and trespass potential were a very large issue to manage during all the field survey efforts that were conducted for the Project. The Project included thousands of landowners along the pipeline corridor, all with varying degrees of property access and survey stipulations. Many of these could change on an hourly, daily, or weekly basis. The ability for all the Project's field teams to better navigate the routing corridor in real time with an iPad and a high-resolution image in the background—while accessing cloud-based data regarding property boundaries, accessibility, and potential trespass issues—helped to prevent instances where teams were on parcels they were unauthorized to survey or to collect data. The importance of this to the ASR Project overall cannot be understated given the relatively contentious nature of the Project for the potentially affected stakeholders in the eastern Pennsylvania region.

As important as the iPads were to the coordination of the field survey efforts and preventing trespassing and unauthorized surveys by the field teams, they were equally valuable for the teams to engage, discuss, and document centerline siting alternatives in a particular parcel with a particular stakeholder. The ability to view the Project in high-resolution imagery and proposed centerline location on the iPad enabled the teams to better explain the rationale(s) for the currently proposed location, or conversely to better receive and incorporate input and site-specific requests from the landowners regarding the preferred or alternative centerline alignments through their property. As many of the parcels in the Project area were large and agricultural, with a variety of land use conditions contained within them, the routers would oftentimes engage with the landowners to re-align the centerline from the middle of their farm fields to the edges and away from residences, buildings, and intact forest patches to the extent practicable. These requests would then be balanced by the siting team to avoid any natural resources and/or engineering and constructability issues and the group would define a new centerline alignment directly within the Collector App using points, lines, polygons, and photographs to depict and document the new centerline alignment (Figure 4). The ability to incorporate this type of site-specific data and information into the siting and design phase of the Project at that earliest point possible proved invaluable to the overall success of the Project from a public outreach and stakeholder input perspective.

Feature Identification, Data Querying, and Cloud Capabilities

Centerline siting teams utilized the Collector App to access publicly available imagery, data, and Project-specific data to assess the proposed location of the centerline along the corridor. For example, the connectivity of stream, wetland, and waterbody features for jurisdictional status were easily determined using the Collector App. The teams relied upon publicly available data such as the NHD data, NWI data, NHP T&E species and habitat data, and Pennsylvania Department of Environmental Protection (PADEP) resource value designations of all mapped state streams, wetlands, and waterbodies. In addition, the teams also accessed other types of centerline siting relevant data, such as local conservation easement and land deed restriction data, roads and transportation line work, utility and civil infrastructure locations, known public and private water supply wells, and mapped cultural resources (Figure 5).

These geospatial datasets provided the centerline siting teams with the ability to assess the centerline location both at a site-specific land parcel scales up to the routing corridor scale to assess the impact on centerline re-alignments up and down the corridor. As depicted in Figure 5, at times, centerline siting teams would need to develop a new alternative centerline alignment altogether (termed a "deviation") outside of the 182.9-m (600-ft) routing corridor to try and balance the centerline siting criteria and develop a permittable and constructible pipeline route. While centerline siting teams had the authority to make alignment changes within the routing corridor, they required additional input from the engineers and Project team if deviations were proposed and sited outside of the proposed corridor. The Collector App proved invaluable in capturing, documenting, and communicating these types of changes and geospatial data to the entire Project team in an efficient and organized manner.

Another important feature of the cloud-connected iPads and Collector App was the capability to "push" data over the cloud to the centerline siting team's iPads in real time. With such a large and complex pipeline Project in development, last minute and "on the fly" siting and design changes to the proposed centerline were not uncommon during the centerline siting effort. The Collector App allowed the Project's GIS and engineeering teams to push these data out to the centerline siting teams via the cloud while they were either travelling to the fieldsite or during actual data collection efforts. This cloud-based connectivity provided the teams with the most up-to-date and current survey areas in real time, making the centerline surveys as efficient and productive as possible—given the dynamic nature of the Project's siting and design.

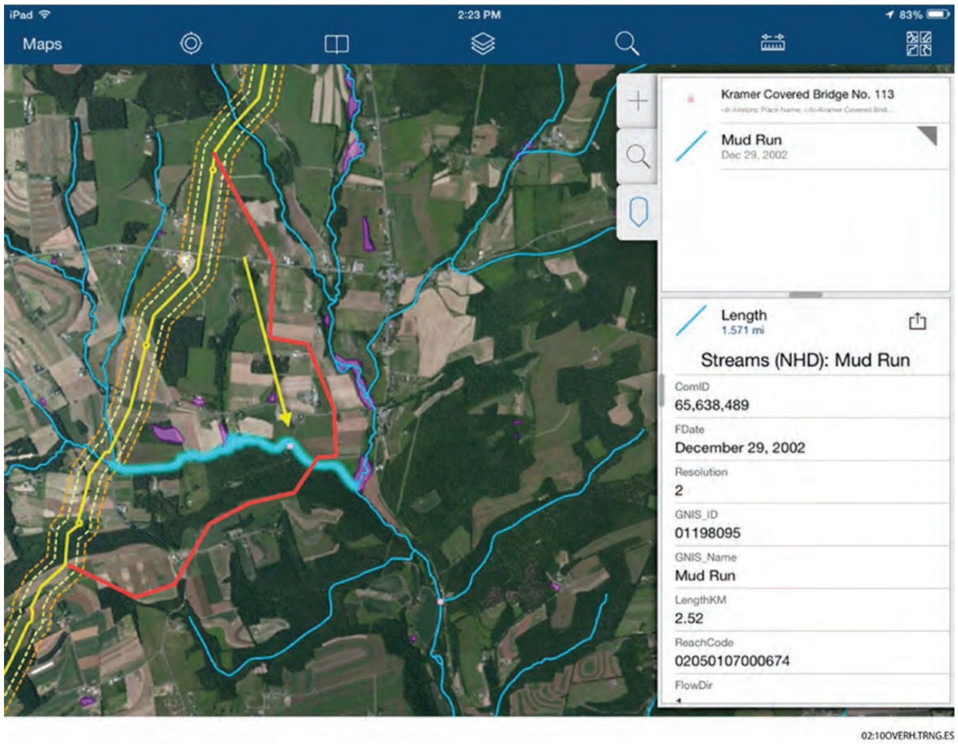

Figure 5. Collector App Centerline Siting Data Proposed Alternative

Finally, a critical functionality of the Collector App was the ability to distribute Project data instantaneously among the Project team members to better communicate regarding siting and design issues. The Collector App allows for access of the Project data in real-time from the confines of the office and can be opened from a Windows desktop computer (or an iPad) by anyone given access to the Project. This cloud-based functionality made it especially easy to share data and information during project conference calls and Webex sessions between the Project team members. Depending on Project responsibilities, different levels of access and functionality can be assigned to different end-users to maintain database integrity and security as required. ASR Project GIS teams leveraged their ESRI ArcGIS enterprise platforms to interface with the Collector App and provide application development and customization capacity, data and workflow management, and quality assurance/quality control procedures.

Example of Collector App Centerline Siting Data and Rationales At MP 21.8

An example from the preferred routing corridor at milepost MP 21.8 helps to illustrate the type of data gathered during centerline siting effort and how it influenced the final alignment of the pipeline. Figure 4 depicts a section of the ASR routing corridor in Luzerne County, Pennsylvania and shows the originally proposed pipeline centerline (solid yellow) within the 182.9-m wide (600 ft) routing corridor (dashed yellow), the two newly sited centerline realignment options (red) collected in May of 2014 by the siting team, the final pipeline limit of disturbance (LOD) (grey) finalized prior to construction, and wetland and stream data (blue lines and hatched polygons).

The centerline siting team working this section of the corridor and the landowner identified several problems

Resource Type (Stream or Wetland)	Resource Name	Resource ID	MP	Chapter 93 Classification, Wetland Classification	Stream Type (Perennial, Intermittent, Ephemeral)	Stream Trout Status (Class A Wild Trout, Wild Trout, Trout Stocked)	Cowardin Classification	Limits of Disturbance (LOD) Adjustments	Field Routing Adjustments within 600-foot Wide Corridor*
Stream	UNT to Fishing Creek	WW-T10-001A	0.24	HQ-CWF, MF	Perennial	None	R3	The LOD was modified to eliminate impacts to WW-T10-001A.	This feature is no longer impacted based on LOD reductions.
Stream	UNT to Fishing Creek (WW-T10-001)	WW-T10-001	0.25	HQ-CWF, MF	Perennial	Wild Trout Waters	R3	LOD has been reduced to 27.4 m (90 feet) to minimize impacts on WW-T10-001.	The pipeline was routed in this location to avoid stream WW-T10-001A (with LOD reduction) and wetland W-T10-001, cross stream WW-T10-001 at a perpendicular angle, and minimize clearing of the riparian forest buffer of the stream.
Wetland	W-T31-001B	W-T31-001B	M-0147 0.57	EV	N/A	N/A	PSS	The LOD was modified to eliminate impacts to W-T31-001B.	This feature is no longer impacted based on LOD reductions.
Stream	Muddy Run (WW-T10-003)	WW-T10-003	M-0147 0.59	TSF, MF	Perennial	Approved Trout Waters	R3	LOD has been reduced to 22.9 m (75 feet) to minimize impacts on WW-T10-003.	This wetland and stream system (WW-T10-003, WW-T10-003A, W-T10-003C) is associated with a documented bog turtle population. The crossing of this system was field routed to occur in an area previously disturbed by existing powerline ROWs, thereby reducing habitat fragmentation and construction in previously un-impacted areas. The proposed route also avoids bog turtle core habitat patches, including an occupied habitat patch northeast of the route. Based on approximately two years of radio telemetry tracking within this habitat patch, bog turtles have not moved to within 173.3 m (570 feet [ft]) of the LOD. Finally, several nearby tributaries and wetland areas are also avoided by utilizing this crossing area. These include: streams WW-T30-001, WW-T30-001A and wetlands W-T31-001A and W-T31-001B. Complete avoidance of this wetland system was not possible because it extends a significant distance along Muddy Run.
Stream	UNT to Muddy Run (WW-T10-003A)	WW-T10-003A	M-0147 0.59	TSF, MF	Ephemeral	Approved Trout Waters	R6	LOD has been reduced to 22.9 m (75 feet) to minimize impacts on WW-T10-003A.	Refer to the notes for WW-T10-003 for a discussion of routing considerations at this location.
Wetland	N/A	W-T10-003C	M-0147 0.60	EV	N/A	N/A	PFO	LOD has been reduced to 22.9 m (75 feet) to minimize impacts on W-T10-003C.	Refer to the notes for WW-T10-003 for a discussion of routing considerations at this location.
Stream	Tucquan Creek (WW-T10-004)	WW-T10-004	M-0184 0.85	HQ-CWF, MF	Perennial	Wild Trout Waters	R3	LOD has been reduced to 22.9 m (75 feet) to minimize impacts on WW-T10-004.	The pipeline was routed in this location to provide a perpendicular crossing of stream WW-T10-004, and to avoid a bridged/culverted area of the stream.
Wetland	N/A	W-T62-001A/ W-T62-001C	M-0354 0.00	EV	N/A	N/A	PEM, PFO	LOD has been reduced to 22.9 m (75 feet) to minimize impacts on W-T62-001.	The pipeline was routed in this location to provide a perpendicular crossing of wetland W-T62-001. In addition, a PI was shifted farther north during field routing to execute a turn outside of the system.
Stream	UNT to Trout Run (WW-T62-001)	WW-T62-001	5.34	HQ-CWF, MF	Intermittent	Class A Wild Trout	N/A	LOD has been reduced to 22.9 m (75 feet) to minimize impacts on WW-T62-001.	The pipeline was routed in this location to provide a perpendicular crossing of stream WW-T62-001. In addition, a PI was shifted farther north during field routing in order to execute a turn outside of the system.

Table 1. Example of Avoidance & Minimization Documentation Generated by The Centerline Siting Surveys

with the original centerline and determined a new alignment was necessary due to:

- *Engineering Issues*. The point of inflection (PI) is located in a steep gulley with a steep longitudinal slope, side slopes, potential instability issues, and considerable elevation change in a short distance.
- *Land Issue*: Landowner plans to build a dam and pond near the PI.
- *Environmental Issues*: Wetland and stream crossings present. Multiple crossings of the same stream, each at an oblique crossing angle, is contrary to FERC and PADEP stream crossing guidance.

After surveying the general area, the centerline siting team identified and surveyed two potential centerline options in the area, ultimately submitting the western-most alternative (in red), which became the final centerline and LOD in this section of the corridor (Figure 4). The realignment resolved all issues identified with the original centerline and included the following avoidance and minimization measures and Project benefits:

- Engineering—Reduced the centerline distance by approximately 30.48 m (100 ft). Reduced the elevation change by approximately 45.72 m (150 ft). The new centerline was sited on more level ground.
- Land—The future pond and dam site are avoided altogether as requested by the Stakeholder.
- Environmental—All direct wetland impacts and stream crossings are avoided. Upland tree clearing was moved closer to the forest patch margin, thus better preserving the interior and size of the remaining forest patch per the USFWS/PADEP guidance.

Although all the identified issues with the original centerline alignment were avoided, the new centerline location in this area was not perfect. There are still considerable drawbacks with regard to landowners along the new route as the new alignment crosses four additional properties/parcels and moves the pipeline considerably closer to residential parcels, which contradicts one of the engineering centerline siting criteria. In this example, which was very common, there was no "ideal" route through the area being surveyed. However, by performing these comprehensive centerline siting surveys, the "best" possible alignment (represented as a balance between the engineering, environmental, cultural, and land criteria through the area) were quickly identified, documented, and integrated into the project siting and design process.

Centerline Siting Data and Agency Avoidance and Minimization Documentation

In addition to generally improving the efficiency of the design and permitting process, the centerline siting data were also utilized to address specific agency and permit requirements for ASR. A good example is how the centerline siting data were used to complete portions of the PADEP Chapter 105 Joint Permit Application required for impacts to Waters of the Commonwealth. One of the requirements of the application is the submission of a detailed mitigation plan, which includes a list of specific avoidance and minimization (A&M) measures related to each jurisdictional stream, wetland, and waterbody crossing in the Project area. By conducting centerline-siting surveys with the interdisciplinary siting teams, all the A&M information and data necessary to complete this permitting task were recorded in the Collector App by the siting teams and geospatially organized along the 320.3-km (199 miles) of the routing corridor with supporting photographs. All that was necessary was to extract the relevant avoidance and minimization information from the Collector App and enter it into formatted tables as shown in Table 1. As the ASR Project crosses over 500 waters of the Commonwealth of Pennsylvania, what could have been a truly daunting data organizational task was made manageable as the required information was already collected and organized in the Collector App as a result of the centerline siting survey efforts.

CONCLUSIONS

The ASR centerline siting surveys were conducted early in the ASR siting and design phase of the Project prior to the comprehensive environmental, cultural, and geologic surveys that were conducted. The objective was to reduce the amount of centerline realignments and/or deviations required during permitting and construction. Using iPads and the cloud-based Collector App, the multi-disciplinary siting teams provided comprehensive input regarding the engineering, environmental, cultural, and land/ROW siting criteria along the centerline route and documented their proposed alternatives, rationales, and A&M measures implemented for each area of the corridor surveyed. By front-running the more comprehensive field surveys, the siting teams were able to identify whole areas of the routing corridor that were not viable and were better able to target and eliminate large portions of the corridor that were unviable to construct, thereby reducing the Project's overall field survey requirements. These siting surveys also identified potential T&E species and habitat along the corridor earlier in the Project lifecycle, which proved very useful for managing field survey windows specific to the T&E species as well as to better plan and coordinate for potential clearing windows imposed by the resource agencies during the construction phase of the Project.

The iPads and cloud-based Collector App technology deployed for the ASR Project were essential to the overall success of the siting, design, permitting, and construction of the ASR pipeline Project. The mobile technology provided instant access to Project data and centerline siting information between all the survey teams and the Project team members not in the field. The ability to use the iPads to navigate the 320.3 km (199 miles) of pipeline corridor more efficiently and to better avoid areas where no access or trespassing were permitted was critical to maintaining positive public and stakeholder relations during the field surveys for the Project. The iPads and Collector App also proved an excellent mechanism for communicating the proposed Project route to the landowners/stakeholders affected by the Project while the siting teams were in the field and more importantly for receiving and documenting their specific input and requests regarding proposed alternative centerline alignments and/or corridor deviations across their property. Finally, the centerline siting data, alternative rationales, and A&M measures generated during the centerline surveys were all readily available in tabular format and organized geospatially for easy export and incorporation into Project documentation and permitting.

The overall contribution of the centerline siting surveys and iPad Collector technology to the success of ASR is illustrated by the very impressive permitting and construction schedule that has been maintained by the Project to date. Permitting for the Project was all completed within just three years, with far fewer regulatory agency requests for information, modifications, and/or variances than is typical for a pipeline project of this large a scale. The construction of the 320.3 km (199 miles) of pipeline only required approximately 14 months to complete with no major engineering, environmental, cultural, or land issues encountered during the construction phases. The early deployment of the centerline siting teams and the iPad Collector technology in the ASR Project lifecycle was critical to the overall success of the ASR Project.

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Pollinator Opportunities Within ROWs: Creating a Spatial Model to Inform Conservation in ROWs

Dan Salas and
Johanna Sievewright

Keywords: Environmental Planning, Pollinator Conservation, Rights-of-Way (ROW), Spatial Modeling.

Many pollinators are in serious decline in the U.S. and worldwide (IPBES 2016). As pollinator populations decline and it becomes more acknowledged as a conservation concern, public and private entities are equally considering their role in pollinator conservation. The American Transmission Company (ATC) has initiated its own pollinator protection program to address these concerns along the approximately 16,093 kilometer (km) (10,000 miles [mi]) of rights-of-way (ROW) they operate. As part of this program, ATC worked with Cardno to define priorities for landscape conservation across ATC's transmission footprint. In doing so, ATC is adding to the conservation science of pollinator conservation by developing a better understanding through models and field studies of how landscape structure influences pollinators. This need for modelling and continued studies is identified as a critical need for ecosystem service management (Kremen et al., 2007, cited by Lonsdorf et al., 2009). To help ATC achieve their goals, Cardno developed the Pollinator Opportunities Within Rights-of-Way (POWR) model to help identify priority areas for pollinator conservation and provide a tool to inform future conservation decisions related to pollinators.

Objectives when reading this paper include:

- Learn about planning and implementation considerations for pollinators along ROWs
- Understand how spatial and decision analysis can make pollinator management decisions easier
- Increase pollinator conservation on ROWs by providing an example for other environmental managers

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Bees and other insect pollinators help sustain the natural environment and agricultural systems that support modern society. Globally, nearly 87 percent of flowering plants rely on insect or animal pollination (Ollerton 2011). More than one-third of the world's crops—including numerous fruits and vegetables—depend on bee pollination. In North America, pollination is valued as contributing as much as $15–20 billion a year to the economy (White House 2016; Spivak et al. 2011 citing Gallai et al. 2009; Klein et al. 2007; Morse and Calderone 2000). In Wisconsin, pollinators contribute to more than $55 million in annual crop production (DATCP 2016).

Many pollinators are in serious decline in the U.S. and worldwide (IPBES, 2016). Using a combination of spatial habitat modeling, national land-cover data, and carefully quantified expert knowledge, Koh et al. (2016) estimated that, between 2008 and 2013, modeled bee abundance declined across 23 percent of U.S. land area. This decline was generally associated with conversion of natural habitats to ROW crops (Koh et al. 2016). The Xerces Society for Invertebrate Conservation maintains a status of insect pollinators in North America, including butterflies and bees (Xerces Society 2016). The resulting Red List of Pollinator Insects of North America includes dozens of species that are facing significant threats and population declines not currently listed under the U.S. Endangered Species Act (ESA 2008). This Red List includes three species native to Wisconsin, including the rusty patch bumblebee (*Bombus affinis*), yellow-banded bumblebee (*B. terricola*), and the cuckoo bee (*Epeoloides pilosula*).

To counter these declines, many conservation organizations and government agencies are turning their attention to pollinator conservation. The U.S. Fish and Wildlife Service (USFWS) has applied endangered status to seven species of bees (Federal Register 2016a). While these listed species were native to Hawaii, the Midwest U.S. has recently had its own listing: the rusty patched bumblebee (Federal Register 2016b). At the same time, the White House has called for restoration or enhancement of seven million acres of land for pollinators within the next five years.

Accomplishing these conservation goals will require an "all hands on deck" approach that harnesses the expertise and capabilities of the Federal, State, Tribal, and local governments, in collaboration with the private, academic, and non-profit sectors, as well as the general public (White House 2016; Thogmartin et al. 2017).

As pollinator populations decline, becoming a global conservation concern, public and private entities are equally considering their role in pollinator conservation. ATC initiated its own pollinator protection program to address these concerns along the ROWs they operate across Wisconsin and Michigan's Upper Peninsula in the Upper Midwest of the U.S.

As they developed this program, ATC enlisted support from the authors to help achieve their goals and help define priorities for landscape conservation across ATC's transmission ROWs footprint. As part of their pollinator program, ATC defined several goals to guide their conservation contributions:

1) Enhance pollinator habitat within ATC-managed ROWS and facilities
2) Work in partnership with Federal, State, Tribal, non-governmental organizations (NGOs), and private entities to raise public awareness
3) Demonstrate ATC's conservation commitment through third-party certifications and outreach.

This need for modelling and continued landscape conservation study is identified as a critical need for pollinators and ecosystem service management (Kremen et al. 2007, cited by Lonsdorf et al. 2009). To help ATC achieve these objectives, we (the authors) developed a geospatial model to help identify priority areas for conservation and provide a tool to inform future conservation decisions related to pollinators. Because of the focus of this modeling effort being on pollinators in electric transmission ROWs, we named the resulting decision process and analytical tool the Pollinator Opportunities Within ROWs (POWR) Model.

METHODS

Development of Conceptual Model

Defining Modeling Goals and Constraints

Development of the POWR model began with consideration of ATC's objective for the effort. As noted in Section 1, ATC's pollinator program has objectives for promoting pollinator conservation efforts within ROW, working in partnership with public and private entities to raise public awareness, and demonstrating ATC's conservation commitment through certifications and outreach. Considering these objectives, the development of this tool was intended to identify priority areas within which ATC can identify partnership opportunities, focus field implementation efforts, and achieve the highest conservation delivery efficiency possible.

Due to time, data availability limitations, and the area of greatest geographic need, only portions of ATC's operational footprint within Wisconsin were included in this analysis. In defining the intent of the modeling effort, we also recognized that ATC does not own most of the land on which their ROWs occur. This consideration plays into the problem framing and objective development for this effort. In achieving the objective, ATC seeks to use the allocated budget and time in the most efficient method possible to promote pollinator conservation, make meaningful conservation improvements to the landscape, and develop partnerships while doing so.

Defining Model Versions and Intent

As we considered development of this spatial model, we used structured decision-making to frame and evaluate the intent and approach to the model itself. We considered how the model will be used, what insights we hope to gain, and clearly communicate how we analyze sections of existing ROWs for pollinator conservation needs. In determining the structure of the analysis, we determined that two distinct approaches were needed to answer the two questions posed by considering pollinator conservation in ROWs:

1. What and where are the most important ROW segments for ATC to restore lost or degraded land cover (i.e., low pollinator value) to build or enhance pollinator connections?
2. What and where are the most important ROW segments for ATC to sustain and maintain high value land cover for pollinator conservation?

The modeling analysis used to answer the first of these two questions was named version 1.0 of the POWR Model. This 1.0 analysis was solely focused on determining where ROWs could help build landscape habitat connections for pollinators. The analysis evaluating the second question posed was considered to be the 2.0 version of the POWR Model. The 2.0 version did not update or change any results from the 1.0. Instead, the 2.0 version helped identify where to maintain already high-value habitats along the ROWs.

Defining Model Variables

As depicted in Figure 1-1, the POWR Model relies on several input variables to inform which areas address our conservation-focused questions. These broadly include considerations for land cover, landscape context, and management focus

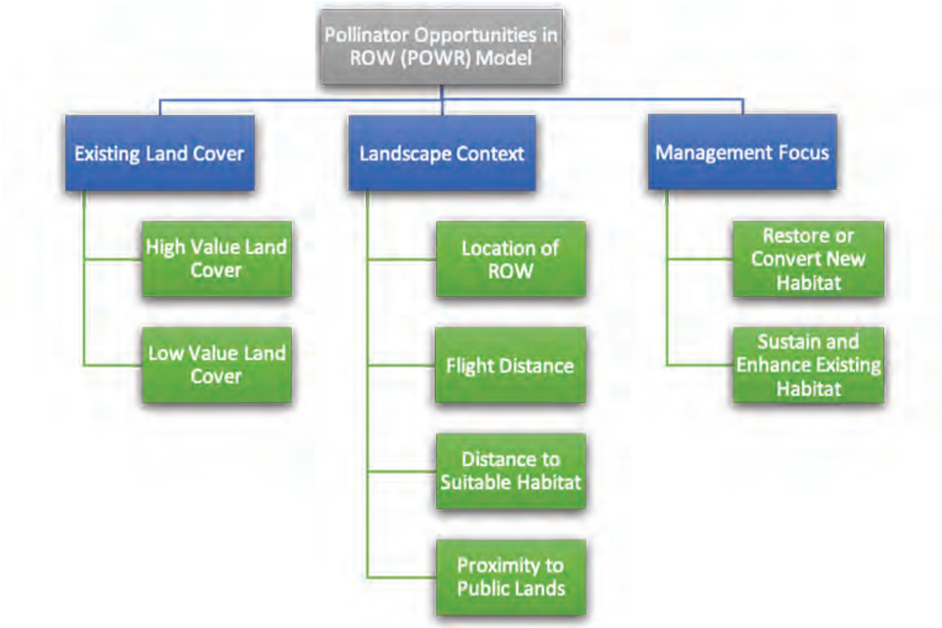

Figure 1-1. Diagram of Influencing Factors Used for POWR Model Development

Influences to the Modeled Landscape

With this in mind, Cardno considered the pollinator conservation role of ATC ROWs within the mixed land-use landscape of Wisconsin. Based on our understanding of the conservation roles and opportunities in ROWs identified in scientific literature (see Introduction) and additional spatial considerations outlined herein, we outlined the influences that were important to our decisions for pollinator restoration and enhancement opportunities. Figure 1-1 illustrates these influences. It by no means provides an exhaustive list of considerations for pollinator management. However, these features were considered to be critical to the decision needed to be answered by the POWR model.

Existing Land Cover

Pollinators rely on a landscape comprised of flowering plants that sustain nectar (carbohydrates) and pollen resources (protein, lipids, and other nutrients). To determine where pollinator enhancements were needed, we had to identify which land covers provided suitable habitat for pollinators, and how the ROWs were situated within landscape context to these suitable habitat patches. Pollinators use a variety of habitats and floral resources. In some cases, developed lands can provide unique seasonal floral needs that may not occur within the surrounding landscape (Hall 2016). Because of the lack of empirical data available regarding pollinator values for land cover types, we had to rely on comparative and relative values assigned to various land cover types.

High and Low Value Land Cover

As part of a national modeling effort to quantify the status, trends, and impacts of wild bee abundance in the U.S. (Koh et al. 2016), a panel of 14 experts evaluated nesting suitability for four bee nesting guilds (ground, cavity, stem, and wood) and floral resource availability for three foraging seasons (spring, summer, and autumn). Experts selected one of five options to represent nesting suitability or floral resource production (0.05, 0.25, 0.5, 0.75, or 0.95) across three seasons in which flowering occurs (spring, summer, and autumn). These expert opinions were compiled into seasonal and single-combined values by land cover types for nesting suitability and floral resource values. Using the combined values of foraging and nesting resources by land cover type, we then cross-referenced the land cover types evaluated in Koh et al. (2016) with the land cover scales and types identified in the best available land cover dataset within ATC's operational footprint: Wiscland 2.0.

Wiscland 2.0 is a 30-meter (m) spatial resolution raster dataset. Using a dataset with a large spatial resolution like this provided both advantages and drawbacks when incorporated into the POWR Model. The value of each pixel within the dataset represents the dominant cover type within a 30 by 30 m area. Due to the large scale, finer scaled details of the landscape will be lost and could not be accounted for during the POWR model analysis. While this could be considered a drawback of the dataset, it was also necessary for an analysis of this large of a geographic area. File sizes for datasets of this geographic scale can also become prohibitive. As the file size increases, the amount of time and processing power within the computer and that can be managed by ESRI's ArcGIS software can cause limitations on analysis capabilities.

Because ATC's vegetation management (VM) and pollinator program are broadly interested in conservation of both floral and nesting resources, we calculated a Combined Average Resource Value (CARV) score by taking the average of the floral resource value and nesting resource value by land cover type. In doing so, our intent was to consider the land cover as a whole resource, since most of the conservation actions undertaken by ATC will consist of preserving, maintaining, enhancing, or restoring natural land cover types. The combined average resource value score is graphed in Figure 2-1.

Tier 1 Land Cover	Tier 2 Land Cover	Combined Average Resource Value
URBAN/DEVELOPED	Developed, High Intensity	0.218
URBAN/DEVELOPED	Developed, Low Intensity	0.414
AGRICULTURE	Crop Rotation	0.161
AGRICULTURE	Cranberries	0.373
GRASSLAND	Forage Grassland	0.326
GRASSLAND	Idle Grassland	0.633
FOREST	Coniferous Forest	0.427
FOREST	Broad-leaved Deciduous Forest	0.541
FOREST	Mixed Deciduous/Coniferous Forest	0.58
OPEN WATER	OPEN WATER	0
WETLAND	Floating Aquatic Herbaceous Vegetation	0.315
WETLAND	Emergent/Wet Meadow	0.339
WETLAND	Lowland Scrub/ Shrub	0.64
WETLAND	Forested Wetland	0.367
BARREN	BARREN	0.233
SHRUBLAND	Shrubland	0.64

Figure 2-1. Combined pollinator floral and nesting resource values for the land cover dataset used within the POWR Model

For the purposes of enhancement and restoration targets, we needed to identify compatible land cover types that may be enhanced. Vegetation maintained within the ROWs must be compatible with the Federal regulatory requirements and ATC clearance standards for reliability and safety. In practice, this means that most woody vegetation is removed from the ROWs as part of routine VM. As such, for ATC's purposes, compatible pollinator habitat must consist of a non-woody land cover type (i.e., no forest or shrubland cover).

Because of this compatibility need, the "Idle Grassland" cover type is considered the target pollinator community for ATC ROWs. Idle Grassland is considered analogous with the mix of native prairie, cool-season grasslands, old field, wet meadows, and other natural cover grasslands along the ROWs. With a combined average resource value score of 0.63, Idle Grasslands were identified as one of the most beneficial land cover types (Figure 1-2).

Landscape Context

Landscape context considered in the model took the location of ROW infrastructure, flight distance of pollinators, and proximity to public lands into account.

Transmission Infrastructure

ATC's transmission line dataset provides the routes of all underground and aboveground transmission lines within ATC's system. This dataset was created by ATC, and is maintained and updated as line routes change, or as more accurate data is collected.

Flight Distance to Connect Suitable Habitat

Creating landscape connections for pollinators varies depending on the size and type of bees (or other species) targeted for conservation. For bees, foraging distance has been shown to increase with body size for various taxa (Greenleaf et al., 2007). For example, for some vertebrate groups, body size is predictive of home range, a metric that is closely related to foraging distance. For many invertebrates, body size and home range area are related (Greenleaf et al., 2007, citing Haskell et al., 2002). The form of this relationship varies among studies and taxa, and it may be linear or either an increasing or decreasing nonlinear function (e.g., Greenleaf et al., 2007, citing Harestad and Bunnell, 1979; McNab, 1963; Milton and May, 1976; Schoener, 1968; Turner et al., 1969).

Body size of bees can be consistently evaluated by measuring the distance between the wing bases, or the intertegular (IT) span. IT span measures the thorax, which contains the flight muscles (Greenleaf et al. 2007, citing Cane 1987). Across diverse bee taxa, Greenleaf et al. (2007) found a highly significant and explanatory positive, nonlinear relationships between IT span and estimates of foraging distance. Using the regression equations outlined in Greenleaf et al. (2007), we calculated a range of estimated flight distances:

$$\log Y = \log a + b \log X$$

Given the relationship of IT span and flight distance, a series of potential flight distances for a range of IT spans was calculated. For the purposes of our POWR model, we selected 2.0 millimeter (mm) as a target IT span. This value was selected as assumed, and biologically comprehensive, mean IT span for several types of native bees (bumblebees, carpenter bees, mason bees, etc.). Larger bees, such as bumblebees, have a larger IT span (up to 4.0 mm). Therefore, using a smaller flight distance for modeling purposes also allows for inclusivity of the larger bees. Based on a 2.0 mm IT span, and the average of typical homing distance (kilometer; km), and maximum feeder training distances calculated, we identified 0.47 km, or 1,556 feet (ft), as the target flight distance for our model.

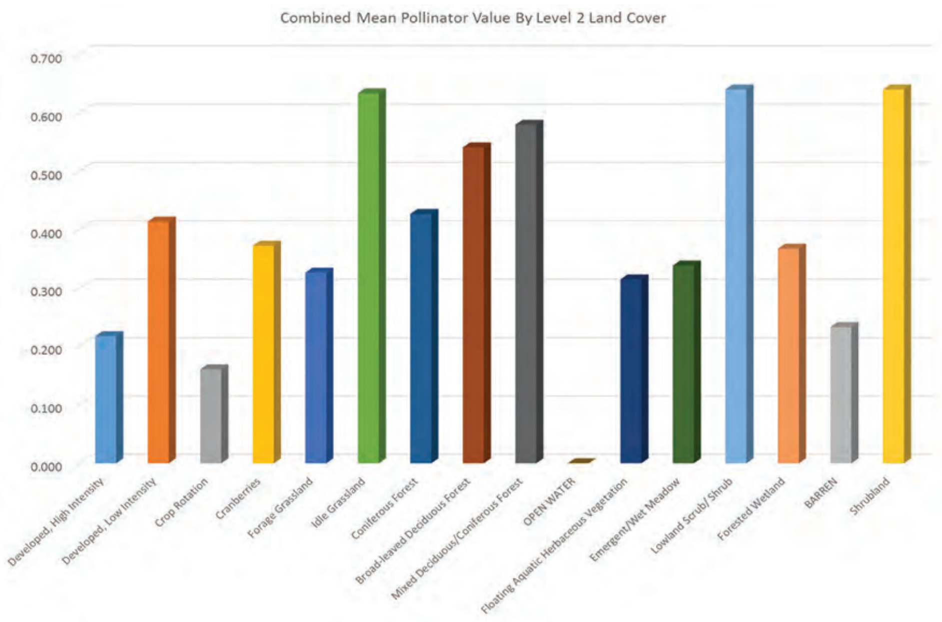

Figure 1-2. Graphical Comparison of Combined Average Resource Value (CARV) Score by Level 2 Cover Type

Public Lands

ATC transmission line segments that are in close proximity to existing public or managed land are considered valuable for land cover enhancements by ATC. Public lands on or adjacent to ROWs typically provide 1) large patches of suitable pollinator habitat nearby, and 2) opportunities for project partnerships. We used a variety of datasets that ranged from private land ownership, up to local, State, Tribal, and federal management. These datasets included Natural Resource Conservation Service (NRCS) Easements, Wisconsin State Natural Areas, WDNR Managed Land, U.S. Forest Service (USFS) National Forests, U.S. Geological Survey (USGS), National Protected Areas Dataset (PAD), USGS Gap Analysis Program (GAP), Great Lakes Conservation and Recreation Lands Dataset, and the National Conservation Easement Dataset.

Determining Management Focus

As we noted, our two model versions considered different questions. The Version 1.0 analysis was solely focused on determining where ROWs could help build landscape habitat connections for pollinators. The analysis evaluated by the 2.0 Version of the POWR Model did not update or change any results from the 1.0. Instead, the 2.0 version helped identify where to maintain already high value habitats along the ROWs.

Identifying Restoration and Conversion Opportunities

For ATC's purposes, we defined restorable lands as non-woody, non-aquatic, enhance-able land cover with values <0.633. When limiting the pool of enhance-able or restorable land covers to this definition, we were left with the following cover types as areas for potential pollinator enhancement. Because idle grasslands are our target cover type for pollinators, we calculated the "enhancement potential" of each restorable habitat type. This enhancement potential indicates the degree of separation from the ideal condition (i.e. idle grasslands). Conceptually, the enhancement potential indicates where ATC can achieve the highest efficiency on its conservation investment. For example, using the enhancement potential score for land covers, restoration of an acre currently in crop rotation (0.473) would generate a greater conservation benefit than restoration of developed, low intensity lands (0.222) because the developed lands already have some pollinator benefit and resource value.

We recognized that using broad assumptions for land cover types, which have much variation between structure and species composition, can overlook some of these elements in the analysis. However, due to the lack of refined data available for pollinator valuation of finer scale habitats, this was the best approach available given the limited timeframe for completion.

To illustrate these finer scale differences, shrublands provide a good example. Shrublands score as one of the highest value land covers for pollinators due to expert opinion of their contribution to nesting and floral resources. Certainly, some shrublands do provide great value for pollinators: Hill and Bartomeus (2016) highlight that maintaining and enhancing the abundance of early flowering willow shrubs (*Salix* spp.) can potentially improve the quality of bumblebee habitat in transmission ROWs. Early flowering willow species provide critical forage for early emerging bumblebee queens and subsequently support successful colony establishment (Hill and Bartomeus 2016, citing Svensson 2002). However, other shrublands dominated by invasive species have been documented as having a negative impact on pollinators as compared to more open grassland systems. In a literature review conducted by Hanula et al. (2016), they cite several examples of non-native, invasive shrublands that were documented as reducing pollinator use and/or populations. McKinney and Goodell (2010) studied the effect of bush honeysuckle (*Lonicera* spp.) and its removal on pollination of a native plant beneath its canopy. Their work demonstrated that shading by the shrub inhibited flower visitation, resulting in poor seed set beneath the shrub canopy (as cited by Hanula et al. 2016). In a study completed by the literature review authors, removal of Chinese privet (*Ligustrum sinense*) from riparian forests increased bee abundance by ten-fold and species richness by four-fold only two years after removal when compared to heavily invaded forest (Hanula et al. 2016, citing Hanula and Horn 2011). Removal of glossy buckthorn shrubs (*Rhamnus frangula*) from prairie fen wetlands in Michigan resulted in a similar rapid recovery of pollinator communities (Hanula et al. 2016, citing Fielder et al., 2012). In a similar manner as privet, removal of buckthorn resulted in increased native plant cover and diversity within two years and an immediate increase in both bee and butterfly abundance and diversity (Hanula et al., 2016). Based on these results, caution should be used when evaluating shrublands for their benefit to pollinators to avoid "apples to oranges" comparisons. When reviewing shrubland enhancement opportunities, consider dominant species, their bloom period, target plant communities, and landscape context.

For both versions of the model, we used structured decision-making to define our fundamental objectives related to this modeling effort and its intent, then outlined measurable aspects that can be evaluated towards those objectives. By assigning decision weights to the spatial attributes associated with our objectives, we were able to consider both biological species requirements, as well as operations management perspectives.

Version 1.0 (Building Landscape Connections) Attributes

For each of the objectives we identified, we used ArcGIS to identify the range of values embodied by the segment data set created by the spatial analysis (Table 1-2). To determine which values were optimal at meeting the desired

Objective	Prioritization Element
Minimize the area required for restoration to suitable habitat.	CARV Value
Maximize restoration of segments on or adjacent to public lands to promote partnership opportunities.	Segment Length
Maximize conservation in habitat patches that are isolated and may provide the only locally available habitat.	Landscape Proximity
Maximize conservation in segments that have minimal suitable habitat acreage on/adjacent to the ROW.	Suitable Adjacent Habitat

Table 1-1. Measureable attributes, values, and normalized scores used for segment analysis in POWR Model 2.0

objectives, we then identified the range of possible values in the data set associated with each prioritization element. The optimized value of each prioritization element depends upon whether the objective sought the maximum or minimal value for the dataset.

For each segment identified, we quantified each prioritization element relative to each segment's size, proximity to public lands, restored length of connected high-value habitat in the landscape, and enhancement potential of the dominant land cover within the segment itself. We then normalized these individual values for each prioritization element. Normalized scores for each segment and each prioritization element was then calculated by taking the ratio of the segment value's difference to the least optimal outcome compared to the range of values making up the distribution of normalized values.

Version 2.0 (Sustaining High Value Habitat Areas) Attributes

We recognize that many portions of ROWs already provide some degree of habitat value and therefore play an important role for pollinators. These areas should be maintained or enhanced as opportunities are found as part of routine VM, capital projects, or special projects. See Section 4 for associated recommendations. To identify where these actions are most important, POWR Model version 2.0 was run to identify these high-priority existing habitat segments.

For Version 2.0 (sustaining high value habitat), we again used ArcGIS to identify the range of values embodied by the segment data set created by the spatial analysis and then used structured decision-making and decision-weighting to apply management values to the conservation and biological needs on the ground (Table 1-3).

Objective	Prioritization Element
Maximize pollinator conservation on areas of high value (CARV >0.326).	CARV Value
Maximize restoration of segments on or adjacent to public lands to promote partnership opportunities.	Prox. To Public Lands
Maximize the stem density of milkweed in ROW to support monarchs.	Milkweed Potential
Maximize the length of suitable pollinator habitat sustained by existing segments.	Segment Length
Maximize conservation in habitat patches that are isolated and may provide the only locally available habitat.	Landscape Proximity
Maximize conservation in segments that have minimal suitable habitat acreage on/adjacent to the ROW.	Suitable Adjacent Habitat

Table 1-2. Measureable attributes, values, and normalized scores used for segment analysis in POWR Model 2.0

Decision Analysis Tools

Using these spatial variables and considering the management intent, we used structured decision-making and associated decision analysis tools to bring these two considerations together into our model.

Multiple Criteria Decision Analysis

Using the normalized scores for each prioritization element within each segment, we then completed a comparison analysis of the segments against one another. To do so, we used a multiple criteria decision analysis (MCDA) approach to quantify the weight and analyze the normalized scores for each segment. MCDAs are helpful for evaluating multiple conflicting criteria in making decisions. The value of framing complex problems, defining objectives, and then considering multiple criteria explicitly can result in more informed and more transparent and defensible decisions—all of which are important elements to consider for landscape level conservation.

In the case of our POWR Model, each of the four objectives for POWR 1.0, and the six objectives for POWR 2.0, address one or more aspects of the fundamental objectives of ATC's pollinator program. Once we defined the values and normalized scores, we could sum the cumulative score for each of the four prioritization elements and corresponding objective. However, doing so would consider each of the objectives for each version with equal weight towards the final decision. Because some objectives may weigh heavier on the decision relative to others, we worked with ATC staff to define weighting of each of the objectives using the point allocation method for each version. In doing so, we discussed a range of ROWs scenarios and examples to help consider the range of weights and underlying importance of each to the decision.

RESULTS

Using the POWR Model methods described, the final analysis identified 2,818 restorable or enhance-able segments consisting of more than 1,466 kilometers (km) (911 miles [mi]) of ROWs. The range of values and number of segments comprising them are summarized here. In both scenarios, we eliminated extremely small segments (less than 61 m; 200 ft in length), since we determined these were too small to influence management decisions. These small areas also often represented small overlap areas in land cover data that were not representative of actual on-the-ground conditions.

Summary of POWR 1.0 Findings

Across the nearly 12,714 km (7,900 mi) of ROWs mapped across state of Wisconsin, 1,466.11 km (911 mi) of restorable segments were identified. Within these priority segments, approximately 73 were located on public lands consisting of Federal, Tribal, State, NGO, county, or other public land are found in close proximity to ATC ROWs.

Crop rotation lands made up the vast majority of dominant land cover 1,466.11 km (911 mi) in the enhance-able segments identified. The balance of segments was comprised of three other cover types (barren, developed high intensity, and forage grassland). Restoration or conversion of priority segments has potential to connect a network of up to 11,909 km (7,400 mi) of suitable/high value cover types along (and adjacent to) existing ROWs.

Summary of POWR 2.0 Findings

Across the nearly 12,714 km (7,900 mi) of ROWs mapped across state of Wisconsin, 5,193.35 km (3,227 mi) of high-value habitat on a total of 21,442 segments that were identified. This indicates that approximately 40.8 percent of ATC ROWs already sustain high-value pollinator land covers. Nearly 886 km (550 mi) of public lands consisting of Federal, Tribal, State, NGO, county, or other public land are found in close proximity to ATC ROWs.

Idle grassland made up the vast majority of dominant land cover (2,438.16 km; 515 mi) in the high-value segments identified. Low intensity development was closely following (2,438.16 km; 515 mi) in both number of segments and overall mileage. The balance of segments was comprised of four other cover types:

1. Wet Meadow/Emergent Wetlands
2. Lowland Scrub Shrub
3. Shrubland
4. Cranberries

DISCUSSION

Using POWR Results to Inform Management

Interpreting Results

The focus of this effort was to identify and prioritize which areas of ROWs can both be enhanced and create a landscape connection to other suitable habitat. Considering the objectives the POWR Model attempts to address, we encourage the following considerations when interpreting its results:

- All segments are priorities for conservation. All segments were identified because they both connect habitat landscapes and enhance degraded land covers for pollinators. Priority levels assigned based on breaks in the segment dataset are to be used for relative comparison between segments based on their ability to address the objectives and weights assigned. Even though a segment may be low priority relative to the others, its restoration or enhancement will still have a conservation benefit.
- The results of the analysis are based on the assumptions, weighting, and criteria outlined. Updated data sets or field-based, site-specific information can be incorporated into subsequent model updates or related decisions.
- ROWs outside of priority segments may already provide some pollinator habitat value. Limitations due to timing and data availability prevented analysis of existing natural land covers within the ROWs. Consider conservation and enhancement measures during activities as appropriate based on site conditions and pollinator needs.

Informing Work Program Recommendations

The results of this model can inform work planning:

- In priority segments, consider how work activities may allow for enhancement through building landscape connections via corridor or stepping stone restoration.
- In areas outside of priority segments, consider protection and conservation measures to minimize disturbance to flowering vegetation and enhance wildflower cover.

Vegetation Management

VM contributes significantly to pollinator conservation by maintaining open areas of natural vegetation, including grasses and wildflowers in some areas. Focus areas of pollinator improvements during VM include restoring/enhancing open grassland in areas degraded by invasive shrub species, and minimizing impacts to high-quality, compatible, pollinator habitat (grasslands with flowering plants) during work activities. The list below provides examples of how the POWR model can inform VM best practices. Within POWR Model priority segments:

1. Continue to maintain high-value foraging and nesting habitat areas within existing ROWs through mowing and herbicide application as part of ongoing maintenance activities.
2. Promote introduction of native species (either through natural reintroduction or direct seeding) in areas where invasive or woody cover is removed via mowing or herbicide applications.
3. Conserve existing pollinator habitat through landowner coordination to ensure long-term success to cleared or restored areas.
4. Consider opportunities to build landscape connections via selective VM, seeding, or landowner coordination during work planning in segments identified as high potential within the POWR Model.
5. Promote partnership opportunities with landowners and managers including Federal, Tribal, State, county and local governments, and private landowners.

Capital Projects

Capital projects consist of any construction-related activities within transmission electrical systems. This includes maintenance, upgrades, rebuilds, and construction of new and existing transmission lines and facilities. Construction may be as minor as installing equipment on an existing structure to the construction new high voltage transmission lines spanning hundreds of miles. During the planning process, environmental professionals are consulted in order to ensure compliance with all applicable law, regulations, orders, and to reduce environmental impacts of construction.

The list below summarizes examples of how the POWR Model can inform best practices during capital projects. Within POWR Model priority segments:

1. Consider opportunities to build landscape connections via project area seeding and landowner coordination in segments of transmission identified as high potential in the POWR Model.
2. Restore/enhance pollinator foraging habitat via seeding of native flowering species in areas of ground disturbance. As part of native seeding, ensure landowner coordination and educate on the pollinator benefits of the native seeding areas.
3. Consider ways to minimize impacts to high-quality, compatible pollinator habitat (grasslands with flowering plants) during construction activities. Consider minimization of soil disturbance in these areas to conserve nesting and foraging pollinators. Evaluate potential access routes to minimize disturbance and vehicle traffic in areas of high-value habitat.
4. Promote partnership opportunities with landowners and managers including Federal, Tribal, State, county and local governments, and private landowners.

Special Projects

Special projects are those which may be implemented to specifically promote pollinator opportunities within ROWs. Within POWR Model priority segments:

1. Review prioritization developed as part of the POWR Model to help identify locations and consider future partnerships.
2. Work with identified partners to implement projects that restore or enhance high-value pollinator habitats.
3. Restore high-value pollinator foraging habitat on owned lands, such as areas around office buildings, substations, or title-owned parcels.
4. Use the POWR Model to help identify areas to conduct pre- and post-enhancement monitoring.
5. Use the POWR Model to demonstrate commitment and decision-making when applying for third-party certifications.

Future POWR Model Refinement

This report summarizes the initial development, rationale, and findings of versions 1.0 and 2.0 of the POWR Model. Subsequent analysis and model updates can incorporate additional decision elements and data sets. The focus of this effort was to identify and prioritize which areas of ROWs can both be enhanced and create a landscape connection to other suitable habitat. Through the course of model development, we identified the following areas where future model refinements can be considered for improved analysis and decision support:

- **Expand POWR Model into other regions.** Limitations in timing and data availability prevented the inclusion of additional lands or regions. However, the framework and tools developed in the POWR Model can be easily applied elsewhere.
- **Consider flight distance and habitat requirements for specific target species.** Flight distances and habitat values used consider a range of native bees (sweat bees, carpenter bees, mason bees, and bumblebees). The POWR Model can be adapted to address needs of specific species, such as the rusty patch bumblebee or the yellow-banded bumblebee. Adaptations for listed (or candidate) species may be used to help facilitate discussions with regulatory agencies regarding suitable habitat, conservation, or restoration via regulatory agreements such as Safe Harbor Agreements, HCPs, or Candidate Conservation

Agreements with Assurances, if needed.

- **Develop/use improved land cover to refine results.** Wiscland 2.0 represents the most up-to-date data set available for Wisconsin. However, if/when more refined land cover information becomes available, it can be incorporated to refine results.
- **Refine pollinator forage and nesting values by land cover type.** This model relied heavily on the pollinator values developed by Koh et al (2016) for landscape modeling. Science regarding pollinator habitat needs and their conservation is growing each year with the sense of urgency expressed by many conservation organizations and agencies. As new information becomes available on pollinators and their habitat needs, these updates can be incorporated to refine results.

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Replacing Aging Infrastructure in the Modern Era: Challenges and Opportunities

Stephen Barker

Keywords: Construction, Pipeline, Restoration.

The Northern Indiana Public Service Company (NIPSCO), a state-regulated utility, is currently modernizing and replacing essential parts of its aging electric and gas infrastructure in the next decade to ensure safety, reliability, and integrity. Some of NIPSCO's earliest rights-of-way (ROW) were established back in the early 1900s, well before the Clean Water Act, Endangered Species Act, and other regulations that often influence how and where new pipeline facilities and ROWs are routed today. Many of NIPSCO's ROWs are currently located within and adjacent to some of the highest quality habitats in Northwest Indiana. Numerous high-quality aquatic resources and state and federally managed lands are juxtaposed with a rural, urban, and industrial landscape in which NIPSCO currently operates. While only 4,828 kilometers (km) (30 miles [mi]) in length, the Aetna to LaPorte Gas Transmission Upgrade Project (Project) dealt with numerous environmental, land, engineering, and construction constraints. Project development began in 2015 with the goal to upgrade an existing 22-inch (in) pipeline with a new 24-in diameter pipeline. The case study will explore the various challenges of the post-regulatory environment, and identify the complexities of natural resource permitting, agency, and stakeholder engagement, pipeline routing, environmental compliance during construction, and long-term, sustainable ROW restoration and management. The case study will thus serve as a "Lessons Learned" to successfully design and replace aging infrastructure in the post-regulatory environment.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Northern Indiana Public Service Company (NIPSCO), with headquarters in Merrillville, Indiana, is one of the seven energy distribution companies of NiSource, Inc. With more than 821,000 natural gas customers and 468,000 electric customers across the northern third of Indiana, NIPSCO is the largest natural gas distribution company, and the second largest electric distribution company, in the state of Indiana. As a part of its modernization program, NIPSCO recently installed a new 24-inch pipeline that upgraded an existing 24-inch (in) line to increase infrastructure safety and reliability. The pipeline was scheduled to be constructed in a three-year span and divided in three separate phases. Inception and planning began in the winter of 2015. Phase 1 of construction was initiated in spring of 2016 with final construction anticipated to be complete by the end of 2018. While only 48.28 kilometers (km) (30 miles [mi]) in total length, the pipeline traversed a diverse socioeconomic landscape. The landscape ranges from residential and rural landscapes along the eastern terminus to the heavy industrial enclaves at the western terminus. In between, the pipeline crosses some of the highest quality wetlands in Northwest Indiana and several critical natural areas, such as the historic Karner blue butterfly (*Lycaeides melissa samuelis*) habitat.

Importantly, some of NIPSCO's electric transmission rights-of-way (ROWs) date back to the 1930s or earlier. These ROWs were often established in large wetland complexes and other areas unsuitable for economic development at the time. Prior to industrial development of the Project area, a vast wetland complex once occupied much of the landscape in Northwest Indiana. The original 22-in pipeline was constructed back in 1952, well before the Clean Water Act (1972 amendment) and other overriding federal regulations. It was largely co-located within portions of NIPSCO's electric transmission ROWs. At that time, wetlands and other environmentally sensitive areas were likely not considered as the ROWs were established. Consequently, high-quality aquatic resources and other wetland features constitute a significant percentage of land cover.

In addition to Clean Water Act implications, the Indiana Dunes National Lakeshore (INDU) was authorized in 1966. While only 6,070 hectares (ha) (15,000 acres) in size, it represents one of the most biologically diverse national parks in the country. Portions of the 22-in pipeline were located within the current boundaries of INDU or directly adjacent to it. Calumet Prairie Nature Preserve, owned and operated by the Indiana Department of Nature Preserves, was officially protected in 1979. The Calumet Prairie wetland complex, including the adjacent fee-owned NIPSCO ROWs and location of the pipeline, represents one of the largest, most intact sedge meadows in the State of Indiana. It includes numerous state-listed plants and the state endangered spotted turtle (*Clemmys guttata*). Consequently, direct and indirect effects of pipeline construction had to be evaluated during pipeline routing and permitting phases.

While NIPSCO system improvement projects have been underway in recent years, the company has not constructed a pipeline project of this scale and magnitude in this region of Indiana for decades. The challenges were many, including the following:

- Active and engaged regulators and environmental community
- State and federally listed species
- High-quality aquatic resources
- Compressed permitting schedule
- Environmental compliance during construction
- Wetland and habitat restoration post construction
- Industrial and residential development, post-1952 (original installation)

METHODS

Design Considerations and Routing Constraints

NIPSCO's goal is to provide continued safe and reliable power delivery for its customers now and in the future. NIPSCO's plan to modernize and replace essential parts of its aging electric and gas infrastructure in the next decade and beyond will proactively address critical areas. At project inception, NIPSCO organized an internal team to address the various constraints anticipated for the Project. The internal team, with support from various consultants and contractors, had to address numerous challenges throughout the design process to ensure construction would be complete by 2018. These include primarily the following categories:

- Constructability
- Long-term operation of maintenance of pipeline facilities
- Pipeline safety, integrity, and reliability
- Costs
- Easement acquisitions
- Environment

In an attempt to minimize impacts, the preferred route of the Project primarily followed existing electric transmission corridors, natural gas pipeline easements, and road ROWs spanning portions of LaPorte, Porter, and Lake Counties, Indiana. In order to maintain serviceability of the pipeline and ensure integrity, the goal was to install the majority of the pipeline using primarily open-cut trenching techniques, including some smaller stream crossings and wetland crossings. During the evaluation of need for the Project, NIPSCO analyzed and dismissed routes that did not follow current utility easements or ROWs. Routes that did not follow an existing easement all involved greater project costs due to the need to acquire easements or outright purchase of properties. NIPSCO's source of funding for the Project is Indiana's Transmission, Distribution, and Storage System Improvements Charges (TDSIC) statute. Indiana Code 8-1-39 allows electric and natural gas utilities to submit seven-year infrastructure improvement plans for Indiana Utility Regulatory Commission (IURC) consideration and approval. The TDSIC statute creates a mandate to evaluate and plan critical projects in a manner that holds costs within certain criteria. Therefore, the statute disallows any alternatives with costs that would exceed the aforementioned thresholds.

Based on the statutory project cost limitations, NIPSCO next evaluated existing utility easements that met the following criteria:

- The easement was owned by NIPSCO or NIPSCO had existing approval from a different utility to co-locate a gas transmission pipeline within an existing easement.
- The easement allowed for the construction of a new gas transmission pipeline, both from a constructability and property rights perspective.
- The easement was located within the targeted service area of the Project (the northern portions of Lake and Porter counties).
- The easement was located within a reasonable distance of existing gas transmission pipeline, which would allow cost-effective taps to existing customers and other gas transmission lines to increase local supply.

The only utility easement that met these criteria was the Aetna Station to LaPorte Station easement (Aetna easement), which comprised the base survey area for desktop and field environmental studies. Routing was further evaluated to identify critical environmental and constructability issues. Virtually the entire easement has been approved for the construction of gas transmission pipelines. In a limited number of areas, new easement was obtained from willing landowners. Co-locating new pipelines within existing, previously disturbed utility ROWs will typically lessen impacts to natural area and cultural resources, as opposed to siting new pipelines in non-developed areas. While this may be the case in other areas, NIPSCO's ROWs still contain some of the highest quality natural areas in the region.

Agency and Stakeholder Coordination

A strategy was developed to engage in early coordination with regulatory agencies. Agency coordination occurred in 2015 after preliminary design and environmental desktop review was complete. Agencies at this time included the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service (USFWS), Indiana Department of Environmental Management, National Park Service, and Indiana Department of Natural Resources. Coordination meetings served several functions, including the following:

- Agency awareness of purpose and need of Project
- Agency awareness of environmental constraints and routing options
- Transparency during permitting and design process
- Solicitation of environmental and regulatory concerns
- Identification of potential fatal flaws early in design and routing

In addition to federal and state coordination, local government, affected property owners, environmental groups, and various stakeholders were also engaged throughout the planning process. Due to potential resource impacts and permitting implications, it was imperative to proactively address any potential concerns with the stakeholders to avoid adverse comments during the public comment periods. Various in-person meetings were held with local governmental agencies, environmental non-governmental organizations (NGOs), and the public.

Environmental Due Diligence and Compliance

Environmental constraints were identified early in project development. Similar to other projects of this scale, an environmental and natural resource desktop review was completed to address the following:

- Water resources
- Protected species and critical habitat
- Cultural resources
- Sediment and erosion control cost estimating
- Contaminated soils

Wetland delineations and other field investigations took place between 2015 and 2016 for baseline documentation in support of permitting. In addition to floristic quality assessments in wetlands, field notes were also taken on uplands to assess natural area quality, vegetation dominance, and restoration potential. Not only did NIPSCO need to ensure temporarily impacted wetlands were restored to pre-construction conditions, but also to improve natural areas and biodiversity as a part of the company's conservation strategy. Restoration planning would therefore need to address all areas impacted by construction activities.

A formal roll-out of NIPSCO's environmental compliance program was also initiated in 2016 with the start of the Project's construction. The intent of the program was to standardize the environmental inspection program and reporting requirements. A full-time environmental inspector was assigned to the Project in 2016 for the Phase 1 construction. In 2016, two full-time inspectors were needed to help oversee some of the sensitive area crossings. In 2017, there have been up to three full-time inspectors overseeing the most sensitive area crossings, including the National Park Service and Calumet Prairie segments. The Project was one of the first to be covered under the newly established program.

RESULTS & DISCUSSION

Understanding the environmentally sensitive areas and ecological setting in the Project area was instrumental to move the Project forward. Early coordination, outreach, and environmental due diligence were necessary to identify and confirm the most sensitive areas along the pipeline route. Measures were taken when possible to avoid permanent conversions of forested wetlands and other sensitive wetlands when re-routes were viable. Horizontal directions drilling (HDD) was also used to avoid impacts to some of the higher quality wetlands and larger streams.

However, due to various other constraints, several of the large, high-quality wetland complexes were not able to be avoided by routing or HDD. Two notable segments would temporarily impact high-quality aquatic resources with numerous state-listed plant species and the state endangered spotted turtle habitat. State-listed and rare plant species likely to be affected by the pipeline construction included northern long sedge (*Carex folliculata*), tall cotton-grass (*Eriophorum angustifolium*), lesser purple-fringed orchid (*Platanthera psycodes*), green-fringed orchid (*Platanthera lacera*) and bay forget-me-not (*Myosotis laxa*). Even though the federally endangered Karner Blue Butterfly was recently extirpated in the State of Indiana, NIPSCO is still required to follow the conditions of its Karner Blue Butterfly Habitat Conservation Plan (HCP). A key condition of the HCP is maintain baseline levels of wild lupine (*Lupinus perennis*), the primary host plant for the larvae. The Project impacted several populations of wild lupine located within the HCP.

In order to minimize impacts to wetlands, species of concerns, and other ecologically sensitive areas, a number of tasks were executed to ensure minimization and restoration success post-construction.

In the planning phase, detailed specifications were written into the project-specific Environmental Compliance Plan, stormwater pollution prevention plan, and contractor specifications to capture the various permit conditions and environmental construction standards. An in-depth restoration plan was developed in order to specify and clearly demarcate site-specific seed mixes, seeding specifications, and performance standards. Customized, local genotype native seed mixes were also developed for the various habitat types, including the high-quality sedge meadows, sand prairie, wet-mesic prairie, and low-quality wetlands. Additional wild lupine was also utilized in the HCP area to further enhance lupine establishment.

In an attempt to enhance restoration success and ensure performance standards are met, invasive species such as hybrid cattail (*Typha* x *glauca*) and common reed (*Phragmites australis*) were treated the previous year of construction. The intent was to remove the non-native seedbank from the project area and then re-seed with a high-quality wetland seed mix. Since final restoration and stabilization will be taking place in 2018, a three-year maintenance monitoring program will help ensure restoration performance goals are obtained.

To avoid impacts to the state-endangered spotted turtle, daily surveys were conducted to detect and relocate if discovered. Silt fence not only served as a sediment filtration device, but also as an exclusion device. DNR biologists also assisted during construction with initial surveys and relocations of spotted turtles. Efforts are currently underway to improve habitat suitability for spotted turtles and other species of concern in the project area. NIPSCO will be serving as a partner with the development of this effort.

CONCLUSIONS

The Project had an extremely compressed permitting schedule due to engineering delays and late route modifications. Despite these challenges, there were no significant construction delays. The Project is currently on schedule, despite the multitude of environmental and constructability challenges. The success of permitting was largely driven by proactive coordination and transparency with regulatory agencies, restoration planning, environmental compliance during construction, and execution. Without the support of regulators and key stakeholders, there could have been significant delays in permitting and construction.

That said, the Project proved to be every bit as complex as anticipated. It traversed numerous wetland crossings and ecologically sensitive areas juxtaposed in an urban and industrial environment. The project team had to contend with numerous constraints unforeseen by their predecessors from 1952. In addition, environmental compliance goals and conservation initiatives further played into environmental permitting, construction, and restoration planning. NIPSCO's sustainability and conservation goals can be well balanced with infrastructure improvement projects, but continued support of restoration ecology and habitat restoration will be required.

AUTHOR PROFILE

Stephen Barker

Stephen Barker has more than 20 years of professional experience in natural resource permitting and ecological restoration and management. Currently, he serves as Natural Resource Permitting Principal at NIPSCO. He has extensive experience in managing projects and teams that involve environmental compliance, wetland permitting, natural resource regulations, and ecological restoration. Although his primary duty at NIPSCO is natural resource permitting and environmental compliance, he is also heavily involved with the conservation efforts throughout NIPSCO's service territory. He is working on a number of initiatives with regional land management agencies to prioritize and restore ROWs and managed lands, focusing on pollinator habitat and habitat connectivity.

Prior to NIPSCO, he served as an environmental consultant and managed various ecological restoration and multidisciplinary environmental planning projects in Northwest Indiana. He has lectured at numerous professional conferences and public events throughout the Midwest. Barker also has extensive wildland and control fire management experience.

Review of Pipeline Abandonment Programs and the Search for Evidence of the Potential Environmental Effects of Pipeline Abandonment in Place

Andrew Hoskins, Grace Mitchell, and Dayna Solmie

Keywords: Abandonment, Cost Estimate, Mitigation, Pipeline, Potential Effects.

Pipeline infrastructure throughout North America is reaching the end of its useful life and is being taken out of service. In Canada, this, combined with the National Energy Board (NEB) requirement for federally regulated pipeline companies to file Abandonment Cost Estimates (ACE) for their infrastructure, have piqued interest in pipeline abandonment plans and the potential environmental effects (EE) of abandoning pipelines in place. Stakeholders require evidence based review of the efficacy of in place abandonment programs to baseline ACEs, inform abandonment planning, and develop mitigations for future end-of-use planning purposes.

The Pipeline Abandonment Research Steering Committee (PARSC) of the Petroleum Technology Alliance of Canada is undertaking a series of projects to increase the understanding of pipeline abandonment through evaluation of previously abandoned projects and investigate the occurrence of environmental and engineering effects of pipelines abandonment.

This paper investigates the potential and realized EE of pipeline abandonment on segments of pipeline abandoned in place adjacent to an operating pipeline in a common corridor. The abandoned segments were compared to the operating pipeline right-of-way (ROW) and the surrounding undisturbed land, while searching for evidence of the potential effects identified in previous research. Surficial evidence of the potential EE of pipeline abandonment in place was not observed.

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INTRODUCTION

This paper presents the findings of a project commissioned by the Pipeline Abandonment Research Steering Committee (PARSC) of the Petroleum Technology Alliance of Canada to begin the process of understanding if empirical evidence of the potential environmental effects (EE) of abandoning a pipeline in place exists. The objective of this project was to review the condition of a 406mm O.D. pipeline right of way (ROW) that was abandoned in place more than 10 years ago. The review included the following:

- A focused field surface assessment to determine whether there was evidence of EE or potential EE of pipeline abandonment in place as currently understood by the industry
- An assessment to determine whether any EE of pipeline abandonment were in evidence, which were outside of the current industry understanding of the risks of abandonment

The potential effects of abandonment in place have been identified by the Canadian Energy Pipeline Association (CEPA) in 2007 and Det Norske Veritas (DNV) in 2010. The effects include the following:

- Ground subsidence and frost heave
- Soil and groundwater contamination
- Subsidence at road, railway, and utility crossings
- Watercourse and wetland crossings
- Erosion
- Creation of water conduits

The abandoned pipeline segments were assessed both from the air, using a helicopter, and by ground truthing, to determine whether there was surficial evidence of the potential EE of pipeline abandonment in place.

METHODS

Field Assessment Planning

The abandoned segments of the pipeline assessed as part of the Project are co-located in a ROW with active pipelines. In the absence of a formal abandonment plan for the segments abandoned in the 1970s, we reviewed existing information about the pipeline corridor. The records review was used to determine specific locations to focus on during the field surface assessment along the abandoned pipeline segments. In addition to a records review, historical aerial photographs from various years prior to and following, construction and abandonment of the pipeline segments were reviewed to determine changes to surficial cover or local hydrology caused by pipeline abandonment. Areas of focus included locations where the potential EE of abandonment of a pipeline in place were most likely to be observed.

The existing information reviewed to inform the field assessment planning included an Environmental and Socio Economic Assessment, Phase 1 Environmental Site Assessment, and the abandonment application made for a pipeline located within the same corridor.

Field Assessment

A helicopter-supported field survey was conducted in summer 2017 to investigate the surficial conditions along the ROW. Approximately 12 kilometers (KM) of pipeline ROW were surveyed.

The focus was on the locations where the potential EE of pipeline abandonment in place would be most obvious during the overflight. In addition to observations made along the abandoned pipeline segments, observations were made along the adjacent ROW (which parallels the abandoned pipeline segments), as well as the undisturbed areas to the west and east of the existing pipeline ROWs. The abandoned segments are located approximately 10 to 12 meters (m) from the western edge of the pipeline corridor, and six m east of the active ROW.

The following characteristics may indicate the potential EE of pipelines abandoned in place, which were assessed during the fieldwork:

- Evidence of subsidence, which may indicate the formation of a water conduit, corrosion, or pipeline collapse
- Evidence of soil or water contamination, which may indicate the disintegration of a pipe wall, the formation of a water conduit, or the presence of corrosion, or that the pipe was not well cleaned (or was cleaned to applicable standards at the time of abandonment)
- Evidence of disruption to drainage, which may indicate the formation of a water conduit
- Change in depth of cover, such as pipeline exposure, which may indicate erosion, frost heaving, or buoyancy
- Evidence of issues at watercourse and wetland crossings, such as disruption in hydrology
- Evidence of special concerns at road crossings, such as trench subsidence
- Evidence of erosion, which may indicate pipeline collapse, formation of water conduits, or issues at watercourse crossings

The habitat and hydrologic functions of the abandoned pipeline ROW and surrounding area were also evaluated during the fieldwork to compare where appropriate (native) functions have returned to the abandoned pipeline segments. The evaluation noted the following:

- Presence and abundance of native vegetation, as well as the type of dominant vegetation

- Hydrology, including the presence or absence of ponded water at watercourse and wetland crossings (beaver activity was also noted as a naturally occurring alteration)
- Habitat suitability for wildlife, including wildlife sign along and adjacent to the abandoned pipeline segment

Each of the previously mentioned criteria noted along the abandoned pipeline segments was compared to the parallel active ROW and undisturbed areas adjacent to the ROWs.

Ground-truthing of each location was completed where possible; however, much of the pipeline corridor is overgrown, so landing in the helicopter was not possible at all areas of focus. Where landing was not possible, locations were surveyed from the air.

Figure 1. View North along the Pipeline Corridor. The abandoned ROW is on the west side, the active corridor is on the east side, and the undisturbed vegetation is immediately adjacent to both.

RESULTS

The results and discussion of the field assessment grouped according to the characteristics listed in Section 2.2 are provided in the following subsections.

Evidence of Subsidence

There was no evidence of subsidence, which may indicate water conduit effect, corrosion, or pipeline collapse observed along the abandoned pipeline sections. Unnatural ponded water or sunken areas along the abandoned pipeline segments were not apparent during the field survey, as shown in Figure 1.

The abandoned ROW is on the west side, the active corridor is on the east side, and the undisturbed vegetation is immediately adjacent to both.

Figure 2. Valve Assembly Adjacent to the Abandoned ROW. No surface-level contamination was noted at the time of the field visit. Successional vegetation is evident around the valve assembly, and in the front of the photo, vegetation control is evident along the active ROW.

Evidence of Soil or Water Contamination

There were no obvious signs that would indicate soil or water contamination along the abandoned pipeline segments, such as a change in vegetation color or a visible sheen on water or soil, including adjacent to a valve assembly, shown in Figure 2.

Evidence of Disruption to Drainage

Changes in vegetation and ponding at watercourses and wetlands may indicate changes in drainage patterns with time. This could indicate changes in subsidence or water conduits. Based on the review of historical aerial photography (Appendix A) and field assessment, it was determined that there was no disruption to drainage from the abandonment of the pipeline segments.

Beaver dams were observed to have altered the hydrology in numerous locations along the abandoned pipeline segments, the active ROW, and the surrounding area. Active beaver dams were noted on and off the pipeline ROWs; however, the beavers did not appear to be preferentially attracted to the specific abandoned pipeline segments when compared to the adjacent active pipeline ROW.

The historical aerial photograph review showed that hydrology was not significantly affected by the pipeline abandonment, but the hydrology has changed as time passes, mainly because of beaver dams or anthropogenic disturbances, such as clear cutting. The historical aerial photograph review also showed that the landscape (such as forest and wetland) has remained similar during pre- and post-pipeline segment abandonment along the ROW.

Change in Depth of Cover

There was no evidence of pipeline exposure at the surface along the abandoned pipeline segments. Approximate screw anchor locations, typically within wetland complexes, were observed as well vegetated with appropriate hydrology (such as open water or floating vegetation mats within wetlands). Based on these observations, it is anticipated that subsurface testing would demonstrate that the screw anchors are providing appropriate pipeline weighting at these locations or that the abandoned pipeline was sufficiently heavy to prevent buoyancy, as shown in Figure 3.

Figure 3. View East across the Abandoned Pipeline ROW. Photo shows beaver dams and where screw anchors were installed; no issues with pipe buoyancy were observed.

Figure 4. Watercourse Crossing Along Abandoned Pipeline ROW in an Area Surrounded by Upland Habitat

Evidence of Issues at Watercourse Crossings

No signs of soil erosion or preferential weathering were observed during the field survey, and the riparian areas and wetland habitat surrounding watercourses were well-vegetated with native vegetation. The watercourses assessed as part of this project were surrounded by upland and wetland habitat, respectively and are shown in Figures 4 and 5.

Figure 5. Watercourse Crossing Along Abandoned ROW in an Area Surrounded by Wetland Habitat. Note the difference in vegetation along the abandoned ROW versus the active ROW.

Evidence of Special Concerns at Road Crossings

No special concerns were observed at the access road and bell hole locations assessed. The area surrounding the private access road crossed by the abandoned pipeline ROW was well vegetated with appropriate woody vegetation and a graminoid understory. No impounded water was observed at the location, nor was there evidence of pipeline collapse (subsidence) within the road observed along the road crossing. There are no county regulated or -maintained road crossings along any of the abandoned segments, and as such, records of additional maintenance related to subsidence at road crossings were not available. See Figure 6.

Figure 6. Access Road Along the Abandoned ROW. There is no surficial evidence of subsidence at this privately managed access route.

Habitat and Hydrological Characteristics

Habitat conditions along the abandoned pipeline segments were determined to be functional because native vegetation was well established on the ROW. When comparing the abandoned pipeline segments to the parallel active ROW, notable differences were observed. For example, woody vegetation was taller on the abandoned pipeline segments when compared to the active ROW, where vegetation was more recently cleared. Dominant tree species in undisturbed upland areas were mature trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), and black-and-white spruce (*Picea glauca*), while on the abandoned pipeline segments, those trees species were present in a successional stage, and shrub species, such as alder (*Alnus*), were more dominant, as shown in Figure 7.

In wetland areas along the abandoned pipeline segments, the dominant tree species were small black spruce (*Picea mariana*), with willow species dominating shrubby areas, and emergent vegetation, such as sedge species and common cattail, abundant in marsh-type areas. Weed concerns were generally not noted along the abandoned pipeline segments. However, trace amounts of Canada thistle (*Cirsium arvense*) were observed to be growing in equal amounts across all the ROWs in upland areas. Successional species, such as fireweed, were also present in upland areas in equal amounts across all the ROWs where woody vegetation was cleared. There was some excess water over the pipeline crown on the active ROW; however, it was not apparent on the abandoned pipeline segments. Open water areas existing along the abandoned pipeline segments are enhanced by beaver activity. This was considered consistent with the natural progression of rehabilitation of the pipeline corridor. Figure 8 shows the regeneration of wetland vegetation along the abandoned ROW.

The historical aerial photograph review confirmed that pipeline abandonment did not substantially alter the habitat and hydrology characteristics along the abandoned pipeline segments. In areas of the beginning and end points on the abandoned pipeline segments, there were no notable differences between the ROW and the parallel active ROW with regard to vegetation indicators, aside from different successional stages, depending on where the ROW was last cleared. Appendix A contains an aerial photographic review of the pipeline ROW before development and after abandonment.

Figure 7. View of Successional Upland Vegetation Looking North Along the Abandoned Pipeline ROW (left side of photo). Compare abandoned pipeline ROW to the active ROW (right side of photo) and undisturbed vegetation adjacent to both left and right sides of the photo.

Figure 8. View of Wetland Vegetation along the Abandoned Pipeline ROW (left side of the photo).

DISCUSSION

The field investigation did not identify any of the potential EE of abandoning a pipeline in place as theorized by the Canadian Energy Pipeline Association (CEPA) (2007) and Det Norske Veritas (DNV) (2010). The location of the abandoned ROW was both beneficial and detrimental to the investigation of the potential effects of pipeline abandonment.

This study took place within a corridor of active pipelines. The location of the abandoned pipeline ROW within an active corridor was beneficial to the investigators because it provided the opportunity to compare the abandoned ROW with an adjacent, active ROW, as well as an adjacent, undisturbed area within the same land use type. The drawback to the location of the abandoned ROW is that some of the potential EE may have been coincidentally mitigated by operations and maintenance activities along the adjacent active ROW. In order to conclusively determine that the potential EE of abandoning a pipeline in place were not observed, the same study would need to be undertaken along a single pipeline ROW.

This study was located in Northern Alberta, Canada, in an area mostly inundated with water. This landscape is beneficial to the observation of buoyant pipe caused by the displacement of product or decreased depth of cover. However, this landscape may have decreased the likelihood that evidence of subsidence, disruption of drainage patterns, or issues at watercourse crossings would be noted at the surface, given that the surface of the water would not likely change if there was subsidence along the ROW or if there was a disruption of drainage patterns. To conclusively determine that an abandoned pipeline may cause subsidence, disruption of drainage patterns, or issues at watercourse crossings, additional studies should be undertaken in different landscape types.

The abandoned ROW is located in a remote area and, as such, no permanent overland access or municipal maintenance records exist. The project team was not able to assess whether there was subsidence at frequently used roads. To conclusively determine that there is no subsidence associated with abandoning a pipeline in¬ place under a road or railway, additional studies should be undertaken in areas where road maintenance records exist.

Finally, this project only included a surface investigation of the abandoned pipeline ROW. The project team had hoped that evidence of groundwater penetration of the pipeline or subsidence could be determined in some locations and that sampling of adjacent material could inform whether contamination associated with product, pipeline degradation, cleaning practices, or pipeline coating could be better understood. A program where sampling adjacent soil and groundwater could still be conducted to determine possible risks associated with pipeline coatings and the degradation of the pipeline itself; however, in the absence of evidence showing the integrity of the pipeline itself (such as water conduits), it is considered unlikely that the same program could address risks associated with remaining undisplaced and/or mobile product or cleaning products. To better substantiate whether contamination is present, excavation of the abandoned pipeline would be required.

Additional studies are being undertaken by the PARSC in Canada and include a subsurface investigation of the same pipeline ROW studied and presented here, as well as a pipeline within an active corridor located within agricultural and developed land use types. It is hoped that the final body of research will provide information that stakeholders can use to inform their abandonment planning for new and aging infrastructure.

CONCLUSIONS

This investigation did not reveal any of the potential EE of abandoning pipelines in place as identified by CEPA (2007) or DNV (2010). Further investigation of pipelines abandoned in place across different landscapes and within single pipeline ROWs is required to provide a body of evidence to support the findings of this study.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Petroleum Technology Alliance of Canada and the Pipeline Abandonment Research Steering Committee for procuring this research project, and TransCanada for providing a case study.

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APPENDIX A.

APPENDIX A. HISTORICAL AIR PHOTOS

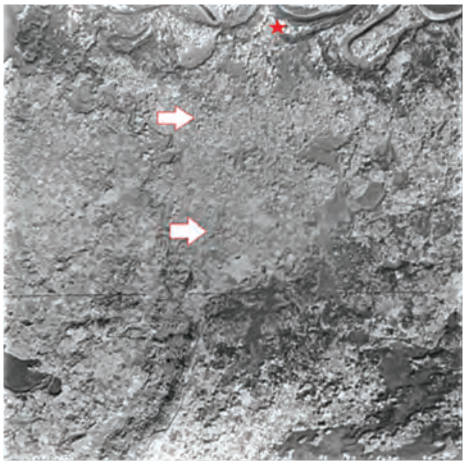

Plate C-1. White arrows show approximate beginning/end point locations prior to pipeline construction (September 1952). Red star provides landscape reference point.

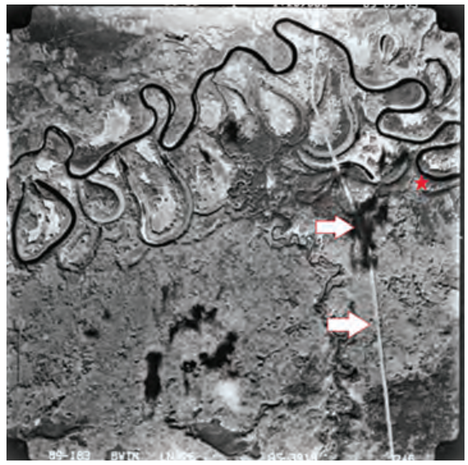

Plate C-2. White arrows show approximate beginning/end point locations after abandonment. The forest type and hydrology are similar (September 1989). Red star provides landscape reference point.

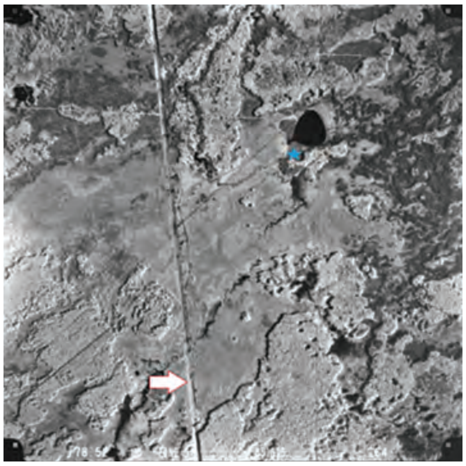

Plate C-3. White arrow shows the approximate screw anchor weight location, immediately following pipeline abandonment (June 1978). Blue star provides landscape reference point.

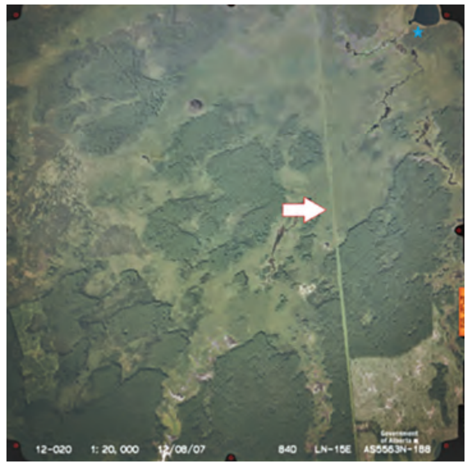

Plate C-4. White arrow shows the approximate screw anchor weight location decades following pipeline abandonment; hydrology is similar in this location (August 2012). Blue star provides landscape reference point.

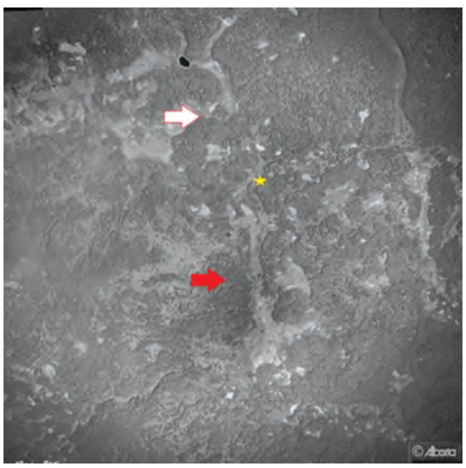

Plate C-5. White arrow shows the approximate location of a screw anchor weight and yellow arrow shows the approximate beginning/end point at NW 16-89-1 W6M, prior to pipeline construction (September 1950). Yellow star provides landscape reference point.

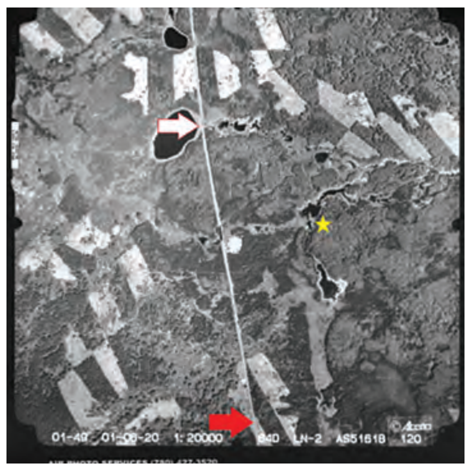

Plate C-6. A white arrow shows the approximate screw anchor weight location; hydrology is similar before and after pipeline abandonment; the forest has been cleared in this image. (June 2001). Yellow star provides landscape reference point.

ROW Management in Saskatchewan's Boreal North: Engaging Indigenous Communities and Power Utilities in Environmental Decision-Making

Tegan Brock, Maureen G. Reed, and Katherine Stewart

Keywords: Engagement, Government, Indigenous Peoples, Industry, Northern Saskatchewan, Stakeholders.

In Canada, management of rights-of-way (ROWs) is increasingly influenced by a societal climate that is shaped by multiple factors. Most notably, these include: political commitments to reconciliation between Indigenous and non-Indigenous peoples, evolving standards set by duty-to-consult case law, and the increasing role that Indigenous communities seek in decision-making and economic development opportunities in their traditional territories. Power utilities must recognize that Indigenous peoples hold rights that are distinct from stakeholders, and that the inclusion of Indigenous peoples requires an approach to engagement that is unique from the status quo. The objectives of the research include identifying principles and practices that support good-practice engagement with Indigenous peoples, and offering recommendations to inform future ROW management policies, strategies, and practices. Research findings suggest engagement efforts can generate trust and positive working relationships when practitioners start early, when they are considerate of Indigenous rights and interests, and when they support capacity-building and economic opportunities within local Indigenous communities. This work is relevant to a multitude of parties, and offers guidance for how practitioners can plan for and manage ROWs in a manner that minimizes their negative environmental and social impacts and enhances positive effects.

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INTRODUCTION

Today, power utilities are expected to engage with members of the public directly on large infrastructure and resource development projects (Doelle and Sinclair 2006; Papillon and Rodon 2016; Gelinas et al. 2017). The Government of Canada describes "public consultation" as the two-way communication between an authorizing agency or project proponent and the public (Canadian Environmental Assessment Agency 2016). Stakeholder engagement on the other hand is broadly understood to include communication with any groups or individuals that have a vested interest in a project decision or outcome. However, it is important for practitioners to understand that good-practice engagement with Indigenous groups requires recognition that Indigenous peoples are separate from non-Indigenous stakeholders, and they often carry distinct interests (Lane 2003; Coulthard 2007; Ruckstuhl et al. 2014).

The distinction between Indigenous and non-Indigenous stakeholders exists for a few reasons, including: Indigenous ancestry to the original inhabitants of North America and the corresponding distinct Indigenous identities, sovereignties, and relationship to place, as well as the diverse histories and relationships between Indigenous nations and the state (Makaa and Flera 2010; CanWEA 2017). Some scholars have coined the collective description of Indigenous distinctiveness as their "indigeneity" (Fleras and Maaka 2010). Together, these aspects of indigeneity often translate into expectations around process and practice that differ from those of non-Indigenous groups (Prno and Slocombe 2012; von der Porten et al. 2015; Wyatt 2016). Considering this difference, this paper uses the term "Indigenous engagement" to differentiate engagement with Indigenous peoples from stakeholder engagement.

Meaningful Indigenous engagement for ROW or natural resource projects is integral for successful project outcomes. Viewed another way, the risks of poor engagement with local Indigenous groups can be severe (CanWEA 2017; Franks et al. 2014). Insufficient Indigenous engagement can lead to the inadvertent exclusion of Indigenous interests and violations of trust among Indigenous peoples. Consequently, the absence of trust among local Indigenous leadership and community members may hinder right-of-way (ROW) planning and management through delayed timelines, or even through resistance to proposed projects. Potential for such unfavorable outcomes offers a strong motivation for practitioners to meaningfully engage with Indigenous peoples.

Research Purpose and Objectives

The purpose of this paper is to offer guidance to practitioners on how to better engage Indigenous communities on large infrastructure and natural resource management projects in order to effectively consider and integrate Indigenous rights and interests into project proposals and outcomes. The research objectives are to: 1) describe the multiple forms that Indigenous engagement takes; 2) identify principles and practices that support good engagement among proponents and Indigenous communities as a framework to inform future interactions among groups; and 3) offer recommendations to inform future policies, strategies, and practices. The work was conducted in the context of determining good strategies for public utilities seeking to employ an integrated vegetation management (IVM) strategy in Northern Saskatchewan; however, findings are transferable to other regions and apply across industries.

METHODS

This project took a qualitative and mixed-methods approach to data collection. Specific methods include field observations, semi-structured interviews, and group workshops. The first author spent three and a half months in the field with each research partner. The first period of fieldwork was situated in the Lac La Ronge Indian Band's Lands and Resources Management office, and the second took place in SaskPower's Indigenous Relations Department. During this time, the researcher was able to witness the day-to-day tasks, observe engagement "in action," and experience the institutional culture of each place. She was able to attend various events relevant to the research subject, including the community tour of a Collaboration Agreement that had been negotiated between the First Nation and a northern mining corporation, introductory meetings with Chief and Council and representatives from a mining company, a federal and provincial roundtable discussion about the duty to consult and accommodate, as well as a workshop geared towards government officials that focused on implementing the duty to consult policy.

Additionally, four workshops that centered on how participants understood the duty to consult and engagement were carried out. Two of these involved the partner First Nation Lands and Resources staff, leadership and land users, and another two involved employees from the partner utility's Indigenous Relations, Indigenous Procurement, and Environment Departments. Finally, interviews targeted people that are directly involved in engagement and consultation in Northern Saskatchewan and Alberta, and focused on three primary groups: industry, Indigenous community, and government. Interview questions addressed the ways in which participants conceptualize engagement with Indigenous peoples, participant roles in Indigenous engagement, elements that support good process and outcomes, barriers to good-practice engagement that they witness or experience, and potential solutions to those barriers. These questions derive from the research objectives, and are informed by the overall purpose to generate tangible and practical recommendations for improved Indigenous engagement. In total, 33 people were interviewed, including four mining company employees, seven provincial government officials, 10 Indigenous participants, and 13 utility employees.

Interview transcripts, field notes, and photos of notes from workshops were entered into a qualitative analysis program *NVivo*. Data was coded both inductively—as shaped by interview themes—and deductively, in response to themes raised by participants. Data analysis also involved a thematic and cyclical content analysis as described by Miles and Huberman (1994).

RESEARCH FINDINGS & DISCUSSION

Given that Indigenous engagement can take many forms, this section begins with a description of some of the predominant configurations of Indigenous engagement and the purposes it serves to fulfill, as raised by research participants. These configurations are discussed in relation to academic and grey literature. The authors then present a principles-and-practices framework that supports good-practice engagement with Indigenous communities, and highlights a few cases from the data that exemplify key principles. The framework is compared to principles and practices as presented in the literature, and findings are discussed in relation to distinguishing factors that set Indigenous engagement apart from stakeholder engagement.

What Constitutes Engagement? Diverse Configurations of Engagement

Indigenous engagement is cumulative of many activities in time and responds to a range of situations and drivers. Therefore, engagement takes a variety of forms depending on who is executing it and for what purpose. In Canada, "early" engagement by during project proposal development is required in order to attain regulatory approval. Beyond regulatory approval, government actively engages with Indigenous peoples to inform government decisions and policy, as well as to establish and maintain good relationships and trust among the Indigenous population. Indigenous communities participate in external engagement with industry and government, while also engaging internally with their band members on a wide range of issues. Lastly, industry engages with Indigenous peoples with the principle objective of achieving a social license to operate (SLO) in a region, which is sometimes framed as seeking local acceptance of their project. In this sense, Indigenous engagement necessitates the building of trust among local Indigenous groups, which is often sought after in the following ways:

1. Where relevant, addressing historical grievances related to existing resource development legacies. This can be done through negotiations to reconcile historical harms via compensation and to mend relationships through proponent commitments to support community programs, and through community donations.
2. Providing economic support and economic inclusion by offering training and employment opportunities to Indigenous community members and Indigenous-owned businesses.
3. Sharing in project benefits through business partnerships or collaboration agreements.

These mechanisms for building trust are supported by various domains of academic literature. As some scholars note, acknowledging and addressing past experiences that Indigenous peoples have had with industry and government is an effective way to reduce the legacies of distrust that may prevail in Indigenous communities (Ansell and Gash 2007; Adams et al. 2014; Halseth et al. 2016). Community engagement carried out for the purpose of achieving a SLO is prevalent in the academic literature on industry-community relations. Moreover, research by Lacey et al. (2017) found that the degree of benefits-sharing in engagement arrangements contributes to local community perceptions of distributional fairness, which—as the authors suggest—is fundamental to shaping company-community relationships. Literature on industry-community relations also illustrates that Impact and Benefit Agreements or Collaborative Agreements between companies and Indigenous communities have become a common tool used by industry to formalize terms for benefits-sharing and to attain Indigenous social license to operate within traditional territories. While these formal agreements are not without shortcomings, they remain representative of the increasingly standardized practices being employed to prioritize Indigenous autonomy in respect to resource development in their lands (Peterson, St. Laurent, & Billon 2015). Moreover, in the context of the forestry industry, Wyatt (2016) alludes to both formal and informal economic partnership, such as training, Indigenous employment, and economic development opportunities as a type of Indigenous engagement that contributes to the development of social infrastructure in communities.

Supporting Effective Engagement with Indigenous Peoples: Guiding Principles and Practices

Results from interviews and focus groups revealed six key principles that support good-practice engagement among industry, Indigenous peoples, and government, along with one core value that underlies each principle. The six principles are: accountability and transparency, mutual respect and commitment, effective communication, reliability, flexibility, and inclusion; the core value is recognition and honor of Indigenous identity and self-determination. There is strong interrelation between the principles, and many practices exemplify more than one principle.

Examples from the Field

A mining company that took ownership of an existing mine in the Lac La Ronge Indian Band's traditional territory took immediate steps towards building a positive relationship with the First Nation. Firstly, they began with an introductory meeting with the Lands and Resources Management Board, which is an arm of the band's formal governing body, Chief and Council. In this meeting, company representatives acknowledged that the mine operates within Indigenous homeland, and recognized that the community and local land users will remain in the area beyond the life of the mine. In lieu of these acknowledgements, company representatives stated that they strive to be good neighbors, and intend to leave a positive legacy—both socially and environmentally—once the mine is decommissioned. In the conversation that ensued, both the company and First Nation took time to understand one another through presentations and questions. Furthermore, company representatives inquired about the former mine owner's relationship with the band. By identifying the capacities, interests, and needs of each other, the company and First Nation were able to develop a base-level understanding about how they may work together moving forward. Moreover, and perhaps most importantly, approaching the First Nation immediately after the transfer of ownership, and with openness to mutual learning on both groups' behalf, demonstrates mutual respect and the willingness to work together through effective communication. Employees from the company have followed up on the First Nation's invitation to attend multiple culture camps in the area, and have committed donations to supporting those events. The company also prioritizes the hiring of Lac La Ronge Indian Band members, and is working towards building skills among the workforce to integrate band members into positions beyond entry-

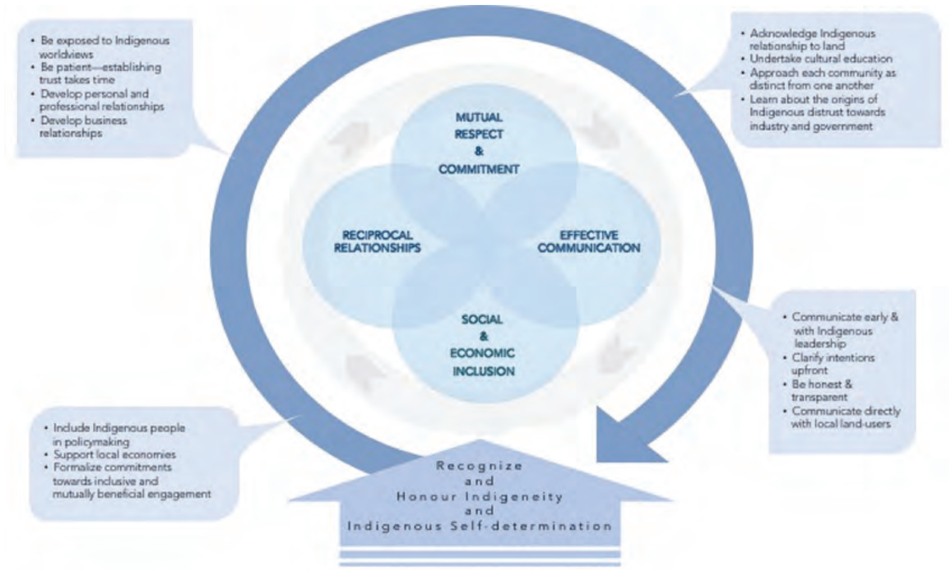

Figure 1. A framework outlining key principles that support effective engagement with Indigenous peoples, informed by a core value that distinguishes Indigenous engagement from stakeholder engagement

Practicing Accountability & Transparency

- Clarity about intentions at the start
- Sharing all relevant information in an accessible way
  - Visuals, layman's terms
  - Indigenous languages
  - Site visits
- Explaining abilities and limitations
- Follow-through on commitments
- Admitting to not having answers; follow-up to provide them
- Maintaining open door to questions beyond meetings
- Keeping a track record of all communication

Table 1. Practices That Exemplify Accountability and Transparency

Practicing Mutual Commitment & Respect

- Learning about Indigenous rights and interests
- Taking the lead from Indigenous community leadership
- Learning about the community
- Demonstrating humility and patience
- Following local protocols
- Commiting to long-term engagement, planning together, problem-solving, & negotiation
- Remaining open to learning
- Formalizing commitments to improve working relationships with Indigenous peoples

Table 2. Practices That Exemplify Mutual Commitment and Respect

level jobs. A year following this meeting, the mining company and First Nation continue to develop a positive working relationship that yields mutual benefits. Such a relationship has been shaped by the principles of mutual respect and a shared commitment to work together. Growth of the relationship is also rooted in the principles of reliability and Indigenous inclusion.

There are numerous examples of more formal business partnerships between industry and Indigenous businesses in Northern Saskatchewan. Oftentimes, business partnerships are developed through in-kind and financial support from the industry to assist in joint ventures, or to enable existing Indigenous businesses to expand the type of work they do. A small Métis community in Northern Saskatchewan was able to grow their local business—which commits funds directly to the community—through a business development contract with a company with whom they share a Collaboration Agreement. By entering into this contract, both entities committed to working with one another to improve the Indigenous business' capacity administratively, as well as through on-site skills training of Indigenous employees. Business growth was also achieved through a bridge loan offered by the company to enable the Indigenous business to expand their operations and take on more contracts. A few hundred miles northwest of this community, a First Nation-owned business sought an opportunity to take on a contract for work that they had little experience doing. In spite of this, the band-owned business and a power utility fulfilled their own respective legwork that enabled the First Nation business to build their capacity and complete the project successfully. The success of this project stems largely from effective communication, patience, and a willingness to work together.

Additionally, both of these examples demonstrate that positive outcomes

Practicing Effective Communication

- Communicate early
- Communicate with Indigenous leadership first
- Discuss category of meeting: is it consultation or engagement?
- Communicate with grassroots people
- Cater information to audience
- Build from pre-established relationships
- Carry out open and truthful conversations
- Actively listen to community members
- Listen to concerns that may seem unrelated to the project
- Record community input
- Demonstrate how information has been integrated into project plans

Table 3. Practices That Exemplify Effective Communication

Practicing Reliability

- Staying in contact with community
- Following up with phone calls
- Being present in communities outside of business-related matters
- Establishing avenues to support consistent communication
- Formalized agreements, such as MOUs, Collaboration and Benefit Agreements help to entrench reliability for all groups

Table 4. Practices That Exemplify Flexibility

Practicing Flexibility

- Set flexible timelines; expect delays
- Let Indigenous leadership guide engagement
    - Tailor engagement to capacity of communities
    - Cater engagement to the community's pace
- Develop adaptable business practices
- Maintain availability for after-hour communication
- Recognize that indigenous leadership might change
- Be open to doing things differently

Table 5. Practices That Exemplify Flexibility

arise from inclusion, as well as from flexibility and trusting in the reliability of partner groups. Participants in both of these examples regard them as win-win situations: Indigenous peoples acquire training, employment, and revenue, while industry benefits from a local company that they can rely on for contractual work in the area alongside a slightly lessened economic dependency on their operations. For small remote communities that lack resources and whose members experience poverty and other repercussions of colonization, supporting local Indigenous businesses is a useful way to build local self-sufficiency, and also to generate an income that can be used to improve the quality of life for community members.

As many participants emphasized, project success is contingent on the existence of trust between communities and proponents, particularly when it translates into local acceptance and support for projects. This finding is supported by SLO scholars, who note that the degree of social license is indicative of the quality of relationship between the company and "host communities" (Kemp et al. 2006; Moffat et al. 2015). Framed in the context of community relations and successful industry operations, effective engagement is purported to cultivate mutual understanding, trust, and support between a company and local communities (Kemp et al. 2006; Lacey et al. 2017). Additionally, like any relationship, social acceptance or SLO needs to be acquired and maintained, and is also vulnerable to diminishment (Parsons and Moffat 2014).

Practicing Inclusion

- Notify communities early
- Meet with leadership prior to developing plans
- Be willing to collaborate
- Keep communities informed
- Economic inclusion:
    - Train and hire local people
    - Prioritize contracts for local Indigenous businesses
- Seek opportunities to complement existing community projects
- Negotiate Collaboration and Benefit Agreements

Table 6. Practices That Exemplify Inclusion of Indigenous Peoples' Rights and Interests

Principles and Practices Supporting Indigenous Engagement in the Literature

Many components of this good-practice Indigenous engagement framework are widely supported by academic and gray literature. For example, within the domain of electricity production in Canada, a recently published renewable energy association's policy and national utility organization's list of guiding principles for engaging Indigenous peoples cite the importance of respect for Indigenous identity, rights, and interests, and emphasize the significance of cultivating constructive relationships that are long term and grounded in trust, collaboration, and accountability (Canadian Electrical Association 2016; Canadian Wind Energy Association 2017). Natural resource co-management scholars also reference the importance of building relationships among participant groups defined by the shared understanding of one another, mutual respect, and mutual commitments to collaborate (Goetze 2005; Fernandez-Gimenez et al. 2008). Furthermore, scholars who work collaboratively with Indigenous peoples cite the importance of being patient when developing relationships with them, and suggest that this can be achieved by being present, demonstrating mutual respect, facilitating a shared understanding through the exchange of information, and welcoming collaboration (Hacker et al. 2012; Tondu et al. 2014; Halseth et al. 2016).

The Canadian Electrical Association's (CEA) National Principles for Engagement of Aboriginal Peoples (2016) also support the framework's principles of Indigenous inclusion by stating industry's role in stimulating capacity-building in Indigenous communities through education, employment, and skills training, as well as through the promotion of economic prosperity that achieves mutually beneficial business outcomes. As has been addressed earlier, the natural resource extraction community-relations scholarship supports the economic inclusion of Indigenous peoples via industry partnership as a means to generate benefits-sharing in local communities. Collaboration with Indigenous peoples is also an importance means to achieve Indigenous inclusion. After extensive public consultation on existing environmental assessment (EA) procedures, proposed reform to Canada's Impact Assessment regulations focuses in part on partnership with Indigenous peoples, recommending a shift towards cooperation and partnership with Indigenous peoples that is founded on the recognition of Indigenous rights (Government of Canada 2017). Both gray and academic literature advocates for partnership and collaboration with Indigenous peoples, exemplifying the framework's principles of Indigenous inclusion, reliability, and mutual commitment, as well as the core value of respecting and honoring Indigenous self-determination.

Recognizing Honoring Indigeneity and Indigenous Self-Determination

Ultimately, engagement that is rooted in mutual respect will build trust with Indigenous peoples, and can cumulate in positive working relationships. In order to reach this outcome, proponents must recognize that Indigenous rights and interests are distinct from those of non-Indigenous stakeholders, and that Indigenous groups are self-determining nations that bare unique relationships with the state (Fleras and Maaka 2010; Wyatt et al. 2010; von der Porten et al. 2015). A good way to start Indigenous engagement is by learning about local Indigenous identities and community characteristics, such as their rights, histories, demographic, governance structures, protocols, and past relationships with the industry and the state (CanWEA 2017). Moreover, approaching Indigenous communities with the recognition that a proposed project is within their lands that they bare autonomy over, along with a demonstrated willingness to work with them, and a desire to learn about their rights, interests, and concerns, exhibits respect and can go a long way towards building trust early on (von der Porten et al. 2015; Wyatt 2016; CanWEA 2017).

Recommendations for Future Practice

The following list of recommendations comes from participant suggestions as well as academic and gray literature:

- Approach Indigenous communities as self-determining nations that are distinct from non-Indigenous communities.
- Take the lead from Indigenous leadership and remain open to non-Eurocentric ways of doing things.
- Formalize institutional policies, such as:
    - o Indigenous Relations or Indigenous Engagement Policy
    - o Indigenous Procurement Policy
    - o Ensure business model facilitates early Indigenous engagement and ensures Indigenous input helps to shape project proposal development
- Educate employees on Indigenous rights, histories, and knowledge systems
- Recognize past experiences and how they inform current experience
- Build capacity to enable enhanced Indigenous participation:
    - Through committing funds and in-kind support to build Indigenous governance capacity, including funding Traditional Land Use Studies
    - Through economic opportunity and business partnership with Indigenous peoples
    - Through education on the history of Indigenous peoples, cultural competency, and social learning among industry employees
- Create opportunities for relationship-building among company employees and Indigenous leadership and membership
- Support local and non-extractive economic endeavors within traditional territory to build self-sufficiency within local communities

CONCLUSIONS

This research offers guidance to practitioners on how to effectively work with Indigenous peoples in the context of planning for power utility development in traditional territory. The good-practice engagement framework is a useful addition to the literature by offering examples of tangible practices that can lead to effective Indigenous engagement. These practices, together with concise recommendations, orient practitioners in the right direction—one towards cultivating positive relationships with Indigenous peoples. Research findings are applicable beyond Northern Saskatchewan, offering insight and guidance to ROW managers in other regions, as well as to broad industry practitioners, government officials, researchers, Indigenous businesses, and Indigenous leadership.

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AUTHOR PROFILES

Tegan Brock

Brock is interested in the ways industry and government include Indigenous communities in their decision-making processes within traditional territory. She is part of a transdisciplinary research project that involves the U of S Department of Soil Sciences, the School of Environment and Sustainability, as well as industry, the Saskatchewan government, and a First Nation community in Saskatchewan's boreal north. Her masters focuses on "good practice" Indigenous engagement, and how this process can be a mechanism to foster trusting relations between the many people involved in land-use decision-making at local levels.

Maureen G. Reed

Professor Maureen G. Reed is currently Professor at the University of Saskatchewan where she teaches in the graduate program of the School of Environment and Sustainability. Since 2010, she has worked on a national advisory committee (Canada-MAB) that provides guidance to the Canadian Commission for UNESCO on managing its program related to World Biosphere Reserves in Canada. Reed is particularly concerned to explain how rural communities practice sustainability and demonstrate resilience in the face of both rapid and slow-moving environmental, social, economic, political, and cultural change.

Katherine J. Stewart

Stewart examines biologically mediated nitrogen input and nitrogen cycling in arctic, alpine, and boreal ecosystems to identify means of restoring sustainable pathways that promote long-term ecosystem health. Her research group works with below-ground soil systems, early successional soil surface communities, and native vascular plants, allowing for an integrated approach to examining both the impact and remediation of contaminants in the environment. Collaborating with industrial partners across northern Canada, she works to develop soil amendment technology and practices for the reclamation and restoration of plant-soil systems impacted by hydrocarbons, heavy metals, and herbicides.

Siting the Manitoba-Minnesota International Powerline Using the EPRI-GTC Siting Methodology

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Maggie Bratland, and
James Matthewson

Keywords: Alternative Route Evaluation, Analytical Hierarchy Process, EPRI-GTC Siting Methodology, GIS, Manitoba Hydro, Multi-Criteria Decision-Making, Suitability Analysis, Team Choice, Transmission Line Routing, Transmission Line Siting.

Manitoba Hydro plans to construct a 213-kilometer (km), 500-kiloVolt (kV) electric transmission line from Winnipeg to the U.S. border, where it will connect to the Great Northern Transmission Line being built by Minnesota Power. Manitoba Hydro elected to utilize the EPRI-GTC Electric Transmission Line Siting Methodology as a framework for the route selection process.

Workshops were conducted to gain local input required to calibrate the siting models. A large volume of information was evaluated leveraging GIS technology and expert judgement. Finally, the preferred route was selected and presented to the Manitoba Clean Energy Commission, who conducted public hearings. In their report, the Commission stated, "In summary, the structured decision-making embedded in the EPRI-GTC methodology represents a significant positive step compared to previous route selection processes. It produced a clear record of the factors that led to decisions and the trade-offs and compromises made."

This paper will review the process used to calibrate the methodology for use in Manitoba with local input. It will also describe how this input was used to drive the ultimate selection of the preferred route. Finally, the paper will offer lessons learned and tools that may benefit others who wish to complete a similar project.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Manitoba Hydro, a Crown Corporation, is the province's major energy utility established to provide power for the needs of Manitobans. They are headquartered in Winnipeg, Manitoba, Canada and serve 573,438 electric and 279,268 natural gas customers.

Manitoba Hydro plans to construct the Manitoba–Minnesota Transmission Project (MMTP), which includes a 213-kilometer (km), 500-kilovolt (kV) transmission line running from the Winnipeg, Manitoba, Canada, area to the U.S. international border at Minnesota. From there, the line will connect with the new Great Northern Transmission Line, planned by Minnesota Power, and will then run nearly 400 km to an area approximately 100 km northwest of Duluth, Minnesota, U.S. (see Figure 1). This project will allow Manitoba Hydro to import and export to and from the U.S., improve reliability for Manitoba power users by increasing the capacity to purchase electricity in emergency or drought situations, and increase Manitoba Hydro's ability to participate in organized electricity markets in the U.S.

The siting process started in 2013. The Project is currently under review by provincial and federal regulators. Pending receipt of approvals, Manitoba Hydro plans to have the MMTP in service in 2020.

Manitoba Hydro elected to utilize the EPRI-GTC Electric Transmission Line Siting Methodology as a framework for the route selection process. In 2003, the Electric Power Research Institute (EPRI) and Georgia Transmission Corporation (GTC) co-sponsored a research project to develop a standardized method for siting transmission lines based on the geographic information system (GIS)-based siting process being used at GTC. EPRI published a report describing the methodology in 2006 (EPRI 2006). Manitoba Hydro selected the EPRI-GTC Siting Methodology as the basis for their routing process because it was a proven process that offered a structured

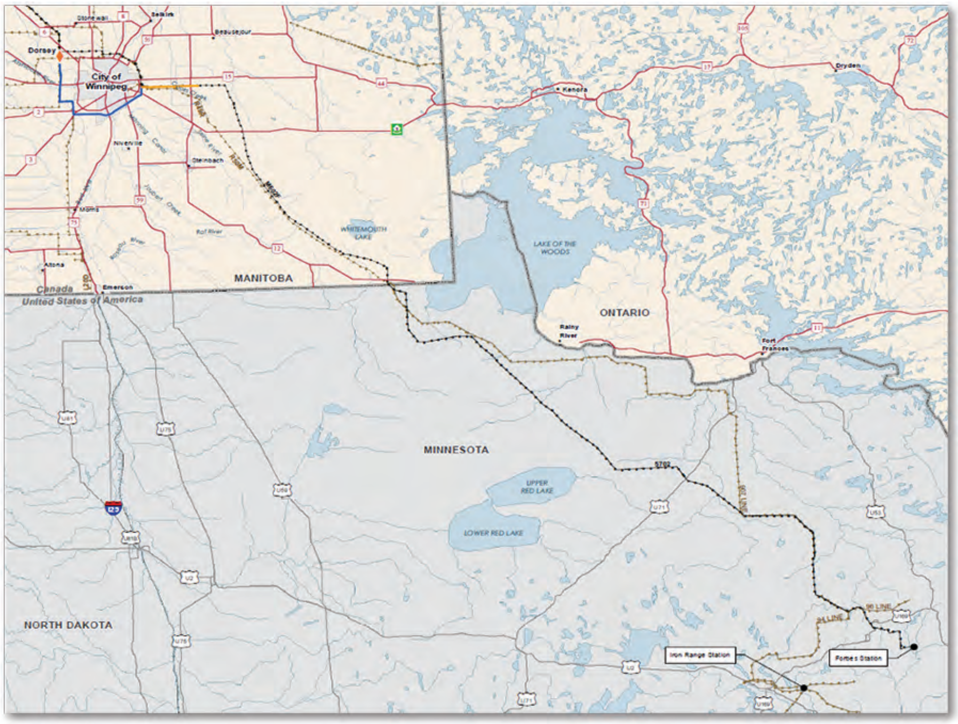

Figure 1. Project Location Map

decision-making process, included transparent documentation of the reasons for decisions, and allowed input from stakeholders, indigenous communities and organizations, and the public to be factored in early in the process.

GTC is a transmission cooperative based in the southeastern U.S. EPRI is an international non-profit industry organization that provides thought leadership, industry expertise, and collaborative value to help the electricity sector identify issues, technology gaps, and broader needs that can be addressed through effective research and development programs for the benefit of society.

In order to implement the EPRI-GTC Electric Transmission Line Siting Methodology (Siting Methodology) workshops were conducted to gain local internal and external input required to calibrate the siting models to the Manitoba context. A large volume of information was evaluated leveraging GIS technology and expert judgement. Finally, the preferred route was selected. An environmental assessment (EA) was conducted on the preferred route and the results were filed in application for approvals from Manitoba Sustainable Development (formerly Manitoba Conservation and Water Stewardship) and the National Energy Board (NEB).

The provincial review included hearings conducted by the Manitoba Clean Environment Commission, tasked by the provincial Minister to review the Project and consider public input. In their report, the Commission stated, "In summary, the structured decision-making embedded in the EPRI-GTC methodology represents a significant positive step compared to previous route-selection processes. It produced a clear record of the factors that led to decisions and the trade-offs and compromises made."

This paper will review the process used to calibrate the Siting Methodology for use in Manitoba with local input. It will also summarize how this input was ultimately used to guide the selection of the preferred route. Finally, the paper will offer lessons learned and tools that may benefit others who wish to complete a similar project. Additional information and a detailed description of the siting process for the MMTP can be found in the EPRI Report (EPRI 2006) and Chapter 5 of the MMTP Environmental Impact Statement (EIS) (Manitoba Hydro 2015).

METHODS

The 2006 EPRI report (EPRI 2006) documented the "state of the art" Siting Methodology at the time. Since that time, the Siting Methodology has been applied in other jurisdictions within a variety of physical and social environments. Because of differences between these environments, the methodology has also often been enhanced in those other jurisdictions. As with many standard processes, it has been refined within the last few years. The implementation of the methodology varies from one jurisdiction to the other. Following are common themes for projects that use the Siting Methodology:

1. Use a data-driven objective process.
2. Leverage external stakeholder input from representative organizations to help calibrate the Alternative Corridor model using the Analytical Hierarchy and the Delphi processes.
3. Rely on siting experts to identify Alternative Routes using the Alternative Corridors as a guide.
4. Leverage internal experts to calibrate the Alternative Route Evaluation Model.
5. Use the Alternative Route Evaluation Model to help identify the top routes.
6. Leverage internal expert judgment to calibrate the Preference Determination Model (also known as the Expert Judgment Model).

Calibrating the Corridor Model with Stakeholder Input

A unique feature of the Siting Methodology is the framework for gathering and infusing stakeholder input early into the siting process. Transmission line siting projects gain input from stakeholders using a variety of methods at various stages throughout siting projects. In addition to the project-specific public engagement process, the EPRI-GTC Siting Methodology gains external stakeholder input from representative organizations on a programmatic basis. This input can be leveraged on multiple siting projects within the area of focus. Manitoba Hydro chose to invite stakeholders from representative organizations to provide input regarding the siting criteria used for siting transmission lines in Southern Manitoba. The resulting model has been used on multiple projects, including the MMTP.

The Alternative Corridor Model was calibrated through a three-day workshop hosted by Manitoba Hydro at their offices in Winnipeg in May 2013. Thirty-six representative organizations were invited, who sent 30 participants to the workshop. After reviewing the methodology, the participants refined the siting criteria within their area of expertise. Once the criteria were established, the stakeholders provided quantitative input processed through multiple rounds of discussion and consensus building. The stakeholders who participated in this workshop defined the criteria, the relative suitability of areas to host a transmission line, and the relative importance of criteria. This resulted in the Southern Manitoba Alternative Corridor Model.

The Manitoba Hydro team facilitated a workshop over three days focusing on a single perspective each day. For example, one day the engineering stakeholders participated and provided input to calibrate the Engineering Model. The other two days focused on the Natural and Built Models.

The stakeholders represented a broad range of interests:

Engineering Perspective

- Manitoba Infrastructure and Transportation road design engineers and railroad design engineers
- Manitoba Hydro electric system planners, transmission line design engineers, and natural gas engineers

Natural Perspective

- Fisheries and Oceans Canada
- Ducks Unlimited
- Nature Conservancy of Canada
- Protected Areas Initiative
- Manitoba Conservation and Water Stewardship Office
    - o Parks and Natural Areas Branch
    - o Wildlife Branch
    - o Forestry Branch
- Manitoba Woodlot Association
- Manitoba Trappers Association
- Manitoba Bird Atlas
- Manitoba Lodge and Outfitters Association
- Manitoba Hydro environmental specialists
- Manitoba Trappers Association
- Seine-Rat River Conservation District

Built Perspective

- Keystone Agricultural Producers
- University of Manitoba
- Manitoba Aboriginal and Northern Affairs
- Manitoba Agriculture, Food and Rural Initiatives
- Manitoba Culture, Heritage and Tourism
- Local Government Planners
- Manitoba Aerial Applicators Association
- Manitoba Hydro real estate specialist
- Ruth Marr Consulting
- Manitoba Trappers Association
- City of Winnipeg - Planning Department

The first step to calibrate the suitability models was to review and refine the siting criteria for each perspective. The

Engineering	
Linear Infrastructure	**35.7%**
No Linear Infrastructure	1
Unutilized ROW (Manitoba Hydro Owned)	1.2
Parallel Existing Transmission Lines (<300kV)	3.8
Parallel Roads ROW	5
Parallel Provincial Highways ROW	5
Parallel Oil / Gas Transmission Pipeline	7
Parallel Railway ROW	7
Future MIT Plans	7.8
>= 300 kV Transmission Line/Within Buffer	8.5
Within Road, Railroad, or Utility ROW	9
Spannable Waterbodies	**10.4%**
No Waterbody	1
Non-Nav. Spannable Waterbody (Standard Structures)	2.8
Nav. Spannable Waterbody (Standard Structures)	4.3
Non-Nav. Spannable Waterbody (Specialty Structures)	6
Nav. Spannable Waterbody (Specialty Structures)	9
Geotechnical Considerations	**30.2%**
Rock	1
No Special Geotechnical Considerations	1.3
100 Year Floodplain	6.6
Wetland / Peatlands	9
Mining Operations / Quarries	**13.2%**
No Mining Operation	1
Abandoned / Inactive Mines (Aggregate Piles, Pits, etc)	6.5
Mine-Owned Land	9
Slope	**5.4%**
Slope 0 - 15%	1
Slope 15 - 30%	3.1
Slope > 30%	9
Proximity to Future Wind Farms	**5.1%**
500m - 10k	1
> 10k	9

Natural	
Aquatics	**10.0%**
No Aquatic Feature	1.0
Ephemeral Streams (Non-Fish Bearing)	4.9
Spannable Waterbodies (Lakes & Ponds)	6.1
Ephemeral Streams (Fish Bearing)	6.3
Swamps	6.8
Ephemeral Streams (CRA Fish Bearing)	6.9
Riparian Floodplain	7.1
Permanent Stream	7.5
Bogs	7.7
Fens	8.2
Marsh	8.2
Permanent Stream (CRA Fish Bearing)	9.0
Special Features	**42.4%**
No Special Land	1.0
Managed Woodlots	5.4
Crown Land With Special Code	7.0
Community Pastures	7.3
Flyways	7.5
Areas of Special Interest (ASI)	7.8
Recreation Provincial Park (Non-Protected Portions)	8.0
Conservation Easements	8.0
Wildlife Management Area (Non-Protected Portions)	8.2
Proposed Protected Areas	8.6
Heritage Rivers	8.7
Important Bird Areas	8.7
Heritage Marshes	8.9
Conservation Lands	8.9
Natural Provincial Park (Non-Protected Portions)	9.0
Land Cover	**10.2%**
Exposed / Urbanized / Open Land	1.0
Agricultural (Forage)	2.5
Agricultural (Crops)	2.8
Burnt Areas	4.9
Grassland	5.0
Decidious Forest	5.5
Coniferous Forest	5.7
Mixed Forest	6.0
Non-Developed Sand Hills	8.1
Native Grassland	9.0
Wildlife Habitat	**37.4%**
Other	1.0
Ungulate Habitat (High)	6.1
Waterfowl Habitat (High)	6.3
Waterfowl Paired Density (High)	6.9
Waterfowl Hotspots (High)	7.0
Grouse Lek Area	7.7
Rare Species Habitat	8.0
Critical Habitat	9.0
Endangered Species Habitat	9.0

Built	
Proximity to Buildings	**10.0%**
> 800 m	1
400 - 800 m	2.7
100 - 400 m	6.5
ROW - 100 m	9
Building Density	**15.0%**
< 1 Building / Acre (Rural Agricultural)	1.0
1 Building per 1-5 acres	2.8
1-3 Buildings/Acre (Rural/Residential)	3.7
3-10 Buildings / Acre (Suburban)	7.2
>10 Buildings / Acre (Urban)	9.0
Proposed Development	**3.7%**
No Proposed Development	1.0
Proposed Development – Industrial	3.0
Proposed Development – Agriculture	4.1
Proposed Development - Commercial	5.1
Permitted Development	6.9
Proposed Development - Rural Residential Zoning	6.9
Proposed Development - Urban Zoning	9.0
Soil Capability & Agricultural Use	**11.9.%**
Other	1.0
Class 6 & 7 (Low Productivity)	3.3
Organic Soils / Peat Bogs / Sod Production	3.9
Artisanal Farms / Wild Rice	4.3
Class 4 & 5 (Forages, Transitional)	5.9
Class 1- 3 (Prime Ag./Cultivated Land)	9.0
Land Use	**16.0%**
Forest	1.0
Open Land (Sand & Gravel)	1.5
Industrial	1.6
Burnt Areas	1.8
Active Forestry Operation	2.3
Hunting / Trapping Locations	3.9
Listed Trails (Existing & Planned)	4.6
Organic Farming	5.5
WMAs (Unprotected)	5.8
Agricultural (Forage)	4.9
Out-of-Park Recreational Development	6.4
Agricultural (Crops)	6.6
Intense Development & Use	6.5
500m Buffer of Irrigated Land	6.6
Intensive Livestock	6.9
In-Park Recreational Development	7.9
Institutional	7.4
Agricultural (Aerial Application)	8.9
Irrigated Land	9.0
National/Provincial/Municipal Historic Sites	**12.0%**
> 300 m	1.0
200 - 300 m	9.0
Proximity to Heritage Sites	**12.0%**
> 300 m	1.0
200 - 300 m	9.0
Landscape Character (Viewsheds)	**7.8%**
Other	1.0
Recreational Trails	4.1
Cottage Subdivisions	6.1
Scenic Provincial Trails & Roads	6.8
Escarpments (Timeless Topography)	7.5
Resort Lodges & Campgrounds	8.6
Residential	8.9
Designated Historic Sites	9.0
Edge of Field	**11.7%**
Road Allowances	1.0
Drains	1.8
Quarter Section / Half-Mile Lines	2.0
Vacant Rail ROW	2.1
Parallel/Adjacent To Road Allowances	2.8
Other (None of the Above)	9.0

Areas of Least Preference
Wastewater Treatment Areas
Buildings
Oil Well Heads
Waste Disposal Sites
Towers and Antennae
Existing Wind Turbine
Military Facilities / Past Military Installations
Protected Areas
Special Conservation Areas/Ecological Reserves
Non-Spannable Waterbodies (>300 m)
World Heritage Sites
Wildlife Refuge
Mines and Quarries (Active)
Contaminated Sites
Wildlife Management Area (Protected Portions)
National Parks
Wilderness/Heritage Provincial Park
Indian Reserves / TLE Selections
Campgrounds & Picnic Areas
Airports/Aircraft Landing Areas (glide path)
Recreational Centers (Golf, Skiing, etc.)
Federal/Provincial/Municipal Heritage Sites
Provincial Park Reserves
Heritage Plaques
Schools / Day Care Parcels
Cemeteries / Burial Grounds
Recreation / Natural Provincial Park (Protected Portions)
Known Archaeological Sites
National,Provincial,Municipal Historic Sites
Religious / Worship Site Parcels

Table 1. Southern Manitoba Alternative Corridor Model

facilitators demonstrated the preliminary criteria based on models developed in other areas. Next, the stakeholders had a discussion regarding local criteria and local data sets that could be used. This resulted in siting criteria categorized by perspective. Table 1 lists the siting criteria that resulted from the workshops. It should be noted that in order to model the relative suitability of features on the landscape, geospatial data needed to be available to represent the features identified by the stakeholders. In some cases, project specific data was created such as the mapping of buildings (see Corridor Model in Table 1).

Once the siting criteria was identified, the features in each layer were calibrated to assign relative suitability for a transmission line in Southern Manitoba. The team used the Delphi process to build consensus. Following is a brief description of this process. Additional information can be found in the EPRI Report (EPRI 2006). Each participant assigned a relative suitability value to the features within a layer. Each layer must contain a 1 (most suitable) and a 9 (least suitable). Other features within the layer were rated based on their relative suitability. The participant's ratings were anonymously presented to the group and evaluated using the mean, standard deviation, maximum, minimum, and median values.

In some cases, stakeholders realized that they used incorrect assumptions when entering their ratings and wished to update their ratings. The group participated in a facilitated discussion for those items where there was a higher deviation in the ratings. For example, if one stakeholder valued paralleling roads as the most suitable feature, and another stakeholder thought this was the least suitable place for a new transmission line, then there was an opportunity to expressing opposing viewpoints in a constructive manner. After discussion, participants had the opportunity to update some, all, or none of their ratings. This continued for a couple of rounds or until the facilitator was convinced that the group was as close to a consensus as reasonably possible. In the end, the ratings were averaged to produce suitability values for each perspective. Please see the suitability values (in yellow boxes) (1-9) in the Corridor Model (Table 1).

After the suitability values were calibrated, the group used the Analytical Hierarchy Process to weigh the relative importance of each layer within the perspective. Following is a brief description of this process. Additional information can be found in the EPRI Report (EPRI 2006). The stakeholders were asked to compare each layer to every other layer in pairs. This is called a pairwise comparison. In each comparison, the participant was asked which group of criteria (i.e. GIS layer) is more important when siting transmission lines. The participants

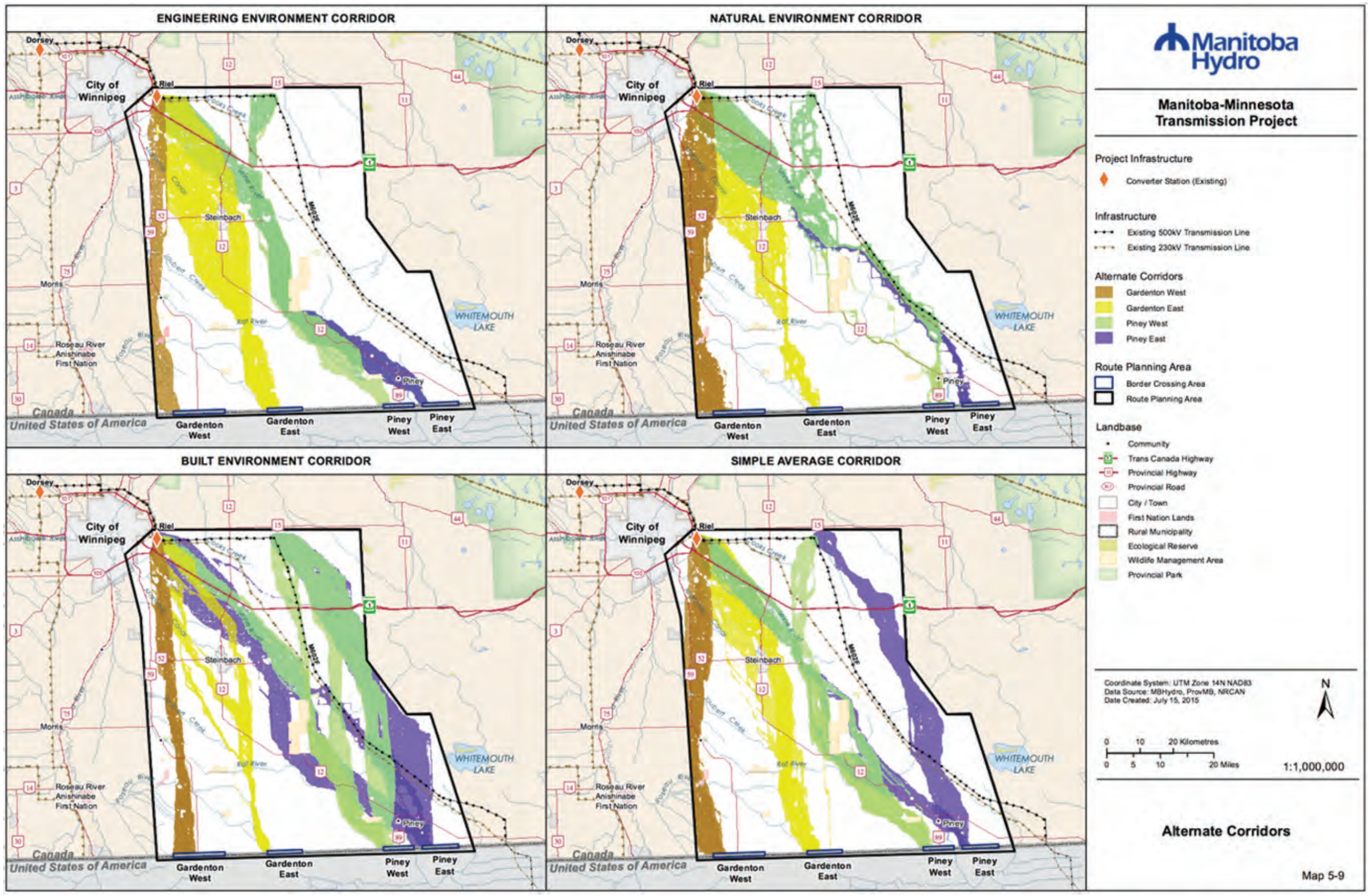

Figure 2. Alternative Corridors

could choose equal importance or they could rate one layer as more important than the other on a sliding scale.

Similar to the feature rating process, each user completed a survey in order to provide their input and the results were anonymously presented to the group. The group evaluated the results using the mean, standard deviation, maximum, minimum, and median values. The consistency ratio was evaluated to help ensure the judgements were consistent. To check if opinions are consistent in scoring, a Consistency Ratio, which is a comparison between Consistency Index and Random Consistency Index (RI), or in formula: CR = CI / RI. (Although not required, the goal is to keep this ratio below 10 percent.) After discussion, participants had the opportunity to update some or all of their answers. This continued for a couple of rounds or until the facilitator was convinced that the group was as close to a consensus as possible. In the end, the ratings were averaged to produce relative weights, expressed as percentages, for each layer. Please see the layer weights values (green cells) (percent) in the Corridor Model (Table 1).

In summary, workshop participants first refined the list of siting criteria based on local considerations. Next, they assigned suitability values to the features within each layer on a 1-9 scale using the Delphi process. Finally, they assigned relative importance weights to the layers using the Analytical Hierarchy Process. This resulted in the Southern Manitoba Alternative Corridor Model [Table 1].

ALTERNATIVE CORRIDOR IDENTIFICATION

The Southern Manitoba Alternative Corridor Model was used to generate Alternative Corridors on the MMTP project. First, data was gathered from a variety of sources and suitability models were constructed, using GIS, which represented each stakeholder perspective (Built, Natural, & Engineering). Using GIS software, the Least Cost Path Algorithm was leveraged to identify the most suitable corridors from each perspective. The Built Corridor considered the Built criteria five times more important than the Engineering or Natural criteria. The Natural Corridor placed five times emphasis on the Natural criteria, Engineering placed five times more emphasis on Engineering criteria and a corridor was created which placed equal emphasis on each of the perspectives. This corridor was called the Simple Average Corridor. The figure below displays corridors to multiple border crossing options (Figure 2).

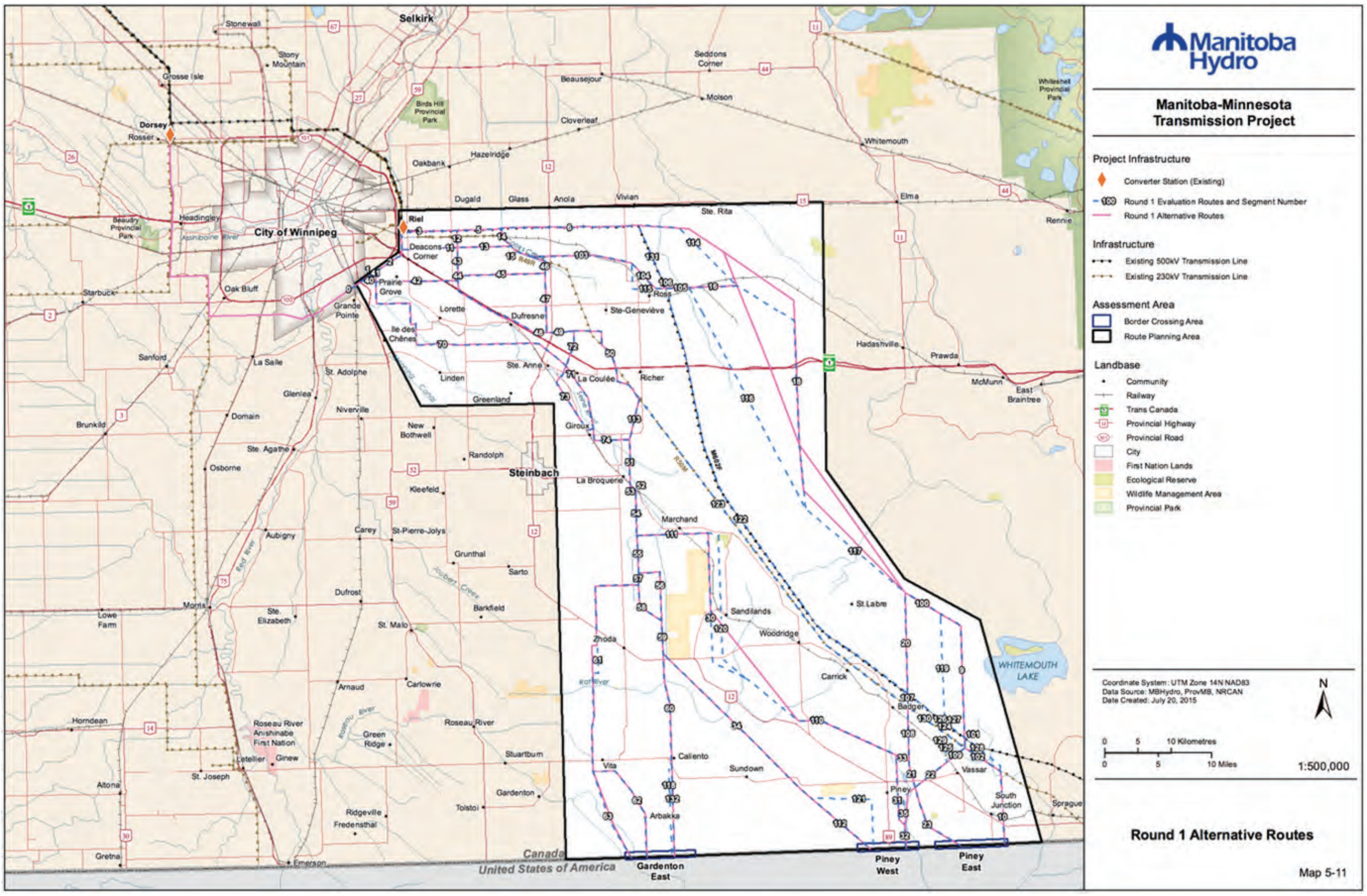

Figure 3. Alternative Routes

These corridors were used to help guide the siting team during the identification of alternative routes. This allowed the team to consider external stakeholders input and help objectively identify the best corridors based on the data available. On the MMTP, there were a variety of factors that prompted the team to perform the alternative corridor identification process in several iterations. For example, there were multiple international border crossing options resulting in multiple end points. For a detailed description of the application of the Alternative Corridor Model, please refer to chapter 5 of the MMTP EIS (Manitoba Hydro 2015).

ALTERNATIVE ROUTE IDENTIFICATION

Once the corridors were established, more detailed data was gathered in the field. For example, buildings were classified by type (residential, commercial, industrial, etc.) and windshield surveys (or surveys from a vehicle on public roads) were conducted to provide the most up-to-date understanding of landscape features and identify important features which may not be identifiable in GIS data. In addition, to provide a detailed understanding of the local area, the siting team drove the study area and even used a helicopter to evaluate potential routes. Finally, using the Alternative Corridors as a guide, alternative route segments were mapped, which connected the end points. These segments were combined to form alternative routes (Figure 3). Initially, the segments combined to more than 700,000 potential routes. Evaluation Routes became Alternative Routes after public input was used to refine the routes.

CALIBRATING THE ALTERNATIVE ROUTE EVALUATION MODEL

The alternative routes were evaluated using the Alternative Route Evaluation Model described in the EPRI-GTC Siting Methodology. Similar to the Corridor Model, siting criteria are grouped into Engineering, Natural, and Built criteria. The Manitoba Hydro team facilitated a workshop in which internal stakeholders calibrated this model. Internal stakeholders included transmission line designers, civil design engineers, property agents, construction and operation experts, environmental staff, engagement staff, and EA consultants from natural and socioeconomic disciplines.

The team determined the criteria in the model as well as the relative weights of each criterion. The criteria were informed by feedback received during previous projects and engagement processes, information from the alternative corridor model workshops, as well as professional knowledge. The criteria were grouped into engineering, natural, and built perspectives and each criterion was assigned a weight, using the Analytical Hierarchy Process. Weights are expressed as a percentage and represent the relative importance of the criteria within a perspective. The higher the percentage, the more important. Please see the criteria and the weighting used in the MMTP Alternative Route Evaluation Model in Table 2.

Criteria	Weight
Built	
Relocated Residences – Within ROW	35.3%
Potential Relocated Residences (100 m) – Edge of ROW	19.1%
Proximity to Residences (100-400 m) – Edge of ROW	6.4%
Proposed Developments – Within ROW	1.1%
Irrigated Land (Acres) – ROW	2.6%
Shelter Belts (Acres) – ROW	6.5%
Diagonal Crossings of Agriculture Crop Land (km)	2.5%
Diagonal Crossings of Agriculture Crop Land (km)	6.7%
Proximity to Buildings and Structures (100 m) – EOROW	1.3%
Public Use Areas (250m) – EOROW	1.1%
Historic/Cultural Resources (250 m) – Edge of ROW	10.1%
Potential Commercial Forest (Acres) – ROW	7.3%
Natural	
Natural Forests (Acres) – ROW	4.4%
Stream/River Crossings – Centerline	1.7%
Wetland Areas (Acres) – ROW	11.2%
High Quality Wildlife Habitat (Acres) – ROW	15.6%
Floodplain/Riparian Areas (Acres) – ROW	8.0%
Special Areas (*e.g.*, ASI, Proposed Protected Areas)	27.5%
Native Grassland Areas (Acres) – ROW	31.7%
Engineering	
% Parallel Existing T/L	8.2%
% Parallel Roads	8.2%
% Rebuild Existing T/L (*e.g.*, Reconductor, Double Circuit)	24.6%
Length in Separation Buffer (Km)	37.1%
Existing Transmission Line Crossings (#)	3.8%
Accessibility	15.2%
Total Project Costs	**2.9%**

Table 2. Alternative Route Evaluation Model

ALTERNATIVE ROUTE EVALUATION

The Alternative Route Evaluation Model is used to evaluate routes using criteria which are measured using a variety of units such as number, acres, length, and cost. In order to compare metrics on the same scale, each metric is normalized on a scale from zero to one, with zero being the best scoring in a category and one being the worst scoring. The model applies the relative importance weights by multiplying the normalized score by the weight (percentage). This resulted in a weighted score for each route and criteria. These scores were summed by perspective to create a score for each perspective. Finally, each perspective was emphasized five times more than the others to arrive at the perspective scores. There was also a score weighing each perspective equally and that is referred to as the simple average score. Using this model, the team identified the top scoring routes from each perspective and the top scoring routes equally weighting each perspective (Figure 4). The boxes in the graphic below are used to highlight groups of routes which are similar and have similar scores.

The Alternative Route Evaluation Model was used to identify the best scoring routes from all combinations of route segments (more than 700,000 routes). For the MMTP, there were a variety of factors that prompted the team to perform the alternative route evaluation process in several iterations. For example, there were multiple international border crossing options resulting in multiple end points. For a detailed description of the application of the Alternative Route Evaluation Model to identify the top routes, please refer to Chapter 5 of the MMTP EIS (Manitoba Hydro 2015). This process resulted in the identification of the five top routes which were promoted to the final preferred route selection phase.

PUBLIC INPUT

Manitoba Hydro shared information about the project, listened to comments and concerns, and considered feedback from landowners, stakeholder groups, government departments, and indigenous communities and organizations in the transmission line routing process. Conversations about the project began in 2013 and, if the project is approved by regulators, will continue through construction and operation. Understanding local knowledge and concerns are important aspects of Manitoba Hydro's planning and decision-making processes. The public engagement process (PEP) and the First Nations and Metis Engagement Process (FNMEP) informs individuals about the project and provides opportunities for them to become involved in the transmission line routing process.

Manitoba Hydro used many notification methods (posters, postcards, newspapers, e-mail campaigns, website, radio) and offered many ways for participants in the PEP and FNMEP to learn about the project and share information in person, by phone, or online. With more than 1,500 people participating in engagement processes, a large volume of information was recorded. This input was documented and characterized by topic, ranging from health, to vegetation, to wildlife concerns, and was considered in the route selection process.

Both the Public Engagement Process and the First Nations and Metis Engagement Process provide opportunities for individuals to learn about the Project, share concerns, and inform decision-making for the routing process for the Project.

The engagement processes have helped develop relationships between Manitoba Hydro and individuals and communities who may be affected by the project. These relationships and information sharing will continue throughout the regulatory, construction, and operational phases of the project. More information regarding the Public Engagement Process can be found in Chapter 3 of the EIS (Manitoba Hydro 2015).

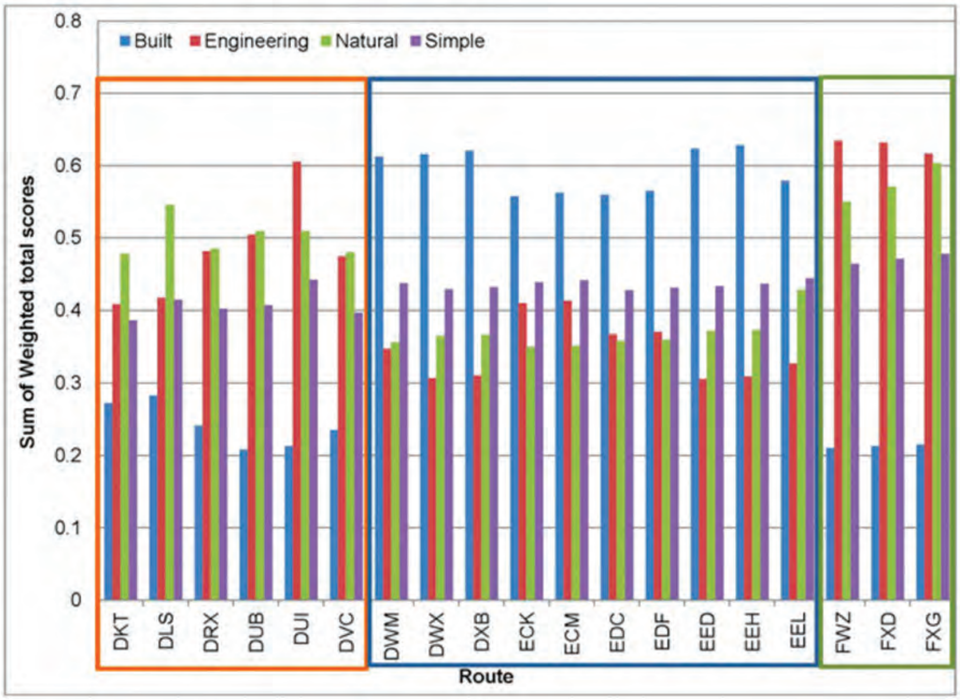

Figure 4. Sample Alternate Route Evaluation–Lower Score is Better

PREFERRED ROUTE SELECTION

The top five routes were evaluated using the Preference Determination Model, which is also known as the Expert Judgement Model in the Siting Methodology (EPRI 2006). The Alternative Route Evaluation Model considered 27 quantitative criteria to identify the top routes. In order to select the preferred route, the Preference Determination Model considered six high-level criteria. These included cost, system reliability, risk to schedule, natural environment, built environment, and community considerations. Please see Table 3 for a list of the criteria and the weightings used in the Preference Determination Model. These criteria were weighted by a group of senior managers and executives from Manitoba Hydro.

Each route was ranked by the project team to create relative scores. The best route in each category received a score of one and the other routes were ranked based on how they scored in relation to the best route. These scores were multiplied by the weight of each criteria and the weighted scores were summed to arrive at the cumulative scores. The route with the lowest cumulative score was selected to be the preferred route.

The route evaluation process occurred in a workshop format that included members of the project team with engineering, socioeconomic, environmental, property, engagement, and operations and maintenance expertise—each bringing to the discussion the sum total of the information gathered on the Project to date, as well as expertise gained on past projects. The workshop included facilitated discussions to drill down on the differences between routes, with consensus on the relative ranking and ultimate selection of the preferred route as the outcome (Table 4 and Figure 5). In the table, TC, EEL, AQS, and DKT are the alternative route finalists.

REGULATORY REVIEW

The project requires a license under The Environment Act (Manitoba), and Certificate of public necessity under the NEB Act. Manitoba Hydro submitted the EIS to Manitoba Conservation and Water Stewardship and the NEB for their review and approval. As part of this review, both review processes include a public review period for any individual to submit comments for their consideration, as well as a process to fund the participation of intervening parties. The Minister of Conservation and Water Stewardship referred the Project to the Clean Environment Commission for further review, which included a public hearing. Separate public hearings were also held as part of the NEB Review.

The Clean Environment Commission (CEC) conducted a public hearing in 2017 that included the participation of eight funded groups of participants or intervenors. The decision that supported the selection of the preferred route was a large focus of the hearings. In their report, the CEC stated, "In summary, the structured decision-making embedded in the EPRI-GTC methodology represents a significant positive step compared to

Criteria	Percent	Description
Cost	40%	Cost was based on high-level construction cost estimates used for relative comparison, defined in the alternative route evaluation criteria (values do not represent actual cost estimates for the Project).
Community	30%	Input received from the public and First Nation and Metis engagement processes.
Schedule Risks	5%	Includes consideration of the need for additional approvals, seasonality of construction, overall level of complication expected that could result in delays.
Environment (Natural)	7.5%	Consideration of the natural based statistics from the alternative route evaluation criteria, further interpretation by the Project team and additional information not captured by the criteria that can inform the relative potential effect on the natural environment of different route alternatives.
Environment (Built)	7.5%	Consideration of the built statistics from the alternative route Evaluation criteria, further interpretation by the Project team and additional information not captured by the criteria that can inform the relative potential effect on the built environment of different route alternatives.
System Reliability	10%	Proximity of the route to existing 500 kV lines. Informed by considering the statistic calculated during route evaluation (index of proximity), as well as the number of crossing points with other high voltage transmission lines

Table 3. Preference Determination Model

Criteria	Weight	Routes			
		TC	EEL	AQS	DKT
Cost[1]	40%	1	2.2	1.4	1.5
Weighted		0.40	0.88	0.56	0.60
System Reliability	10%	1	1	1	2.5
Weighted		0.1	0.1	0.1	0.25
Risk to Schedule	5%	1	2	1.5	3
Weighted		0.05	0.1	0.075	0.15
Environment (natural)	7.5%	1	1.5	1.5	3
Weighted		1	1.5	1.5	3
Environment (built)	7.5%	2.75	3	2.5	1
Weighted		0.21	0.23	0.19	0.075
Community	30%	1	2	1	1
Weighted		0.3	0.6	0.3	0.3
TOTAL	**100%**	**1.13**	**2.02**	**1.34**	**1.60**
RANK		**1**	**4**	**2**	**3**

Table 4. Preference Determination Model Used to evaluate the Top Four Routes–Route TC Preferred

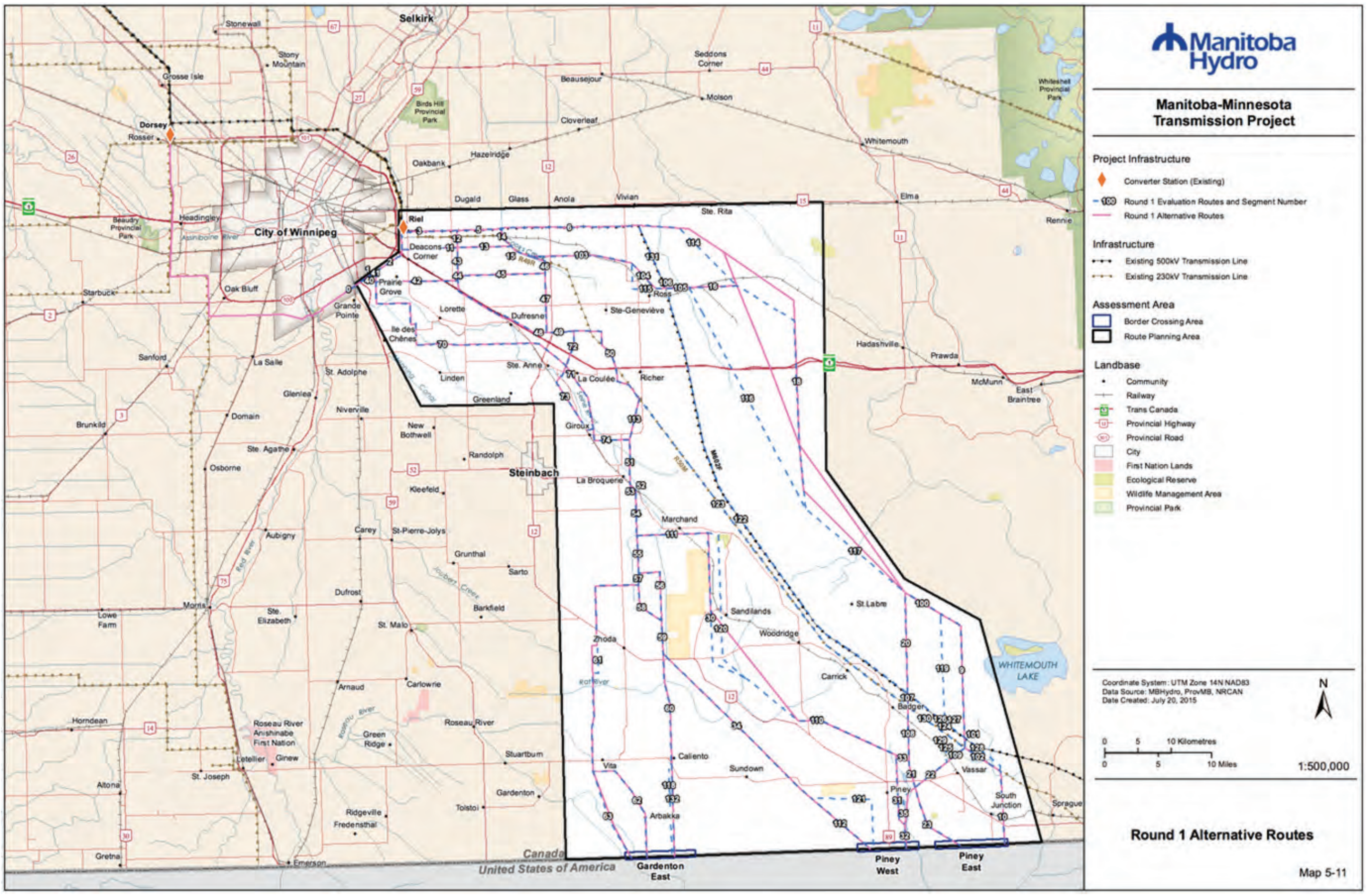

Figure 5. Preferred Route

previous route selection processes. It produced a clear record of the factors that led to decisions and the trade-offs and compromises made" (Manitoba CEC 2017).

Since the transmission line will be connecting to a similar line in the U.S., the project will undergo review through Canada's NEB, under the NEB Act, and the Canadian Environmental Assessment Act of 2012.

As of September, 2018, Both the NEB and Manitoba Sustainable Developing are in deliberation of the information. Manitoba Hydro is hopeful that approvals will be forthcoming in the Fall of 2018.

DISCUSSION

This section seeks to answer the following questions: did the use of the Siting Methodology lead to better results when compared to previous projects? What are challenges with the Siting Methodology on this project and opportunities for improvement?

1. **Creative Application of Tools**: The Siting Methodology included various models, which are tools that help inform decision-making. On this project, these tools were used in an iterative manner to make decisions based on the stage of the project. For example, this project had multiple potential end points which resulted from multiple border crossing options. The tools were applied to help inform the choice of a border crossing location in iterations. The first iteration helped select representative routes to optional border crossings. Finally, the representative routes to each border crossing option were evaluated and a preferred crossing was determined based on the cumulative effects of the routes to that crossing.
2. **Data Availability**: Availability, quality, and currency of geospatial data were all significant challenges in the development of the model. Some datasets did not exist and had to be created, others had to be updated, or, due to lack of availability, were excluded from the models.
3. **Workshops**: Alternative Corridor Model Stakeholder Workshops were a valuable learning and relationship-building opportunity. Participants gained knowledge about the transmission line construction process, ways that effects are mitigated, and the interests and concerns of other participating groups.
4. **Defending Decisions**: The Siting Methodology was valuable in helping to defend decisions that

were made. Routing professionals are often asked who made the routing decision and the initial perception is usually that one high-ranking corporate officer or engineer drew the route. Political representatives are lobbied by constituents affected by a proposed project to change the outcome with the goal of moving a project off of their land. Consistent application of a methodology like the EPRI-GTC Siting Methodology provides a consistent, defensible way to address these challenges. While affected parties may be unlikely to accept the outcome, they can understand how the decision was made and what the key factors influencing the decision were. They can understand that decisions were made in a considered and informed way, including thorough analysis.

5. **Communicating the Process**: While the process is defendable, it is still complex and takes a fair bit of time to explain to the point of true understanding. Feedback from the CEC was that we should simplify the language and make it more accessible to non-experts. Proponents that use the methodology need to invest time and effort into explaining and communicating the process to interested parties.
6. **Tools**: The EPRI-GTC Siting Methodology describes several tools, or processes, that can be leveraged to implement projects.
    - **Analytical Hierarchy Process**: During the stakeholder engagement process, the Analytical Hierarchy Process was used to perform pairwise comparisons of the siting criteria to determine the relative importance of criteria and the results were expressed as a percentage.
    - **Delphi Process**: During the stakeholder engagement process, the Delphi Process was used to rate features in multiple iterations with consensus building discussion between each round of input.
    - **Microsoft Excel**: Spreadsheets were used to evaluate the stakeholder data, implement the Alternative Route Evaluation Model, and implement the Preference Determination Model.
    - **ArcGIS**: Commercial off-the-shelf (COTS) desktop GIS software was used to build suitability models and run the least cost path algorithm. COTS GIS software was used to generate alternative route statistics, which were input into spreadsheets and used to implement the Alternative Route Evaluation Model.
    - **Team Choice**: After this project was implemented, the Team Choice web application was developed in order to streamline and standardize the model development, stakeholder input, and suitability analysis processes. It includes tools 1-4 above in a single web app. *www.teamchoice.com*

CONCLUSIONS

Manitoba Hydro used the EPRI-GTC Transmission Line Siting Methodology to select the preferred route for the MMTP project. External stakeholders provided input which informed the Alternative Corridor Model. The Alternative Corridor Model was used to help identify areas for developing detailed route options. The Alternative Route Evaluation Model, calibrated with internal stakeholders, was used to compare routing options and help identify the top routes. Finally, the Preference Determination Model, calibrated by management, was used to select the preferred route. "In summary, the structured decision-making embedded in the EPRI-GTC methodology represents a significant positive step compared to previous route-selection processes. It produced a clear record of the factors that led to decisions and the trade-offs and compromises made" (Manitoba CEC 2017).

ACKNOWLEDGMENTS

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AUTHOR PROFILES

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James Matthewson

James Matthewson has an Honours Bachelor of Science degree in Forestry. He has been with Manitoba Hydro for 10 years, and currently functions as a senior EA officer with Licensing and Assessment for Manitoba Hydro. Matthewson led the route-planning portion of the process. Prior to Manitoba Hydro, Matthewson was a forester with Manitoba Conservation.

Jesse Glasgow

Jesse Glasgow has a Bachelor of Science degree in Professional Geography, is a Certified Project Management Professional, and is a Certified GIS Professional. Glasgow is the team leader and principal consultant for Team Spatial. Glasgow has 20 years of experience leveraging location intelligence to improve business performance. Prior to founding Team Spatial, he worked for national geospatial services firms in roles as an analyst, consultant, facilitator, mentor, project manager, operations manager, and director of analytics and software. Glasgow worked with GTC and EPRI to develop the GTC-EPRI Standardized Methodology for Siting Overhead Transmission Lines which has been widely adopted in the U.S. and Canada. He worked with Manitoba Hydro to implement this project. He is experienced customizing this method to local considerations and has implemented it on more than 300 projects. Glasgow led the development of the Team Choice web application which is used to implement the EPRI-GTC Siting Methodology.

The Quest for Sustainable Pipelines: Practical Strategies for Impact-Neutral Projects

Jody Bremner and
Jason Smith

As linear projects are subject to increasing scrutiny, concerns related to cumulative impacts are at the forefront. Unprecedented conditions require proponents to navigate the implications of requirements for ecological restoration within an operating pipeline right-of-way (ROW), and implement biodiversity offsets (or compensation mitigation) within developed landscapes, often with conflicting land use objectives, limited guidance, and lack of policy. This paper presents the drivers and trends towards regulatory requirements for proponents to target impact-neutral or net-benefit outcomes. Strategies for rigorous restoration, enhancement, and offset programs are presented as an approach to demonstrating the sustainability of a proposed project.

Keywords: Compensation Mitigation, Cumulative Impacts, Enhancement, Impact-Neutral, Multiplier, Net-Benefit, Offset, Ratio, Restoration, Sustainable Pipeline.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Pipeline projects have been the subject of a substantial amount of media coverage in recent years. As proposed pipeline projects continue to face increasing scrutiny and opposition, often marked by highly publicized court proceedings and protests, the concept of sustainability is becoming more prevalent in regulatory reviews. In the late 1980s, the World Commission on Environment and Development (1987) defined Sustainable Development as development that "seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future." The Commission's report affirmed that "policy makers guided by the concept of sustainable development will necessarily work to assure that growing economies remain firmly attached to their ecological roots and that these roots are protected and nurtured so that they may support growth over the long term" (World Commission on Environment and Development 1987). The concept of benefiting present and future generations is consistent with sustainability analysis. Projects that demonstrate sustainability will likely progress through the permitting and approvals phase more efficiently and with lower risk of appeals and litigation.

Offsetting adverse residual impacts through compensation mitigation is one strategy for alleviating adverse residual impacts, thereby enhancing project benefits, such that the benefits outweigh the burdens of the project. Regulatory requirements for offsets are becoming more prevalent, particularly where a project would impact sensitive resources, or where a project is located in a region where existing cumulative impacts are perceived to be exceeding acceptable levels. This paper explores strategies for designing impact-neutral or net-benefit pipeline projects with the objective of seeking sustainable development such that the regulators, landowners, stakeholders, and Indigenous peoples are confident that, all things considered, the benefits outweigh the burdens of a project.

METHODS AND APPROACH

Drivers and trends towards the use of offsets to achieve impact-neutral or net-benefit pipelines are briefly reviewed to provide context. To help proponents successfully navigate the planning process, there are essentially four phases of planning and executing an impact-neutral or net-benefit pipeline project. Practical strategies for each of these phases are presented using examples from previous projects.

DRIVERS AND TRENDS

3.1 Perception, Priorities, and Political Pressure

Public opposition is having an increasing influence on new pipeline projects, sometimes delaying and even halting projects. One reason contributing to this is that the perception of safety risk by those potentially affected differs significantly from the safety risk assessed by experts (Fahlbruch 2012). Other factors identified for this trend include increasing activism related to climate change and environmental justice, perception of a local community bearing the burden while others profit, lack of access to the resource by the community affected, increasing access to scientific and expert resources, lack of trust in the competence or adequacy of technical or scientific analysis, and lack of confidence in government or regulatory processes and enforcement (e.g., Gough and Boucher 2013; Widener 2013; Gough et al. 2014). The use of social media has had a key role in substantially increasing the influence of public perception and non-government organizations with alternative agendas. Opposition groups have demonstrated skillful use of social media to quickly and broadly spread tactical messaging to influence public perception and cultivate support (Deffenbaugh and Davis 2017).

3.2 Focus on Cumulative Impacts

As governments work towards reconciliation with Indigenous communities, there is increased focus on cumulative impacts to traditional land and resource use, and how additional developments might impact Indigenous rights. Further, public awareness and scrutiny of new developments proposed in increasingly fragmented and disturbed landscapes has heightened scrutiny of regulatory decisions. In response, regulatory agencies expect more rigorous and detailed analysis, and conduct their reviews with an eye towards scientifically defensible rationale for conclusions.

Significant cumulative impacts are becoming increasingly evident in regions with continued high levels of development. Questions and statements of concern related to cumulative effects have become increasingly common in information requests, written evidence, and hearing proceedings for new linear developments. With the advent of more determinations of significant cumulative effects in project assessments, decision-makers are left without regional impact assessments (RIAs) to help them frame the overall cumulative impacts. This gives rise to concern that the nature and extent of cumulative impacts is not well understood and information is lacking to understand how the landscape—and the relationship of Indigenous peoples within it—has changed due to cumulative impacts.

3.3 The Role of Offsets in Achieving Sustainable Development

The trend in recent years is for regulatory agencies to implement cumulative effects management policies through approval conditions that impose offset requirements on new linear projects. Offsets are one strategy in achieving an impact-neutral or net-benefit pipeline project, but should remain a measure of last resort, as emphasized by the standard mitigation sequence and accepted offset standards

(British Columbia Ministry of Environment [BC MOE] 2014a, BC MOE 2014b; Business and Biodiversity Offsets Programme 2012; Department of Sustainability, Environment, Water, Population, and Communities 2012; Environment Canada 2012). Avoidance and on-site mitigation must be prioritized since the ability of offsets to counterbalance ecological losses is more uncertain and of greater risk than mitigation measures applied to the project footprint (Bull et al. 2013; Gibbons and Lindenmayer 2007; Morris et al. 2006).

DISCUSSION & RESULTS

While offsets may be explicitly required by regulatory approval conditions to alleviate some project impacts, there may be latitude for some level of residual impact before offsets are warranted, depending on the resource impacted, the scale and duration of impacts, and the context of existing cumulative impacts. Putting increased effort on mitigation on-site (i.e., restoration or enhancement of the project footprint) can substantially reduce the amount of offsets required, and should be prioritized as indicated by the mitigation sequence.

Planning and executing an impact-neutral or net-benefit project can be described in four phases. Phase 1 encompasses the early planning stages of a project. Phase 2 deals with minimizing residual impacts, which is essential before moving along the mitigation sequence to offsets. Phase 3 presents strategies for quantifying residual impacts and offset value, and Phase 4 is the final stage of implementing and monitoring an offset program.

4.1 Phase 1: Proactive Planning

4.1.1 Identify the Key Issues

A project should not quickly jump ahead to offsets without first fully considering and applying the first stages of the mitigation sequence to avoid and minimize impacts. For most projects, it is reasonable to predict early in the planning phase which valued components or resources are likely to require additional efforts to avoid or minimize impacts, such as routing adjustments, trenchless construction techniques, narrowing the construction footprint, or adjusting the location of workspace and above-ground facilities.

Proponents are being tested by regulatory agencies to demonstrate how their project has made all reasonable efforts to avoid, minimize, and mitigate residual impacts on sensitive resources, particularly those where regulatory or environmental thresholds for cumulative disturbance have already been exceeded. Despite lack of RIAs and established thresholds in most jurisdictions, there are several strategies that can be used to anticipate the potential issues associated with cumulative impacts.

First, early and meaningful engagement and consultation with Indigenous groups, public and local interest groups, and all levels of regulatory agencies is key to understanding important project impacts and determining where to focus efforts in project design and mitigation. Proponents are encouraged to initiate dialogue about issues that will be raised during the regulatory review phase. Discuss options and alternatives, the limitations and challenges, and be open to recommendations and ideas for mitigation and offsets.

Proponents should refer to regional planning documents to determine whether a proposed project fits within the regional development and conservation objectives, and review the available scientific literature for research that demonstrates important declines in biodiversity or ecosystem function when regional disturbance levels reach high levels. These sources provide indicators of acceptable development and important cumulative thresholds.

Another approach is to identify policies and mitigation guidance that place emphasis on certain valued components. For example, regulations or development guidelines might target sensitive areas like native grasslands, wetlands or riparian areas, or habitat for certain species at risk or species of management concern. Often, such regulations and development guidelines are associated with resources that have experienced high levels of cumulative disturbance.

Finally, consider current political pressure and recent project precedents. Determine whether regulatory agencies have been tested through legal proceedings on their decisions for past projects, identify what valued components were contentious, and consider what the regulators need to make informed and sound decisions. Agencies will be looking for evidence that a project aligns with their mandate and policies, will stand up under scrutiny, and will enable them to avoid litigation.

4.1.2 Objectives for Baseline Data

Proactive planning also includes getting the most out of baseline environmental studies. Field studies are typically designed to collect data that will help to scope, characterize, and assess project impacts, and support development of site-specific mitigation planning. These objectives should remain priorities, but also consider how baseline study design might be adjusted to provide value beyond the permitting phase. A proactive approach to designing baseline studies anticipates how residual impacts and mitigation effectiveness will be monitored and measured. This approach can require additional resources during the initial stages of project planning and design, but substantial time and cost savings can be realized by reducing the requirements for additional pre-construction studies. It is important to balance the level of effort and expenditure with the risk of baseline data becoming obsolete due to shifts in routing or project design.

One strategy for maximizing the value of baseline data is to use standardized protocols and measures that can be applied to pre-construction baseline data collection in addition to post-construction monitoring. When designing a baseline field data collection program in this way, start by identifying performance indicators or measures that are ecologically relevant and sensitive to change. Consider what data will be needed to establish reference conditions, and whether trends towards desired outcomes can be determined from measures repeated with time. Use measures that change predictably with changes in disturbance, and avoid redundant measures. Measures of vegetation structure, cover, density, species assemblage (including richness, diversity, native vs. non-native), vigor, or health are examples.

Where it makes sense to do so, collect baseline data that can be replicated during post-construction monitoring. Ecosystem or habitat function ratings and indices of biotic or ecological integrity are good examples. These kinds of ratings and indices measure parameters indicative of ecosystem health or integrity, and convert those measures to standardized scores that allow for comparison across sites or within a time frame. Establishing good baseline measures becomes important in later stages of offset planning, as a common currency for measuring residual impacts and offset values is needed.

4.2 Phase 2: Minimize Residual Impacts

Phase 2 of planning an impact-neutral pipeline focuses on demonstrating that the early stages of the mitigation sequence have been fully considered and implemented. It is important to be transparent about project alternatives and to demonstrate how the project design avoids impacts where feasible. For those sensitive resources or valued components identified during Phase 1 as likely needing additional effort to address unavoidable impacts, emphasis should be placed on restoration and enhancement of the project footprint. In doing so, a project can reduce its residual impact, bringing it closer to impact-neutral.

4.2.1 Restore and Enhance

Standard reclamation measures for pipeline ROWs has typically involved restoring instream habitats to pre-construction conditions, stabilizing slopes, preventing soil erosion, and establishing vegetation cover, often through application of grass seed mixes, including cover crops. When a project is required to demonstrate that all reasonable measures have been taken to avoid and minimize a residual impact, standard construction and reclamation practices may not be sufficient.

On-site restoration measures should incorporate as many of the ecological elements or features important to the function of the ecosystem as practical. For example, consider abiotic factors such as soil compaction or permeability, microsite features, and surface hydrology. In addition, target diversity in vegetation species or structure. Where it is logistically feasible, leverage baseline and pre-construction field studies to find efficiencies, such as collecting seeds or propagules for later use in revegetation, identifying restoration targets, and locating site-specific areas where retention of on-site materials will be stored.

Various strategies can be used to keep restoration programs technically and economically feasible. When there is variability in the types of ecosystems, land uses, and levels of disturbance intersected by a pipeline ROW, one strategy is to develop a rating system that characterizes the function or value of the ecosystems. The level of restoration effort is then scaled to match the ecosystem values. Another practical restoration strategy is to replace or enhance ecosystem structural features to restore key functional elements and, therefore, the value of the ecosystem without the lag time associated with successional progression towards mature forests. For example, where characteristics of mature or old forests are important to the function or value of the ecosystem component, incorporating enhancement measures into the restoration strategy can replace functional features that would otherwise take decades to develop naturally.

Restoration on an operational pipeline ROW must consider the implications for pipeline safety and integrity, as well as operational access requirements. Maintaining dialogue between project and operations teams to relate challenges and implications from both viewpoints can increase mitigation options, strengthen effectiveness of mitigation, and improve regulator and public understanding and acceptance through transparency and well-supported rationale.

4.3 Phase 3: Quantify Residual Impacts and Offsets

Phase 3 involves measuring and assigning value to residual effects and offsets. It includes:

- Measuring the effectiveness of on-site mitigation, including restoration and enhancement
- Defining a common currency to allow comparative valuation of impacts and offsets
- Setting offset ratios or multipliers
- Conducting a transparent evaluation of offset options

4.3.1 Demonstrate Effective Mitigation

Measurable, outcomes-based monitoring programs are becoming more prevalent in the industry to demonstrate the effectiveness of project mitigation, and is the basis for quantifying a project's residual impacts. Monitoring programs should establish clear goals that are achievable and measurable. Performance indicators and targets are the basis of measuring whether mitigation goals can be achieved, and need to be relevant to the ecological elements or processes that will be affected by the project. Good indicators are practically measured, and change predictably with variation in disturbance level or successional stage.

Targets are an important component of a monitoring program. They act as thresholds for determining success or failure and indicate when an adaptive management protocol should be implemented. Often, there are few established thresholds or targets that can be practically applied to measure success of mitigation, which leaves proponents tasked with creating acceptable targets. An effective strategy is to design targets that have a direct link to the functional elements important to the ecosystem component. Such linkages can be derived from scientific literature, Indigenous knowledge, and applicable management, conservation, or recovery documents.

Qualitative targets can be an effective approach, and need not be complex. For example, visual observations can be used to qualitatively measure soil stability, extent of erosion, or re-establishment of surface contours to evaluate successful restoration of surface hydrology or connectivity between aquatic and riparian habitats. Alternatively, simple quantitative methods can measure effectiveness of reclamation techniques, such as the use of soil penetrometers to measure soil compaction in areas where burrowing mammals might be affected by soil compaction.

When designing a monitoring program, it can be useful to link goals to the expected interaction of the valued component with the project. This enables a clear linkage between the impact, the corresponding avoidance, mitigation or enhancement measures, and the performance indicators and targets used to measure success of the mitigation. First, consider goals that relate to maintaining or improving the function of an impacted ecosystem relative to baseline conditions. Identify the measures that the project will implement to address the interaction, and determine whether there is a practical, standardized approach to measuring the success of those measures. Also consider the timeframe needed for the functional element to be successfully restored, and whether it can be monitored within a timeframe acceptable for the project. During this process, it should become apparent if adjustments in the monitoring timeframe or goals are needed to ensure the goals and targets are achievable and realistic.

Establish a Monitoring Timeframe

The typical post-construction monitoring program for pipeline construction projects in western Canada extends within a five-year period following construction, with monitoring conducted at intervals (e.g., at years one, three, and five following construction). Extended monitoring periods are becoming more commonplace for some sensitive resources where recovery occurs slowly, such as in arid ecosystems (e.g., 10-year monitoring timeframe for native grasslands and select watercourses), or in forested areas where growing conditions slow the establishment and growth rates of woody vegetation (e.g., 15- to 20-year monitoring timeframe to establish a trajectory to forest vegetation in boreal woodland caribou range).

For many ecosystem components, the timeframe for restoring pre-construction ecological function cannot be measured within the timeframe of a five-year, 10-year, or even 20-year monitoring program. In these scenarios, goals that target establishing a trajectory towards the desired ecosystem may be the best approach. In some cases, monitoring in the entire lifespan of the project may be necessary. For example, monitoring of the effectiveness of access management may be required where the unpredictability of human use patterns could change how the project impacts an ecosystem component during the life of the project.

Align Post-Construction and Operations Monitoring Milestones

Project inefficiencies can occur from repeated mobilization of field crews in different monitoring years, and if there is lack of alignment in regulatory reporting deliverable dates. Repeated access by monitoring crews can also impact the establishment and recovery of regenerating vegetation. Efficiency in post-construction monitoring programs can be improved by establishing an appropriate project milestone or date for the start of all post-construction environmental monitoring programs. This will not always be possible as approval conditions do not always allow for flexibility to adjust the starting milestone for initiating the monitoring phase.

Where long-term post-construction monitoring is necessary, look for opportunities to leverage pipeline integrity monitoring programs over the operations phase of the project. Aerial overflights, for example, are a good opportunity to monitor the effectiveness of access controls along a ROW. Integrity monitoring crews can be accompanied by an additional crew member tasked with recording environmental data. Alternatively, electronic data capture platforms are an increasingly common tool that can be used to support consistent data collection by the integrity monitoring staff.

4.3.2 Common Currency

Using a common currency to measure project impacts and offset value provides a clear indication of the adequacy of proposed offsets. In most situations, disturbance area alone should not be used to represent the currency as it does not reflect the condition, value, or function of the affected ecosystems. Instead, currencies should include a measure of area, and a measure or rating of the ecosystem condition, value, or function (McKenney and Keisecker 2010). In this way, the offset currency will ensure offsets compensate for adverse impacts by protecting, enhancing or restoring equivalent ecological mechanisms. Ecosystem or habitat function ratings and indices of biotic or ecological integrity are useful measures, as they can be applied to quantifying change in ecosystem value within the project footprint (before and after construction), as well as the value of offset measures relative to the residual impacts.

4.3.3 Offset Ratios or Multipliers

When quantifying offsets, applying multipliers to achieve offset ratios (typically greater than 1 to 1) is a standard procedure. Multipliers are used to address factors such as time lags, risk of offset measures failing to achieve target conditions, or equivalence of the offset relative to the environmental value lost. Despite ratios being a long-standing component of offset protocols worldwide, there remains a substantial amount of debate and uncertainty whether the multipliers implemented attain adequate offset ratios to achieve no-net-loss.

While some jurisdictions have established offset calculators that incorporate multipliers or ratios, many do not, or only have established ratios for certain ecosystems. Aquatic habitats (fish habitat in particular) and wetlands tend to have established ratios (e.g., Environmental Law Institute 2002; Harman et al. 2012; Alberta Environment and Parks [AEP] 2018; U.S. Army Corps of Engineers 2018). As with setting monitoring targets, the proponent is often tasked with developing offset multipliers or ratios in the absence of regulatory policy or guidance.

The Wetland Replacement Matrix

Value of Lost Wetland	Value of Replacement Wetland: D	C	B	A
A	8:1	4:1	2:1	1:1
B	4:1	2:1	1:1	0.5:1
C	2:1	1:1	0.5:1	0.25:1
D	1:1	0.5:1	0.25:1	0.125:1

*Ratios are expressed as area of wetland

Figure 1. Wetland Replacement Matrix. *Source: AEP 2018.*

The National Energy Board (NEB) has suggested that quantification of residual effects and multipliers used to determine offset requirements for pipeline projects should account not only for issues of effectiveness, time lag, and equivalence, but should also provide incentive to avoid new cuts (NEB 2016). Assuming that ecological values are higher in undisturbed areas, this logic to incentivize parallel routing is generally in line with accepted offset approaches, which use multipliers or offset ratios to account for the ecological value of an offset relative to the value lost due to project impacts (i.e., measured through a common currency).

There are various approaches to establishing offset ratios or multipliers. A matrix that sets out ratios based on ecosystem values can be a simple but effective approach. The Alberta Wetland Policy uses a matrix method (AEP 2018), which has been adopted as a framework for project-specific offset programs in Canada. The Wetland Replacement Matrix (Figure 1) uses a relative index of wetland value to quantify offsets relative to residual impacts, and area defines the measure. In practice, regional land values are used to derive the monetary value of wetland replacement on a per-hectare basis.

Alternatively, there are mathematical approaches in the scientific literature that aim to establish defensible, repeatable methods for determining appropriate offset ratios (e.g., Moilanen et al. 2009; Curran et al. 2014; Laitila et al. 2014). In practice, these methods may be limited by the need for empirically derived information that is simply not available, therefore requiring assumptions that are often difficult to rationalize and can be subject to ongoing debate and opposition.

4.3.4 Evaluate Offset Options

Reasonable offset options should be identified and evaluated based on standard offset design elements, as well as costs and predicted ecological benefits. Using standard offset design elements to assess the offset value lends transparency. Design elements include equivalence, additionality, location, and temporal factors (BC MOE 2014b; Doswald et al. 2012; Environment Canada 2012; Pilgrim and Ekstrom 2014; Sustainable Prosperity 2014). These can be used to quantitatively or qualitatively evaluate the costs and benefits of various offset options.

Offset banks are often the preferred offset option where they exist because they are a relatively simple method for a pipeline proponent to meet compensation commitments as part of a regulated process. In addition, offset banks can allow a proponent to implement compensation mitigation before project impacts occur.

Where offset banks are not available, are inadequate to fully compensate for the residual impact, or are unable to replace equivalent function or value, the typical suite of offset options include:

- Off-site habitat restoration or enhancement
- Land securement
- Conservation covenants
- In-lieu offsets for ecosystem or land management.

A simple tabular evaluation procedure can be a useful tool for transparently assessing various offset options. For each of the potential offset options identified, evaluation criteria could include the following:

1. Primary Objective and Treatment: provide an indication of the scope of work involved in implementing the offset (provides necessary context).
2. Effectiveness: account for uncertainty in implementation of the offset (i.e., the risk that an offset action would fail to achieve its objective).
3. Equivalence: account for ecological value and location of the offset as it relates to replacing in-kind or like-for-like ecosystem values or function.
4. Temporal Risk: account for time lag between the project disturbance (loss of the ecosystem value) and the point in time where offsets become effective. Temporal risk should also consider the timeframe wherein offsets will be effective. Ideally, offsets are effective in perpetuity, but at minimum, they should be effective for at least as long as the duration of the project's residual impact.
5. Relative Costs: costs are incurred by the proponent to implement, document, monitor, and maintain the offset. In some scenarios, costs may consider cost to another party, such as loss of land use rights. Where absolute monetary values are not available, relative ratings (for example, negligible, low, moderate, or high) can be used. Ratings should be clearly defined, and rationale for ratings provided.
6. Overall Value: offset value should represent a cost/benefit analysis of all of the above evaluation criteria. The method may be qualitative. As noted above for relative costs, qualitative ratings should be clearly defined and rationale for ratings provided.

4.4 Phase 4: Offset Execution

The offset execution phase involves selection of offset methods and locations, further consultation and engagement, preparing final offset plans to meet regulatory requirements, and implementing offsets.

Use of habitat banks, in-lieu offsets, or land securement and protection will involve establishing collaborative partnerships and outlining responsibilities, as well as legal agreements, contracts, and transfer of funds. Agreements should explicitly outline expectations and responsibilities for monitoring and reporting results to the proponent or regulatory agency. Ideally, offsets would be implemented, at least in part, prior to the occurrence of the residual effect. This reduces the time lag between disturbance and replacement of the valued component.

In-kind or like-for-like offsets generally take the form of replacement, restoration, or enhancement of an ecosystem at a location outside the project footprint. The consultation, permitting requirements, and logistics of contracts, scheduling, accessibility, and procurement of materials for this approach can be complex and time consuming. In many jurisdictions, there are no permitting procedures established for compensation mitigation. It is important to work closely with regulatory authorities and other land users to successfully execute in-kind offsets without incurring additional costs, such as from delays in schedules. In some jurisdictions, there are organizations that can implement in-kind offsets on behalf of a proponent.

Monitoring and documentation of offset effectiveness is an essential component that, in the past, has often been poorly executed in offset programs. Monitoring should be accompanied by an adaptive management protocol to improve probability of success. Options for remedial or corrective measures should be clearly established at the outset of the offset program. This improves certainty that offsets will be effective.

CONCLUSIONS

Based on the drivers and trends reviewed, objectives for impact-neutral or net-benefit outcomes will likely become the norm for future pipeline projects, particularly where sensitive resources are encountered, or when a project is located in an area with high cumulative impacts. Robust restoration, enhancement and offset programs can be an effective strategy for meeting impact-neutral or net-benefit objectives and seeking approval for a project.

The early stages of the mitigation sequence must be fully considered and implemented before a project moves to offsets as a mitigative option. Routing has always been key to addressing environmental impacts of pipeline developments. Routing to avoid or minimize impacts to a sensitive valued component is generally considered the ideal approach. However, avoidance may not be a practical or effective solution if it means greenfield routing through otherwise intact areas. For example, proponents cognizant of the cost and complexity of restoration and offsets will look to options that will mitigate those issues. Reducing their project's residual impacts by taking the most direct route rather than paralleling existing disturbances is a consideration when offsets are measured only on the basis of area or length of the project footprint. Regulatory decisions have recognized that incentive should be given to promote avoiding unnecessary impacts to intact areas, despite the complexities and challenges with managing cumulative impacts in already highly developed or disturbed landscapes (NEB 2016). Incentives can be realized through incorporating measures of ecosystem value or function when quantifying residual impacts and offsets.

Offsets are more likely to be necessary if there is a moderate to high level of uncertainty that mitigation, restoration, or enhancement measures will be effective, and meet the targets set out in the monitoring program. When designing an achievable mitigation, restoration, enhancement, and monitoring program, it is important to establish goals that that can be measured within the constraints and spatial context of a pipeline ROW. Regional and population-based goals are impractical and essentially impossible for a pipeline company to measure. If a project has potential to have regional or population scale impacts, appropriate means of addressing these impacts include participation in regional industry initiatives that focus on the ecosystem component impacted, or contributing to management, conservation, or monitoring programs led by government authorities.

The need for offsets is also more likely if critical functional elements of the affected ecosystem cannot be restored within the monitoring timeframe. Since offset ratios generally will increase to address uncertainty and time lag, it is important to determine early in project planning whether offsets will be needed, and endeavor to implement offsets as early as possible. Habitat banks can be a desirable option as they provide opportunity to implement offsets before or at the same time as the impact occurs.

Determining the suitable quantity of offsets that will result in an impact-neutral or net-benefit outcome is possibly the most debated component of ecological offset programs. There are various approaches to setting offset ratios and multipliers, but there is a growing body of evidence suggesting that past offset ratios have been inadequate in replacing equivalent or better ecosystem values (e.g., Quigley and Harper 2005; Minns 2006; Curran et al. 2014; Bull et al. 2017). Setting ratios in the absence of an established offset calculator or regulatory process is challenging. A proactive proponent anticipates any proposed offset ratios to be scrutinized and tested by regulators and opponents and will seek to set ratios that can be rationalized with scientific evidence.

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Tribal Partnerships in Transmission Line Permitting

Michelle Bissonnette and Michael Justin

Keywords: Energy, Stakeholders, Utility Lines.

Minnesota Power (MP), a division of ALLETE, provides electricity in a 41,843-kilometer (km) (26,000 square miles) electric service area in northeastern Minnesota to 144,000 customers, and wholesale electric service to 16 municipalities. The Great Northern Transmission Line will carry predominantly emission-free energy supply from Manitoba Hydro to MP's customers. In return, MP will provide Manitoba Hydro with renewable wind energy. The international nature of the project requires a Presidential Permit and coordination with Canada and the U.S. Department of Energy. The Great Northern Transmission Line will consist of a 500-kiloVolt (kV) transmission line from the Minnesota-Manitoba border to the Blackberry 500-kV Substation near Grand Rapids, Minnesota. While the project schedule is driven by state and federal regulatory requirements, meeting this schedule required thoughtful planning and participation with stakeholders and interested parties. By reaching out early to the Red Lake Nation, and other American Indian tribes in the region, MP was able to work through siting issues that could have potentially affected historic resources important to tribes. MP representatives met personally with the Red Lake Nation tribal leadership and the Tribal Historic Preservation Officers (THPOs) to arrive at mutually beneficial routing options. As a result, the project will adversely affect only one historic property, and stakeholders were able to arrive at mutually satisfactory mitigation strategies. This paper explains some of the methods used to achieve solutions agreeable to agencies, MP, and tribes. These included:

- Meetings with tribal councils
- Independent, respect-based consultation with tribes
- Face-to-face investment in building productive relationships
- Outreach and meetings with local communities
- Broad, regional approach to historic landscape and resource identification
- Cultural resources surveys that included tribal archaeologists
- Being a Signatory on the Programmatic Agreement
- Integrated Pre-application Process
- Providing for Monitors during construction
- Genealogy interviews and research to establish historic ties to the local community in the early 1900s

Objective: achieve solutions agreeable to agencies, Minnesota Power, and tribes for siting.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

There is an area of northern Minnesota commonly known as the Big Bog. This poorly drained, inhospitable country is generally flat and hosts vast areas of tamarack and black spruce swamps and floating bog. This is where Minnesota Power (MP) chose to cross for its new 354 kilometers (km) (220 miles [mi]) long 500-kiloVolt (kV) transmission line that will bring renewable energy from a Manitoba Hydro hydroelectric facility. The Great Northern Transmission Line will consist of a transmission line from the Minnesota-Manitoba border to the newly constructed Blackberry 500 kV Substation near Grand Rapids, Minnesota. MP chose this route after countless hours of discussions with private, public, and tribal entities for its Great Northern Transmission Line because it would affect the fewest private landowners, have the least amount of impact to valued resources, and follow an existing transmission line for portions of the route. The crossing of an international border meant getting a Presidential Permit issued by the Department of Energy (DOE). While relying on the DOE acting as a lead federal agency to conduct the requisite consultations for compliance with Section 106 of the National Historic Preservation Act, MP ran concurrent consultation with the public, private, and tribal concerned parties. While the larger consultation effort sponsored by the DOE was not as successful with reaching concurrence with tribes, early work by MP with the Red Lake Nation, and other Ojibwe bands in the region laid the foundation for a continuous dialogue that benefitted both MP and the Red Lake Nation.

Although they have not always occupied the region, the area is now home to multiple bands of Ojibwe people with whom MP made a concerted effort to contact early in the planning and routing process in order to avoid affecting significant cultural properties. Directed by the DOE, MP sponsored surveys conducted by HDR archaeologists and architectural historians, as well as traditional cultural property studies by the Red Lake Tribal Historic Preservation Office.

In the last several years, HDR has been assisting MP with permitting details related their Great Northern Transmission Line project. HDR cultural resources professionals assessed areas of the Project for archaeological properties and historic buildings and structures. The extensive bogs and remoteness of the line showed little promise of important cultural resources affected by the Project. MP, in talks with RLN, resulted in a shift of the route near Roseau Lake to avoid major historic Indian village of the Ojibwe chief Mickinock.

Other agencies, the Minnesota Department of Natural Resources (DNR) in particular, were concerned with state resources, such as state and federally protected species and sensitive plant communities. During negotiations with state and federal agencies regarding siting the new transmission line, MP was asked by the DNR to shift a roughly 13-km (eight mi) segment of the line to the east to avoid a stand of old-growth trees in the vicinity of the Black River. This shift put the transmission line directly over the site of a historic homesteader's log cabin complex that was subsequently found eligible for the National Register of Historic Places. Continued conversations with public agencies and tribes arrived at a mutually satisfying solution for mitigating adverse effects to the property.

METHODS

In order to arrive at these solutions, a number of approaches were used:

- Meetings with tribal councils
- Independent, respect-based consultation with tribes
    - o While DOE consulted with a number of tribes on a broad scale, MP chose to independently work with the Red Lake Nation and other tribal governments by meeting with tribal leaders to discuss topics of mutual benefit. Because much of the land through which the GNTL passes is checker-boarded with Red Lake tribal land, it was important to collaboratively site the line to avoid the tribal lands.
- Face-to-face investment builds productive relationships
    - o Through independent consultation, MP built on positive meetings to create relationships and an atmosphere where trust could lead to future collaborations.
- Outreach and meetings with local communities
    - o From July 2012 to January 2017, HDR and MP reached out to tribal communities and stakeholders in the region through letters, workshops, and open houses, contacting them by mailings of letters, postcards, newsletters, reports, questionnaires, and in-person attendance at tribal council meetings. Input was sought on routing, historic property inventory strategies, and sensitive resource concerns.
- Integrated Pre-application Process
    - o Use of the Department of Energy's Integrated Interagency Pre-Application (IIP) Process. This voluntary process is designed to improve coordination among intergovernmental agencies and encourage early participation and engagement between project proponents and stakeholders (DOE website). The result of early coordination and information sharing is increased efficiency in processing permit application and an improvement in permitting times.
- The creation of a Programmatic Agreement among federal and state agencies laid out details on how to deal with any historic property affected by the project,

and established a method of communication among interested parties. The PA specifically called for the creation of detailed plans for historic property treatment, monitoring plans, and quarterly construction updates. All plans were reviewed and accepted by local tribal Tribal Historic Preservation Officers (THPOs).

- Broad, regional approach to historic landscape and resource identification
    - o (*Kade's historic landscape study*) The Red Lake Band of Chippewa Indians (Red Lake Nation), with MP, and in cooperation with the Bois Forte Band of Chippewa, Fond du Lac Band of Lake Superior Chippewa, Leech Lake Band of Ojibwe, Mille Lacs Band of Ojibwe, and the White Earth Band of Ojibwe, completed a Traditional Cultural Property and Traditional Cultural Landscape report documenting results of tribally directed surveys. This approach took into account a more holistic view of significant resources, including landscapes that might not be understood or identified by federal agencies and project proponents and their consultants.
- Cultural resources surveys that included tribal archaeologists
    - o Several THPOs provided cultural staff and archaeologists to work alongside HDR staff during critical areas of the survey in 2016, 2017, and 2018. Those tribes participating included Red Lake Nation, the Mille Lacs Band of Ojibwe, and the Fond du Lac Band of Lake Superior Chippewa.
- Providing for Monitors during construction
    - o By including provisions for construction monitoring by tribal representatives in the PA, the project furthered communication and trust between MP and tribes. Only one National Register-eligible historic resource that would be adversely affected by the project required a mitigation plan that included tribal monitoring.
- Genealogy interviews and research to establish historic ties to the local tribal community in the early 1900s
    - o By researching and developing a new historic context that focuses on Ojibwe involvement in the lumber industry, the Project further establishes ties by showing an interest in local and tribal economies. Logging has played an important role in the lives of the Ojibwe people in the region from the very beginnings of the logging boom through the present day. Through interviews with local tribal elders and research, HDR and MP (with the assistance of a subcontracted service, 106 ANCS), the Project was able to continue to forge ties with the Native communities and the resulting historical context and short documentary video will provide benefits to the local community, the professional history community, and MP.
- Reassessment of cultural resources using state-of-the-art technology
    - o Through conversations with SHPO, Red Lake THPO, and the Office of the State Archaeologist, MP agreed to minimize effects to the eligible historic property by doing construction-related tree clearing during the winter from pallets on frozen ground. Careful tree removal around the cabin ruins was monitored by archaeologists and tribal representatives as called for in the Programmatic Agreement. A site revisit was scheduled for late spring to see how the site and cabin ruins fared during the removal process and to assess if any additional subsurface damage occurred that would negatively affect the archaeological component of the site. Part of this reassessment included precise and detailed aerial imaging using unmanned aerial vehicle (UAV) technology provided by the Red Lake THPO on May 21, 2018, using UAV technology to conduct detailed photogrammetry (geo-referenced orthophotographics) and light detection and ranging (LIDAR) data collection. "LIDAR is a surveying method that measures distance to a target by illuminating the target with light and measuring the reflected light to make digital 3D representations of a landscape" (Ferris 2018).

DISCUSSION

Employing the methods outlined above, MP has now reached a point where construction of the line has begun. Multiple options were weighed for siting, consultations were initiated, and agreements reached. Numerous cultural surveys were implemented that ultimately resulted in very few resources affected. Only one property was found within the Project's area of potential effects that rose to a level of significance requiring additional considerations. HDR archaeologists, acting on a tip from civil surveyors, discovered the ruins of a small log cabin missing its roof, and the remains of two other structures situated at the edge of a large black spruce swamp within the GNTL right-of-way (ROW). HDR historians and archaeologists, along with regional THPOS, dug into historic records and discovered that this was the property of Mr. John Frosch, a homesteader who acquired title to the land in 1915, and who died a few short years later. Deed research indicated that after Frosch, the deed fell to a mortgagor, John Elliott of Minneapolis, and then to the state through tax foreclosure. Currently, the property is part of a state forest, and has been since the 1920s. The property is unusual in that it had so few owners, and has remained virtually untouched for 100 years.

CONCLUSIONS

Respectful meetings with tribal councils and local communities created trust and generated good will among the project proponents and indigenous communities. These interactions have led to lasting relationships and development of cooperative agreements on future projects.

Making use of the IHP-facilitated communication and kept the permit process moving forward in an efficient manner.

Use of a programmatic agreement (PA) facilitated the resource inventories, outlined detailed plans for treatment and mitigation of adverse effects to historic properties. It encouraged broad, regional approaches to historic landscape and resource identification, provided for monitoring and resource surveys that included tribal participation, and allowed for interviews and genealogical research in order to develop a historic context on historic Ojibwe participation in the lumber industry in Northern Minnesota.

Teaming up with the Red Lake Nation THPO to use of state-of-the-art technology in assessing the effects of construction techniques to a National Register Eligible property helped to solidify relationships between MP and RLN by working on a project of mutual interest and local importance.

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AUTHOR PROFILES

Michael Justin

Michael Justin has extensive professional experience in the field of cultural resources management, archaeology, and historic preservation issues. He has worked as a professional archaeologist since 1983. Justin's cultural resource experience includes working with federal and state agencies, in two different museum settings, and most currently in the private consulting sector. Justin specializes in Section 106 compliance issues and precontact cultures of the Upper Midwest, but has participated in projects located throughout the country, providing cultural resource experience to a variety of federal, state, county, and municipal agencies. Since January of 2012, Mr. Justin has retained a volunteer position on the Saint Paul Heritage Preservation Commission, an advisory body to the Mayor, and the City Council on municipal heritage preservation matters. Justin is also a member in good standing of the Register of Professional Archaeologists and the Society for American Archaeology.

Michelle Bissonnette

Michelle Bissonnette has more than 26 years of consulting experience in the energy industry. She serves as a senior project manager and strategic services practice lead (public involvement, environmental, real estate services, and environmental compliance monitoring) for HDR's Power program. She manages teams that conduct environmental assessments (EAs) and permitting for transmission line, wind power, and energy projects. Bissonnette is responsible for organizing and participating in public and agency meetings related to EAs, with emphasis on power and energy projects.

Use of Quantitative Mitigation Analysis to Facilitate Timely and Defensible Compensatory Mitigation

Timothy Reilly, Brian Bub, and Josh Arrigoni

Instead of traditional and often arbitrary methods for gauging linear development-induced environmental impacts on a single resource or habitat, impacts of development activities may be reviewed on an ecosystem level with a focus on services provided by ecosystem components. This way, relative impacts to ecosystem services can be evaluated in order to determine the overall impacts to the system as a whole, resulting in a more comprehensive approach to quantifying environmental impacts and respective compensatory mitigation (CM). Further, mitigation strategies that implicitly address climate change issues may be integrated into chosen mitigation or restoration strategies. Quantitative mitigation analysis (QMA) is a methodology developed to assist project developers and regulatory agencies alike with developing or evaluating cost-effective, defensible, quantitatively based CM strategies for developments/betterments that result in the taking of, or diminution in quality to, habitats and related natural resources. QMA quantifies loss of ecological function from proposed developments and determines the amount of mitigation required as compensation. This paper introduces and describes QMA and presents a case example that demonstrates how QMA may be applied to a linear project for the benefit of project developers and the regulatory community alike.

Keywords: Compensatory Mitigation (CM), Ecosystem Services, Quantitative Mitigation Analysis (QMA).

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Current guidance for compensatory mitigation (CM) is developed for wetlands, but despite a 2015 Presidential Executive Memorandum to mitigate for development-induced losses to all sensitive habitats, proven strategies for CM in many habitats (e.g., upland, intertidal, subtidal lands), and sensitive biological resources are not adequately considered under current policies and regulations in the U.S. and abroad. Regulatory agencies and project developers alike seek a quantitative tool for scientifically based mitigation strategies to quantify losses and cost-effectively mitigate for development-induced losses in order to make the public whole. Instead of traditional and often arbitrary methods for gauging environmental impacts (such as wetland mitigation ratios) on a single resource or habitat, impacts stemming from development activities may be reviewed on an ecosystem level with a focus on services provided by ecosystem components. This way, relative impacts to ecosystem services can be evaluated in order to determine the overall impacts to the system as a whole, resulting in a more comprehensive approach to quantifying environmental impacts and respective mitigation. Further, mitigation strategies that implicitly address climate change issues may be integrated into chosen mitigation or restoration strategies. Quantitative mitigation analysis (QMA) is a methodology developed to assist project developers and regulatory agencies alike with developing cost-effective, defensible, quantitatively based CM strategies for developments that result in the taking of, or diminution in quality to, habitats and related natural resources such as threatened and endangered (T&E) species. QMA quantifies loss of ecological function from proposed development and determines the amount of mitigation required as compensation. This paper introduces and describes QMA and presents a case example involving a new power transmission line right-of-way (ROW), demonstrating how QMA may be applied for the benefit of project developers and the regulatory community alike.

QMA Description and Methodology

QMA is a methodology developed to assist (construction) project developers and regulatory agencies with developing defensible, quantitatively based compensatory mitigation strategies for large and/or complex construction projects that result in the taking of, or diminution in quality to, habitats and related natural resources (Reilly et al. 2012).

QMA quantifies loss of ecological function from proposed development and determines the amount of mitigation required as compensation. The cost of CM required is the cost of a project required to provide an equivalent nature, type, and degree of ecological and/or public use services which were directly or indirectly lost by a development.

QMA leverages Habitat/Resource Equivalency Analysis (HEA/REA), which are analytical tools developed to determine compensation for losses to natural resources from a spectrum of human-induced impacts (NOAA 2016). HEA/REA applies a framework for scaling (i.e., sizing) project impacts for quantifying compensatory mitigation. HEA/REA computes resource losses over time resulting from environmental perturbations, and resource gains with time resulting from CM projects. As such, HEA/REA may be used for calculating mitigation requirements for practically any habitat or natural resource. Moreover, HEA and REA analytical tools are widely-accepted methodologies for calculating lost and gained services following an environmental perturbation. Federal and state governments in the U.S. have used HEA and REA in both natural resource damage assessments and for some mitigation computations; hence, conferring acceptability for QMA methodologies.

Additional information regarding HEA and REA scaling tools may be found at:

https://coast.noaa.gov/archived/coastal/economics/habitatequ.htm (NOAA 2016).

QMA is implemented according to the following general methodology:

Step 1: *Proposed Project Review*: The development project design is reviewed to scope the potential for natural resource impacts, takings, and degree of impacts.

Step 2: *Compliance Review*: Local, state, and federal natural resource management laws are reviewed to determine if resource takings are special status (e.g., T&E species, critical habitats, or other protection status) that may affect calculation and identification of appropriate CM.

Step 3: *Invitation Of Permitting Authority or Developer to Participate in QMA*: In many cases, the project developer may invite the regulatory authority to participate in the calculation of losses and/or identification of appropriate mitigation projects, thereby facilitating a comprehensive consideration of natural resource losses and appropriate mitigation projects that are consistent with local natural resource management objectives and priorities. Conversely, the regulator may invite the project developer to participate in a QMA to ensure a thorough understanding of the proposed development. While this is not a required step, cooperation between project developer and permitting/regulatory authority has been found to facilitate and accelerate QMA-based CM project development.

Step 4: *Site Visit/Field Data Collection*: Site visits and other field data collection strategies, as appropriate, are used to collect data to aid in determining and calculating the nature, degree, and spatial and temporal extent of natural resource takings resulting from the proposed project using industry-accepted techniques (e.g., literature reviews, field surveys, and ecological modeling) to assess natural resource losses.

Step 5: *Derivation of Direct/Indirect Natural Resource/Habitat Present Value Losses*: Using data collected in Step 4, resource service losses resulting from the proposed development are quantified (e.g., acreage lost, quantified loss of T&E species, etc. over a presumed time period using generally accepted survey methods). Loss quantification may be aided by computer modeling, geographic information systems (GIS) analysis, and other accepted methods. For habitat losses, once habitat resource losses are quantified, lost ecological services are calculated using HEA with the general formula:

$$\text{Habitat Loss} = \sum_{t=0}^{t=\text{recovery}} (\text{Habitat Area}) \times (\%\ \text{Service Loss})_t \times (1 + \textit{discount rate})^{P-t}$$

Where P=present year, % service loss is the estimated percent habitat service losses at loss year t, and t= each year that a loss occurs (i.e., resulting from the development-induced project) until full system recovery is reached. The discount rate is described below.

Similarly, resource-based losses (e.g., the number of impacted members of a given species) may be quantified using the following formula:

$$\text{Resource Loss} = \sum_{t=0}^{t=\text{recovery}} (\text{Resource Units}) \times (\%\ \text{Service Loss})_t \times (1 + \textit{discount rate})^{P-t}$$

Where the resource units may be the lost or otherwise adversely impacted number of plants or animals. As above, the % service loss is the estimated loss of resource-based services at loss year *t*; P=the present year and t=each year that the resource-based loss occurs until full recovery of the resource.

Ecological service losses from proposed developments may have a temporal as well as spatial or biological resource loss component (i.e., losses are not instantaneous, but continue for some duration of time until full ecosystem recovery). Therefore, to accurately compare habitat/resource service losses from some perturbation to gains from a specified mitigation project over time, certain losses (and gains in services from a compensatory mitigation project) to ecological services must be put into a present (ecological service) value context. To facilitate a present value comparison between habitat service losses and gains, habitat service acres are converted to discounted service acre years (DSAY) with losses summed through a period where the habitat provides services below its baseline state (i.e., services provided but for the construction project). In such an analysis, ecological services are discounted.

Discounting is an economic procedure that weighs past and future benefits or costs such that they are comparable in a present value context. The area unit of measure used here (acres) may be changed based on location and resource. For example, we often used square meters for certain losses, such as coral reefs.

The discount rate incorporates the standard economic assumptions that people place a greater value on having resources available in the present than on having their availability delayed until the future. The annual discount rate used in a HEA (or REA) calculation represents the public's preference towards having a mitigation or restoration project in the present year, rather than waiting until next year. The economics literature supports a discount rate of approximately three percent (NOAA 2000). However, this discount rate can vary depending on the nature and uniqueness of the natural resources/habitats in question and other site-specific factors.

Accordingly, by convention, we normally apply a standard three percent discount rate to contemplate this service value weighting in time.

Step 6: *Identify And Evaluate Candidate Compensatory Mitigation Projects and Select Project(s) That Best Compensate for Nature, Degree, and Quality of Lost Natural Resources From Development*: Once the nature (type), degree, and spatial/temporal extent of anticipated losses to natural resources from the proposed project are determined, a set of alternative projects are identified which compensates for the same type, quality, and extent of anticipated losses. The project developer may want to work with the regulator and/or other local natural resource managers to identify pertinent natural resource management priorities and appropriate projects. Projects that provide resources of the same type and extent as the anticipated losses are prioritized, as are cost-effectiveness and the ability to size the project to offset the amount of losses (i.e., scalable projects are generally preferred).

Step 7: *Scale CM Projects Using Service-to-Service or Other Appropriate Mitigation Project Scaling Methodologies*: CM projects are scaled to determine the discounted service flows from the selected project(s) and scaled (sized) to provide the same level of comparable ecological services lost from the proposed project. The mitigation project scaling equation is (in this case geared to habitats; a similar equation is developed for biological resource gains):

$$\text{Habitat Gain} = \sum_{t=0}^{t=\text{recovery}} (\text{Habitat Area}) \times (\%\ \text{Service Gain})_t \times (1 + \textit{discount rate})^{P-t}$$

Where Habitat Area is the area of habitat being restored (in acres, square meters, or other appropriate area metric), Percent Service Gain is the gain in habitat services from the proposed CM project at year *t*; P=the present year; and t=each year that a gain occurs until full system recovery to a habitat's baseline condition is reached (or has produced ecological services equal to those lost from the construction project development).

Step 8: *Report Results to Project Developer/Permitting Authority for Decision-Making, Approval, and Implementation*: Once projects are identified and scaled to produce an equivalent amount of comparable ecological services to those anticipated lost from the proposed development project, the results of the QMA are reported to the project developer and/or permitting authority. Decisions regarding the appropriateness and acceptability of the project are made and amended by the project developer and permitting authority as necessary. Once the compensatory projects are accepted by the project developer and permitting authority alike, the project designs are finalized, and mitigation projects are implemented.

Example QMA Application to a ROW project in the Midwest

As part of the construction of a new 97-kilometer (km) 345-kiloVolt (kV) transmission line project (TLP) in the Midwest (U.S.), a ROW was constructed, resulting in approximately 12 hectares (ha) (30 acres) of moderate-to-high-value migratory bird forest habitat being cleared. At the request of the U.S. Fish and Wildlife Service (USFWS), the project developer, a Midwest Utility, is voluntarily mitigating for this loss of habitat. The project developer requested its environmental consultant, Stantec Consulting Services Inc., to develop mitigation strategies to compensate for lost migratory bird habitat. A QMA approach (Reilly et al. 2012) was used to derive appropriate mitigation for the assessed migratory bird habitat losses along the transmission line ROW. The results of the migratory bird habitat QMA are presented in the Results section below.

RESULTS

The TLP QMA case study results are presented below by QMA step as described in the preceding section.

Project Review (QMA Step 1)

The project developer's TLP Project is a new 345-kV electric TLP that was constructed between two of project developers' pre-existing substations in the Midwest. The line connects these substations and travels across the four counties. The approximately 97-km line is constructed of single-pole steel structures and was placed into service in summer 2017.

Compliance Review (QMA Step 2)

State, federal, and county laws were reviewed to determine requirements and constraints for any CM project(s). As part of the Endangered Species Act section 7 technical assistance coordination with the USFWS for the project, the USFWS recommended that migratory bird habitat impacts be mitigated pursuant to the Migratory Bird Treaty Act (MBTA).

Invitation of Permitting Authority to Participate in QMA (QMA Step 3)

To ensure any mitigation was appropriately developed and designed for this project, the project developer invited USFWS to participate in the development of CM alternatives. USFWS responded stating they would review and provide input regarding any CM project proposed by the project developer. This discussion was important to establishing the roles and responsibilities of the regulator and project developer in this instance.

Field Data Collection (QMA Step 4)

Aerial imagery was used to identify migratory bird habitat (mainly forested habitat) along the TLP transmission line ROW route. These images were analyzed using GIS to quantify identified migratory bird forest habitat.

The aerial imagery/GIS analyses also served to provide a preliminary evaluation of habitat quality: identified migratory bird habitat was further divided based on relative (habitat) quality per the Relative Quality Index summarized in Table 1.

Based on an analysis of the TLP route, the total number of permanently impacted forest acres was quantified for all impacted areas (52.98 ha; 130.92 acres). Of this area, the forest acreage of moderate-to-high value to migratory birds (i.e., having moderate to large contiguous and intact forest stands that provide suitable forest habitat for migratory birds) was found to be 29.76 acres (Table 1; Arrigoni 2016). Given its suitability as migratory bird habitat, this latter acreage was agreed upon between the project developer and the USFWS as an appropriate amount for CM. As such, it was chosen for further analysis of lost migratory bird ecological services and normalized in terms of service acres lost due to clearing of habitat (See QMA Step 5 below; Table 2).

Derivation of Migratory Bird Habitat Present Value Service Losses (QMA Step 5)

Estimated percent service losses are based on relative use of each RQI class of forest stands by migratory birds relative to undisturbed baseline habitat. For migratory bird habitats of moderate quality (Relative Quality Index of 2; Table 1), we conservatively assume that these habitats provide 50 percent of full migratory bird habitat services (i.e., relative to an baseline/undisturbed remnant forest habitat community); for those habitats having higher ecological value, we conservatively assign a migratory bird habitat factor of 75 percent (i.e., a diminution of baseline ecological services relative to an undisturbed high quality habitat of 25 percent), corresponding to an RQI of three. These service factors are multiplied by the area of their respective RQI 2 and RQI 3 cleared parcels to derive a cumulative lost migratory bird habitat of 8.11 ha (20.02 acres) for the clearing of the TLP ROW (Table 2).

Migratory bird habitat losses for the presumed 50-year TLP project are discounted and converted to present value in Table 3.

Therefore, from Table 3, CM projects must provide 535 discounted migratory bird habitat service acre years to fully compensate for habitat losses sustained from the TLP ROW project.

Identify and Evaluate Candidate CM Projects (QMA Step 6)

The project developer, through its consultant, solicited migratory bird habitat proposals from area nature/forest preserves located near the ROW route.

Relative Quality Index (RQI)	Relative Habitat Value	Migratory Bird Forest Habitat Description	Impacted Acres Along TLP Route (Acres)
0	Very Low/Nil	Individual or clumps of trees occurring singly or at the edge of an isolated forest stands or narrow fencerows that do not provide suitable forest habitat for migratory birds.	31.88
1	Low	Small, isolated, and/or fragmented forested stands (or portions thereof) that provide limited forest habitat suitability for migratory birds. Not limiting on the landscape.	69.28
2	Moderate	Moderate size, contiguous, and intact forest stands that provide suitable forest habitat for migratory birds. Somewhat limiting on the landscape.	9.21
3	High	Large size, contiguous, and intact forest stands that provide suitable forest habitat for migratory birds. Limiting on the landscape.	20.55
		Total Number of Acres	130.92
		Total Number of Moderate and High Value Acres	**29.76**

Table 1. Relative Quality of Migratory Bird Forest Habitat Impacted by the TLP ROW (per Arrigoni 2016)

RQI Index	Acreage by RQI Category (Acres)	Migratory Bird Service Factor	Service Acres for Compensation
0	31.88	0	0
1	69.28	0	0
2	9.21	0.5	4.61
3	20.55	0.75	15.41
Total Service Acres Required for Compensatory Mitigation (Non-Discounted)			20.02

Table 2. Service Acres Requiring Compensatory Mitigation (Non-Discounted)

Proposals were scored using a rubric based on a common set of qualitative migratory bird habitat restoration evaluation criteria. Because each of the received proposals sought to affect avian forest habitat enhancement through modification or restoration of extant ecosystems, they were evaluated based on their demonstrated capability to restore a range of woodland ecological services. These services include the establishment of sustainable, high-functioning native plant communities, restoration of appropriate site hydrology, conservation of existing site resources, and restoration of specific avian habitat functions in addition to factors such as implementation feasibility, ecological relevance or equivalence to the suitable forest habitat sites impacted by the project, and cost efficiency.

While each of the proposals evaluated would serve to mitigate for potential TLP project impacts, work proposed by one particular Forest Preserve District (FPD) near the TLP ROW was determined to be the most likely to achieve positive outcomes for the greatest number of criteria. The preserve selected for mitigation work is more than 80.93 ha (200 acres) and contains 40 ha (99 acres) of State Nature Preserve. The communities protected include high-quality flatwoods dominated by swamp white oak and high-quality dry-mesic upland forest. The upland forest canopy is dominated by white, bur, and red oaks. The proposed project would thin invasive brush out of the understory of both upland forest and flatwoods. This would focus on buckthorn and bittersweet populations in the forest understories of various portions of the Preserve. There would also be a focus on eight acres of grassland habitat that are located between two isolated forested parcels of the Preserve. The proposed restoration project would also control invasive weeds and plant several large oak trees to increase structural diversity in an attempt to reforest the area. These proposed restoration actions would provide additional habitat to migratory birds, decrease fragmentation, reduce edge, and reconnect forested portions of the Preserve (Chess and Haberthur 2016).

Present Year (of Analysis) (P)	Loss Year (t)	Annual Service Acre Loss (Service Acres Migratory Bird Habitat Loss/year)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Sum Losses to Migratory Bird Habitat from TLP Project (Discounted Service Acre Years)
2016	2016-2066	20.02	1.03	0-50	(1.03)P-t	535.13

Table 1. Discounted Migratory Bird Habitat Loss in Present Value

Scaling of CM Projects (QMA Step 7)

The overall proposed project at the selected Forest Preserve includes invasive brush removal, native seeding, planting of native trees, and long-term management of invasive species to varying degrees in several management units. Given the project's conceptual design and goals, HEA and communications with personnel at the selected Forest Preserve Unit were used to size (or scale) the project components to determine:

- The required acreage of invasive brush removal
- The required acreage of native seeding
- The required acreage of native tree planting
- The required acreage of invasive plant maintenance and duration (in years) of this maintenance

Quantification of the annualized ecological service gains (in DSAY) from the proposed mitigation projects requires the consideration of an a.rray of parameters, including:

- Area of restoration
- Ecological services provided to migratory birds (a weighed sum of the various critical components of a woodland/savanna habitat, including: groundcover, shrubs, understory plants, canopy, presence of surface water, habitat edge morphology (feathering), invasive plant control, and presence of contiguous vegetation (Chicago Department of Environment 2007).
- The discount rate (normally three percent in most HEA applications by convention and used here) to normalize ecological service gains in present value terms.

The proposed restoration areas were iteratively derived using a developed HEA model for these mitigation projects to determine the acreages of tree plantings and invasive plant maintenance, assuming a 10-year invasive management program time period used in the HEA mitigation project service gains model. (Ten years was chosen in HEA project scaling as a reasonable period of time that the FPD believed to be feasible to implement.)

Ecological services provided by mitigation projects were weighted based on their relative migratory bird habitat importance, which was based on information provided in a migratory bird habitat improvement guide published by the City of Chicago (Chicago Department of Environment 2007), which is geographically appropriate to the Helm Wood area of interest.

The resultant annual migratory bird service gains from the mitigation projects (in DSAY units) are summed over the life of this project and discounted (per Equation 3) to yield the present value ecological service gains for the life of these projects. Based on the proposed mitigation projects, the present value service gains over the lives of the mitigation projects yield the full value DSAYs required to compensate for losses resulting from habitat clearing conducted during the TLP ROW construction (Table 5), assuming the HEA-derived acreages of mitigation (i.e., 8.3 acres of tree planting/invasive control/seeding and 84.5 acres of invasive plant management over a period of 10 years.

Results Reporting, Decision-Making, and CM Implementation (QMA Step 8)

Based on the present QMA analyses, and refining (scaling) of projects at the FPD, the project developer and regulatory authority (USFWS) agreed on the nature and scope of the derived set of mitigation projects at the FPD. Project implementation began in 2018 and is anticipated to continue through 2027.

Description	Result
Moderate-to-High Value Migratory Bird Habitat lost resulting from TLP Project Construction (Acres)	30
Migratory bird habitat service acres lost (Service Acres)	20
Discounted Service Acre Years Lost (DSAYs) from TLP ROW Development	535
Service Gains from 8.3 acres of tree planting/invasive control/seeding (DSAYs)	96
Service Gains from 84.5 acres of invasive plant management over a period of 10 years (DSAYs)	441
Sum of Total Service Gains from All Mitigation Projects (DSAYs)	537
% Service Gains to Service Losses	100%

Table 5. Forest Preserve District Mitigation Project Service Gains Compared to Lost Migratory Bird Habitat Resulting from the TLP Project

DISCUSSION

With the exception of wetlands and a few other resources, there is a general lack of protocols, procedures, and methodologies to *quantitatively* derive appropriate CM that is of a similar nature, quality, degree, and spatial/temporal scope as those natural resources taken (lost) as a result of substantive or complex linear development/ROW construction projects. QMA provides an analytical construct that focuses on ecosystem service losses (from a development) and gains (from CM projects) put into present value, using accepted HEA and REA as an exchange system for ecosystem losses and gains. Discounting of lost and gained resources allows a comparative (present value) analysis of the quantified extent of CM requirements, reducing the qualitative or "horse-trading" factor so common in CM negotiations between the project developer and regulatory community. Importantly, the incorporation of accepted methodologies such as HEA and REA serves to establish QMA as a CM best practice.

We have found QMA to work in a variety of marine and freshwater aquatic and terrestrial habitats and also with specific biological assemblages (e.g., special protection status plants).

Critical to the success of a QMA analysis, it is the collection of high-quality data that defines 1) the nature, degree, and spatial/temporal extent of losses and gains from a proposed ROW (or other) development; and 2) candidate CM project(s), and their respective ecosystem service gains. These data are critical to define and defend as they comprise inputs to the loss and gains of QMA analyses. Project developers and regulators alike will need to defend their inputs in order to reach general concurrence regarding project-specific mitigation requirements.

Further, QMA facilitates strategic cost analyses of candidate CM projects by comparing the costs of alternative mitigation projects. For example, in the QMA case study featured in this paper, the costs of the mitigation projects at the selected FPD was compared to the costs of acquiring either moderate or high (ecological) value forest properties in the area of the ROW for preservation in perpetuity, deriving precisely how many moderate or high value acres would be required to procure to compensate for migratory bird habitat losses resulting from ROW construction (in this case, 41.25 acres moderate value habitat or 27.50 acres of high ecological value habitat would have to be acquired to compensate for ROW construction-based losses). Using real estate prices at *Landwatch.com* (2016), we demonstrated that the price of the proposed mitigation at the FPD was much more cost effective than land acquisition, or other considered mitigation techniques. Accordingly, QMA may be used to facilitate a unit mitigation cost analyses, thereby economizing mitigation costs while ensuring that mitigation is conducted comprehensively and appropriately.

CONCLUSIONS

QMA may be applied to a variety of projects and industries, from major construction developments to linear projects spanning tens to hundreds or thousands of km to offshore wind farms. QMA's use of accepted HEA and REA methods makes it a best practice for calculating CM requirements, and is flexible across habitats and locations, and useful for an array of land and resource construction/development projects. Developers and regulators alike benefit from QMA by knowing that quantified mitigation is sufficient and cost-effective for a given development, thereby limiting arbitrary decisions regarding mitigation appropriateness and sufficiency.

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PART IV

Regulatory

Assessing Cumulative Effects on Traditional Land Use in Canada: An Approach for Pipeline Projects

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In their submissions to the Expert Panel for Review of Environmental Assessment (EA) Processes, Canadian Indigenous groups have commented on the scope of cumulative effects assessment and EA processes that honor their holistic view of the world. Many Indigenous groups advocate for changes to the temporal and spatial scales used in the cumulative effects assessment performed by proponents and for greater inclusion in the assessment process. Temporal scales that use preindustrial development as baseline and spatial scales that use traditional territory boundaries, rather than resource use boundaries, have been requested. Indigenous groups argue that these boundaries more adequately allow for the assessment of the effects of development on their traditional land use and the holistic nature of their relationship with the land. For linear projects in Canada, which often involve multiple Indigenous communities, assessing the cumulative effects on traditional land use presents challenges. In this paper, Indigenous perspectives on the EA process are reviewed, proposed changes to the federal EA process are considered, and it is recommended that current practice with respect to temporal and spatial boundaries continue, traditional knowledge is more explicitly incorporated into the EA and project planning, and that future assessments consider effects on rights rather than traditional land use.

Keywords: Cumulative Effects Assessment, Indigenous Rights and Interests, Traditional Land Use.

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INTRODUCTION

In 2016, the Canadian federal government conducted a review of federal environmental assessment (EA) processes and sought input from Indigenous groups and other Canadians. This review would have a direct impact on major energy infrastructure across Canada, and in particular, pipeline and powerline projects that cross interprovincial boundaries. In their submissions to the Expert Panel for Review of Environmental Assessment Processes, Canadian Indigenous groups commented on the scope of cumulative effects assessment and EA processes that honor their holistic view of the land and water. Many Indigenous groups advocated for changes to the temporal and spatial scales used in the cumulative effects assessment performed by proponents. More specifically, requests were made to include temporal scales that use preindustrial development as baseline, and spatial scales that use traditional territory boundaries, rather than resource or government assigned (i.e., legal survey) boundaries. Indigenous groups argued that these traditional territory boundaries more accurately reflect the assessment of the effects of development on their traditional land use and the holistic nature of their relationship with the land.

For linear projects in Canada, which often involve multiple Indigenous communities with overlapping traditional territories and interests, assessing the cumulative effects on traditional land use presents challenges. Unlike projects with a localized footprint like mines and discrete site facilities, linear projects can traverse hundreds of kilometers (km), and in doing so, they cross the traditional territories of many different Indigenous communities with differing interests. In addition, unlike other projects, pipelines generally move oil or gas from start point to end point, so they do not provide any service to the lands they span or the Indigenous communities whose lands are crossed.

Currently, the regulatory authority for the EA of federally regulated pipeline projects is the National Energy Board (NEB). The NEB Filing Manual (NEB 2017) is prescriptive in that it outlines the valued components that are to be assessed and proponents follow this guidance in completing their EAs of pipeline projects. The NEB Filing Manual requires that proponents assess the effects of the project on current traditional use of land and resource by Indigenous groups and states that traditional knowledge should be incorporated into the assessment process where possible.

In February 2018, the Canadian federal government announced its intention to combine all federal EA processes under one umbrella organization, the Impact Assessment Agency of Canada, and abolish the NEB, which is currently the regulatory authority for federal pipeline projects. At the same time, the federal government announced its intention to address issues related to reconciliation with Indigenous groups and their rights through this new EA process (Canada 2018; Environment and Climate Change Canada 2018). When these changes are implemented by the federal government, pipeline projects will be overseen by a new regulatory authority, which will require changes to the assessment process to accommodate Indigenous groups' rights and require teams to work within the truth and reconciliation process.

This paper reviews the input from Indigenous groups during the engagement for the Expert Panel for Review of Federal Environmental Assessment Processes, identifies concerns and recommendations regarding effects assessment and cumulative effects assessment, examines the changes to the federal EA process announced by the federal government in February 2018, and provides recommendations for assessment of the cumulative effects of linear projects (specifically pipelines) on Indigenous traditional land use and interests when the new regulatory regime is implemented.

METHODS

In this paper, the submissions to the Expert Panel for Review of Environmental Assessment Processes of 154 Indigenous groups from across Canada were reviewed to identify Indigenous perspectives on the Federal Environmental and Socio-Economic Assessment (ESA) Process (changed to Impact Assessment process in new legislation). Current practice for environmental and socio-economic assessment for federal pipeline projects was then reviewed to determine the extent to which the existing process already addresses concerns raised by Indigenous groups. Finally, the paper makes recommendations to proponents for conducting cumulative effects assessment considering proposed changes to the federal ESA process.

RESULTS

Issues Raised and Recommendations Made by Indigenous Groups Regarding Federal ESA Processes

More than 150 Indigenous groups participated in the review of federal EA processes and identified a range of concerns with the existing processes and proposed solutions to these concerns (Federal Expert Review Panel on Environmental Assessment Processes 2016). This section summarizes the issues raised by Indigenous groups with respect to the cumulative effects assessment, including overriding issues and concerns that pertain to it, and the recommendations identified by Indigenous groups to address these concerns.

Table 1 summarizes the concerns expressed by Indigenous groups with respect to the federal cumulative effects assessment process and the recommendations from Indigenous groups.

DISCUSSION

Based on the matters raised by Indigenous groups in relation to cumulative effects assessments, this section explores the concerns raised and the recommendations proposed by Indigenous groups. This section also examines how federal ESA processes are currently conducted for pipeline projects in Canada, but more importantly, where the assessment process is trending for future assessments.

Regional and Strategic EAs

Indigenous groups support the establishment of regional or strategic EA frameworks, stating that existing project-specific cumulative effects assessments do not meet their needs in several ways:

- Inability to protect the environment from activities that exceed environmental thresholds.
- Inability to account for historical and ongoing environmental effects resulting from prior to existing projects.
- Inability to ensure that the collective adverse environmental

Concern with Existing Process	Recommendations by Indigenous Groups
Project-specific cumulative effects assessment cannot capture all effects from multiple projects in a region.	Regional and strategic environmental assessments should be used more.
Lack of involvement of indigenous groups in the environmental assessment process.	Co-management. Parallel environmental assessment processes. Involvement in all aspects of the environmental assessment process, including issues scoping and significance determinations.
Lack of incorporation of indigenous knowledge at all stages of project development.	Incorporation of indigenous knowledge in all aspect of project planning, including scoping of valued components.
Narrow requirement to assess effects of a project on traditional land use rather than indigenous peoples' rights and interests.	Assess the effects of a project on indigenous groups' rights and interests rather than traditional land use.
Assessment of effects of a project on traditional land use on an aggregate basis fails to account for the differences between indigenous groups.	Assessment of the effects of a project on individual indigenous group's rights and interests.
Narrow western focus in scoping of effects and selection of valued components.	Broader scoping of effects to include intangible elements, such as the effects on culture and the interconnectedness between effects, attuned with the holistic view that indigenous groups hold. Include culturally important species in valued components, not just species at risk.
Spatial boundaries are not appropriate for assessing the full spatial effect of the project.	Landscape, watershed, and ecological EAs.
Temporal boundaries are not appropriate for assessing effects on indigenous groups' rights because temporal boundaries focus on current use of land and resources.	Use a pre-industrial baseline for assessment of cumulative effects. Include future use in assessment of cumulative effects.
Significance determinations and thresholds do not reflect indigenous values.	Establishment of thresholds for species at risk and culturally important species, and assessment according to these thresholds. Inclusion of trends over time with respect to a valued component so as to be able to determine thresholds or limits.

Source:
Indigenous group input to the Federal Expert Review Panel on Environmental Assessment Processes.
http://eareview-examenee.ca/submissions-received/

Table 1. Indigenous Groups' Concerns and Recommendations

effects do not result in situations where the exercise of Indigenous or Treaty rights is precluded.

- Inability to establish a process for relationship-building with the federal government (i.e., the Crown).

Indigenous groups outline specific situations where regional and strategic EAs should be conducted: 1) industrial sectors where individual projects are widely distributed in the landscape, but are too small to individually trigger an assessment; 2) locations where there are widespread existing cumulative effects; 3) locations where species are at risk; and 4) locations where culturally important species have large home ranges and may be affected by a project.

Others have advocated for regional and strategic EAs as a better means of managing cumulative effects than project-specific cumulative effects assessments (Duinker and Greig 2006; Thrievel and Ross 2007; Gunn and Noble 2009; Noble 2009; Noble et al. 2014; Sinclair et al. 2017), but they also acknowledge the obstacles to establishing regional and strategic EA frameworks. Barriers to the establishment of regional or strategic EAs include the lack of a lead agency to take responsibility for the framework, funding and human resources, enabling legislation, and multi-stakeholder coordination, and difficulty in managing data and establishing baseline indicators and thresholds (Noble et al. 2014; Sinclair et al. 2017).

Currently, the structures are not in place for regional or strategic EAs. Regional and strategic EAs place the onus on government intervention and collaboration with Indigenous groups and stakeholders. A move towards regional assessments will require that new policies and legislation be enacted (e.g., the development of a National Energy Policy to provide clear guidance to the nation and allow for the completion of regional and strategic EAs). In the absence of these frameworks, project-specific cumulative effects assessments will still be required. If these frameworks are established with the new federal legislation around EA, proponents would then be responsible for the assessment of their project-specific effects and would no longer be responsible for a cumulative effects assessment.

At this time, the federal government has not set up a single agency or department responsible for developing a regional or strategic assessment. It could take years before these assessments can be established, the data can be gathered and analyzed, and science can then help define acceptable thresholds. An enormous amount of funding to develop these assessments for all regions throughout Canada would be required. Through each step of the way, consultation with stakeholders and Indigenous groups would need to take place. If these are set up under the new legislation, proponents could support regional and strategic assessments by providing baseline information from their projects and post-construction monitoring programs.

Involvement of Indigenous Groups

Indigenous groups provided a variety of recommendations with respect to their participation in the EA process. The extent of involvement in the assessment process varied among groups. Some Indigenous groups recommended that all resources be co-managed, with the federal government and affected Indigenous groups jointly making decisions on how resources are managed. Others recommended that Indigenous groups be funded to complete their own parallel EA process, citing Squamish Nation's assessment of the Fortis British Columbia (BC) project, and Stk'emlupsemc te Secwépemc Nation's (SSN's) assessment of the Ajax Mine Expansion as examples of parallel EA processes. Others advocated for the inclusion of Indigenous groups in all phases of the EA process.

Specifically, Indigenous groups recommended that potentially affected groups should be involved during the conceptual stages of the project and involved in decision-making regarding the scoping of the cumulative effects assessment. This involvement would include deciding the following: what the valued components should be, how these valued components should be measured and addressed, what the spatial boundaries and temporal boundaries should be, how the determination of the significance of effects will be defined, and what the significance thresholds should be. Indigenous groups argue that their involvement in all aspects of the assessment process allows for a different perspective in assessing effects.

Current best practice for federal pipeline projects is to include Indigenous groups in all stages of the EA process. However, the extent of involvement varies. This is in part due to an Indigenous group's capability and capacity to engage on all projects in their traditional territory, and a proponent's requirements to engage based on the type of project and existing federal requirements. While parallel processes have been successfully used in the EA of the Fortis BC pipeline project and Ajax Mine, their use has not been efficient and effective in reaching conclusions, particularly for pipeline projects where there are many different Indigenous groups involved. Regulators have the responsibility of balancing all these factors and the interests of Indigenous groups. A decision can be more contentious when a project is deemed to be in the "public or national interest" and requires a balancing of the benefits and burdens for all Canadians.

Incorporation of Traditional Knowledge

Currently, the use and incorporation of traditional knowledge in the EA process is subjective. While there is clear direction to use traditional knowledge in the assessments themselves, how it is incorporated and decisions that are made on what should or should not be incorporated at what stage of the process remains unclear. Traditional knowledge can complement western scientific information collected to inform the project design, and in areas where little western science knowledge exists, Indigenous groups are closest to the land and water and hold the knowledge of the natural resources within their traditional territory. Indigenous groups recommended that traditional knowledge should be compulsory in all stages of cumulative effects assessment and should be fully incorporated into project planning. Proponents should be required to describe how traditional knowledge has been incorporated into each section of the EA in order to demonstrate that the proponent has made efforts to understand the Indigenous group's perspectives and rights with respect to the project and to meaningfully include them in project planning. Ideally, Indigenous groups wish to be involved and retain control of the collection of baseline information on traditional use and be engaged in the process for incorporating into the ESA and project planning.

While the incorporation of traditional knowledge has been subjective, it is standard practice for traditional knowledge to be incorporated into EA for pipeline projects in Canada. Opportunities for Indigenous groups to share traditional knowledge vary by project and proponent, but may include meetings, map reviews, site visits to proposed project sites, participation in biophysical studies conducted by western scientists for the project, and/or funding of traditional land use studies. Indigenous groups can choose to collect and provide their own traditional knowledge, work with an independent consultant, or work with the proponent's consultant to provide this information.

Traditional knowledge gathered from various opportunities given to Indigenous groups is then woven into the various valued components in the ESA. While traditional knowledge is sought to inform the assessment of the effects of the project on traditional land and resource use, knowledge is also shared about other valued components, such as vegetation, wildlife, fish, and fish habitat (the resources that are utilized in traditional use activities) and informs mitigation measures and project planning. How often the way in which traditional knowledge is incorporated is not explicitly stated in the ESA and Indigenous groups cannot see it.

Assessment of the Project Effects on Indigenous Rights and Interests Rather Than Traditional Land Use

Current EA legislation requires that proponents assess the effects of the project on the current use of land and resources. Indigenous groups argue that the scope of the EA process must be broadened to include consideration of impacts on their rights, socio-economic conditions, and culture. The narrow focus on current use of lands and resources fails to account for the effects of the project on Indigenous peoples' rights, which are distinct from the effects on the natural environment that supports those rights. For example, a focus on traditional land use does not allow for temporary non-use of specific areas or specific resources (e.g., caribou) while waiting for stocks to replenish. Although an area or resource may not currently be in use, the Indigenous groups' rights to harvest that particular species or in that particular area still exist. Many of these types of pressures on resources and scenarios exist on the landscape before the project comes along. Similarly, the focus on traditional land use suggests that fish are abundant in the territory as a whole and, therefore, the right to fish is not affected. However, this approach ignores potential project effects that might make access to fishing sites more difficult and ignores perceptions about the quality of food in the harvest area.

Current practice for pipeline projects assessed within federal processes is to assess the effects of the project on traditional land use as directed by the NEB Filing Manual, not rights. Several provincial processes require the assessment of the effects of the project on rights, including BC and Alberta. When the new legislation is enacted, proponents will need to assess the effects of the project on the right to hunt, fish, and gather plants. This may require adjustments to the scoping of valued components to be assessed and how the assessment proceeds.

Assessing Effects on Indigenous Rights at the Individual Community Level

Many Indigenous groups recommend that the spatial boundaries for the assessment of effects on traditional land use should be the traditional territory of the affected Indigenous group. Currently on many pipeline projects, the effects of a project on traditional land use are assessed on an aggregate basis rather than an individual community basis. Indigenous groups argue that each community may be differently affected. While there are common elements to activities, resources, and locations where Indigenous groups use lands and resources, each community may be differently affected relative to the location of the proposed project and may have different mitigation preferences; therefore, the assessment should be conducted on an individual community basis.

Indigenous groups argue that the spatial boundary that should be used in assessing the effects of a project should be the extent of the Indigenous group's traditional territory. This approach allows for the proponent to include the significance of particular areas to individual communities in their assessment. For example, while only a small percentage of all of the berry patches in a project effects assessment area may be affected by a project, the area affected may be a preferred harvesting site for an individual community because of its proximity to the community or because there are few sites within their individual traditional territory. In addition, Indigenous groups contend that this allows for a more holistic approach to the assessment and consideration of project effects that may occur beyond the designated project area.

Current practice for pipeline projects is to assess the cumulative effects of the pipeline on traditional land use at an aggregate level and at spatial scales based on the spatial extent of the effects of the project rather than traditional territory boundaries. There are sufficient commonalities in the resources used for traditional land use and the traditional land use activities conducted among Indigenous groups such that assessing at an aggregate level provides enough information to the decision-maker to make a decision about the project. While it is appropriate for the assessment to occur at an aggregate level, it is important that the discussion within the assessment provides information relating to individual Indigenous groups, and that site-specific mitigation decisions are made with individual Indigenous groups whose specific traditional use sites are affected by the project. Additionally, preferred harvesting locations within traditional territories for individual communities can be built into the assessment and mitigation measures developed accordingly. The cumulative effects assessment can both reflect individual Indigenous group preferences and assess the effects on traditional land use at the aggregate level without using traditional territories as the spatial scale.

Narrow Western Focus in Scoping of Effects

Many Indigenous groups contend that the narrow western focus in scoping of effects does not allow for the full consideration of the effects of a project on Indigenous rights and interests. The following specific concerns have been identified by several Indigenous groups:

- Impacts on culturally used species that are not rare or endangered are not fully considered.
- Impacts on less tangible environmental elements (e.g., cultural continuity, spiritual, stewardship) are not included.
- Pathways to secondary effects on socio-economic conditions and health as a result of traditional uses are not considered (e.g., changes in diet, income, increased cost of living, loss of culturally important knowledge, and changes to social fabric).

When considering the selection of valued components for cumulative effects assessment, Indigenous groups recommend that the following questions should be asked: What are the uses taking place? What are the environmental values that support those uses? What is the historical baseline that existed prior to environmental impacts associated with previous projects?

Although current best practice for federal pipeline projects is to include Indigenous groups in all stages of the EA process, the valued components that must be assessed by proponents are specified in the NEB Filing Manual, and proponents often limit their valued components to those required in the NEB Filing Manual. Although intangible elements such as cultural continuity, spiritual issues, and stewardship are not explicitly included as valued components, these elements are captured in other elements that are assessed, such as social and cultural well-being. Similarly, effects on culturally used species are considered in the EA in the evaluation of vegetation, wildlife, and wildlife habitat, but are not explicitly assessed in a separate section as the rare or endangered species are. For example, moose are not considered rare or endangered, so they are not included in the specific assessments of effects on individual species, but the effects on moose are considered in the assessment of the effects of the project on wildlife and wildlife habitat.

When the new legislation is enacted and EAs are no longer conducted based on the NEB Filing Manual, the valued components to be considered may not be as prescribed as they are now. Proponents will potentially then need to develop project-specific valued components, although those outlined in the NEB Filing Manual will potentially be used as a basis because these have provided sufficient information for decision-makers to date. One proposed intent of the new legislation is to expand project reviews to assess what matters to Canadians (Canada 2018). It can therefore be expected that valued components identified as being important to Indigenous groups will be added to meet this new objective of the new legislation regarding effects assessment.

Landscape, Watershed, and Ecological Assessment Spatial Boundaries

Indigenous groups state that they have a more holistic perspective with respect to land and resources within their traditional territory. As part of this perspective, they contend that spatial boundaries for biophysical resources that may be key resources related to Indigenous rights should be based on the species lifecycle range, and adverse effects from all sources should be considered. Similarly, other Indigenous groups argue that spatial boundaries should be based on sensitive receptors to project effects identified in traditional use baseline studies (or a composite of the study areas) for aquatic life/fish and fish habitat and terrestrial ecology and wildlife value components.

Indigenous groups argue that the proximity to a project does not always correlate to the magnitude of the impact for communities. Many community members spoke of the movement of animals or the connectedness of the river systems and how the potential impacts should properly reflect the dynamic nature of the environment in which the project may occur. In addition, impacts on the environment through a western science worldview may not be the same thing to an Indigenous group who is looking to sustainably carry out cultural activities on the land.

Arguments for landscape and watershed spatial boundaries for cumulative effects assessment have been made by others (Noble et al. 2009; Noble et al. 2014) because these boundaries focus on the valued component being assessed and the spatial extent of that valued component. It is argued that in focusing on the spatial boundaries for the valued component, all of the stressors within the landscape are considered. Government guidance documents recommend that spatial boundaries for cumulative effects assessment should be set for each valued component based on the valued component's geographic range and the zone of influence of the project (CEAA 2016). For example, for Indigenous groups whose territory includes caribou range, the spatial boundary for traditional use activities should include the maximum extent of the caribou range. For project-specific cumulative effects assessment of pipelines, it is standard practice for the spatial boundaries used to reflect the spatial extent of the effects of the individual project on the valued component being assessed rather than landscape or watershed boundaries (Hegmann et al. 1999; Hegmann et al. 2002). While landscape or watershed boundaries are likely to be employed in regional or strategic EAs, proponents cannot be expected to assess effects beyond the zone of influence of their individual project's effects.

Temporal Boundaries

Indigenous groups expressed concerns that the narrow requirement for assessing the effects of the project on current use of land and resources is inadequate for fully assessing cumulative effects because the current practice does not require consideration of a pre-industrial/pre-contact baseline and does not account for future use of land and resources. Indigenous groups are concerned that in assessing the current use of lands and resources, proponents often do not assess the effects of projects that already exist; as a consequence, there is often little information on the pace of environmental effects to the current date. Indigenous groups recommend that temporal boundaries extend back to include past conditions or less disturbed conditions, ideally pre-contact, and describe historical trends or contexts to characterize the sensitivity and resilience of valued components. At the same time, desired future uses of lands by Indigenous groups should be included.

Currently accepted practice is to use current conditions as the baseline for pipeline cumulative effects assessment (Antoniuk 2000). While Indigenous groups request that a pre-industrial baseline be used for cumulative effects assessment with respect to traditional land use, in using current conditions as the baseline, the effects of existing projects are included in that baseline and the new project's contribution to effects can be determined. It is likely that when assessing the new project's contribution to cumulative effects, the results of using a pre-industrial baseline or a current baseline would be similar, and the assessment conclusions would not change.

Significance Determinations and Thresholds Do Not Reflect Indigenous Values

Indigenous groups raise concerns about the lack of thresholds for cumulative effects assessment and that significance determinations do not reflect Indigenous values. To address this, Indigenous groups propose that the cumulative effects assessment should focus on the overall capability of an area or region to sustain resource values in the face of all projects and activities, establish thresholds for species at risk and culturally important species, conduct the assessment according to these thresholds, and include trends as time passes with respect to a valued component so as to be able to establish rates of change with time, determine thresholds or limits, and whether it has already been passed or is approaching a limit.

Currently, thresholds for some valued components have been established through the Species At-Risk Act (SARA) for various wildlife species at risk in Canada, including various caribou herds and orca whales. Where thresholds exist, they are applied to the cumulative effects assessment process, including the cumulative effects assessment of traditional land and resource use for pipeline projects.

RECOMMENDATIONS

With the proposed changes to the federal government EA process and the transition period from the current to new legislation, proponents may need to alter the way in which they conduct cumulative effects assessment for traditional land and resource use. In consideration of the Canadian federal government's proposed new framework and based on feedback received from Indigenous groups on the existing cumulative effects assessment process identified above, the following recommendations for an approach or general framework for cumulative assessment of pipeline projects are proposed.

1. Encourage the establishment of regional and strategic EA. The regional and strategic EA approach has been discussed for many years by energy companies, researchers, governments, interest groups, stakeholders, and Indigenous groups. Unfortunately, the task of developing regional or strategic assessments would be extremely difficult to accomplish. Governments need to take the lead on these assessments, and—despite best efforts and political agendas—it is an approach that requires an amalgamation of all the data for a region and requires constant updates and maintenance. Funding

and support are needed at all levels of government, and governments must be able to provide current and reasonably foreseeable project information at the pace at which industry moves. At a minimum, pipeline companies can encourage the establishment of regional and strategic EA frameworks by the federal government. Pipeline companies can also support these assessments with the provision of information regarding their projects and baseline data from post-construction monitoring programs.

2. Include Indigenous groups in all stages of project planning, including scoping of effects. Engagement with Indigenous groups is encouraged as early on as possible in the project development. This may mean different things to different proponents or perhaps for different types of linear projects. For example, a new pipeline in an area with little development could require engagement at the project concept stage, while building a pipeline within an existing rights-of-way (ROW) where there is an established relationship between an Indigenous group and a company may have different engagement requirements. Either way, the earlier the better, and typically, early isn't early enough. The new EA process is seeking to address issues of reconciliation and rights with Indigenous groups, which will include involvement in the scoping of the effects assessment, development of mitigation measures, and significance determinations.

3. Incorporate traditional knowledge explicitly in the ESA and project planning. It is recommended that proponents explicitly demonstrate how traditional knowledge was incorporated into project planning and design, including the assessment. This approach is critical because engagement and refinement of a project often happen concurrently, and changes will occur while clear documentation of these changes is not always captured. Proponents are often left with the certainty that they have listened and made changes where practical, and Indigenous groups are unable to see that their input has shaped the project decisions. Indigenous groups and regulators will often ask the question: "How was the traditional knowledge incorporated into the project design?"

   Where Indigenous groups have shared traditional knowledge to inform the project, it is recommended that the assessment demonstrates clearly how traditional knowledge was included and provides documentation on how decisions regarding the use of traditional knowledge were reached with participating Indigenous groups. This includes the identification of important sites on the footprint for the project and site-specific mitigation measures to address Indigenous concerns with respect to these sites. Site-specific mitigation measures should be determined in collaboration with the potentially affected Indigenous group. Where Indigenous groups have shared traditional knowledge to inform general mitigation measures for the project, proponents should document how the traditional knowledge was used to amend the mitigation measure. In cases where the traditional knowledge matches information from western science and does not alter findings or mitigation measures, this should also be explicitly stated. For cumulative effects assessments, it is also important that traditional knowledge shared about preferred harvesting locations is considered, and the role of a particular site within the collective of traditional harvesting sites is considered.

   Even before the project application has been submitted to the regulator, it is important for proponents to return to the community and discuss how the information received can and cannot be used to inform the project. Often, the traditional knowledge received provides valuable baseline information and an understanding of traditional use for an area, but it cannot facilitate the development of mitigation measures, or there is little opportunity to alter the design of the project, and this should be communicated to the Indigenous community.

4. Assess the effects of the project on Indigenous peoples' rights rather than traditional land and resource use. It is likely that the new federal EA legislation will require that the effects of the project on Indigenous groups' rights be assessed rather than the effects of the project on traditional land use. Proponents should work closely with Indigenous groups to identify the rights that will be potentially affected and develop mitigation measures to address effects on these rights with individual groups. Because issues related to rights and strength of claim and the duty to consult rest with the Crown, proponents should work closely with government agencies to design engagement plans that support assessing the effects of the project on rights.

5. Conduct assessment at the aggregate level, but allow for the differences between individual Indigenous groups. For most pipeline projects, assessment of the effects of the project on Indigenous rights and interests can occur at the aggregate level. There are sufficient commonalities in the resources used for traditional land use and the traditional land use activities conducted among Indigenous groups—so much so that assessing at an aggregate level

provides enough information to the decision-maker to make a decision about the project. While it is appropriate for the assessment to occur at an aggregate level, it is important that the discussion within the assessment provides information relating to individual Indigenous groups and that site-specific mitigation decisions are made with individual Indigenous groups whose specific traditional use sites or rights are affected by the project. The cumulative effects assessment can both reflect individual Indigenous group preferences and assess the effects on Indigenous rights and interests at the aggregate level.

For projects that have the appropriate scope and spatial scale and where a single Indigenous group's rights and interests can be clearly ascertained, there could be an opportunity to assess the effects at the individual level. This would allow for the consideration of the effects of the project on individual rights and interests, and for the differences in how the project affects each community and community preferences with respect to mitigation measures. Assessing effects at the individual community level also allows for the examination of preferred harvesting areas for individual communities, cultural and spiritual connections to particular places, and access concerns and aesthetic considerations that affect where harvesting occurs. For projects that cross multiple Indigenous communities and their traditional territories, with varying strengths of claim, this approach would not be feasible for a proponent, nor manageable, because several assessments would need to be completed, which would not capture an overall view of the project.

6. Work with Indigenous groups on scoping of effects. It is recommended that proponents work with Indigenous groups to determine culturally important species and other valued components important to each Indigenous group and be more explicit in including these in the assessment. Indigenous groups often prioritize different resources for environmental management depending on factors such as their proximity to the project and different use patterns. Some Indigenous groups might prioritize water, others vegetation, others wildlife and wildlife habitat, or fish and fish habitat. Indigenous groups should be provided the opportunity to identify specific plants, wildlife, and fish species that are important to the continuation of their traditional use and cultural practices. For example, a list of culturally important wildlife species can be included in the assessment (in the traditional land use section), and the assessment can indicate where these species were considered and direct Indigenous groups to mitigation measures designed to reduce the effects of the project on these culturally important species. Some Indigenous groups may seek to understand the economic benefits and employment opportunities once they realize that environmental and socio-economic effects can be mitigated.
7. Continue with temporal boundaries currently used for cumulative effects assessment. It is recommended that the current temporal boundaries that use current use as baseline are appropriate for assessing the cumulative effects of the project on traditional land and resource use.
8. Continue with spatial boundaries currently used for project-specific assessment. Landscape and watershed spatial boundaries for cumulative effects assessment are more appropriately applied to regional or strategic EA frameworks. The aim of the project-specific cumulative effects assessment is to assess the individual project's contribution to cumulative effects and, as such, spatial boundaries that reflect the zone of influence for the effects of the individual project are appropriate.
9. Use established thresholds in making significance determinations and provide information gathered from post-construction monitoring programs to bodies responsible for establishing thresholds. It is recommended that proponents continue to use established thresholds in making their cumulative effects assessment determinations. Proponents can also contribute to trend analysis and threshold determination by providing the results of their baseline data collection and post-construction monitoring programs to organizations responsible for determining thresholds for species at risk. The sharing of information collected for the project with the public and government repositories is encouraged to make the data available so that regulators and decision-makers can make the best decisions with the available information.

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Assessing and Mitigating Impacts on Interior Forests for Pipeline Projects in West Virginia: The Mountaineer XPress Project

Julia Yuan, Robyn Susemihl, and Clifford Brown

Keywords: Cerulean Warbler, Core Forest, Federal Energy Regulatory Commission (FERC), Fragmentation, Interior Forest, Mountaineer Xpress (MXP), West Virginia Division Of Natural Resources.

Assessing the impacts on interior forests from linear right-of-way (ROW) projects, such as natural gas pipelines, is particularly important in states such as West Virginia, where there are no state regulations limiting forest clearing. Activities such as oil and gas extraction and transportation operations can have a dominant presence in certain landscapes. In West Virginia, interior forests provide important breeding habitat for state-sensitive species, such as the cerulean warbler (*Setophaga cerulean*). The Mountaineer XPress Project (MXP or Project), sponsored by Columbia Gas Transmission, LLC and regulated by the Federal Energy Regulatory Commission (FERC), consists of approximately 273.5 kilometers (km) (170 miles [mi]) of natural gas transmission pipeline traversing mainly through upland forested areas of West Virginia. During preparation of the Environmental Impact Statement, the environmental staff at the FERC received comments from the public and agencies regarding the potential impacts of the MXP on interior forest. Traditionally, FERC staff categorized "interior forest" based on a linear 91.44-meter (m) (300-foot [ft]) buffer from an existing corridor or from a proposed new ROW. For the MXP, FERC environmental staff used this definition, but additionally, with the assistance of staff from the West Virginia Division of Natural Resources, further refined the analysis of potential impacts on interior forest using a dataset produced by the Natural Resource Analysis Center at West Virginia University that differentiated the sizes of contiguous interior forest areas. This improved approach calculates core forest areas based upon the acreage of contiguous habitat, and allows for a more nuanced evaluation of various forest densities. As a result of this assessment, the environmental impact statement (EIS) concluded that construction of the MXP would directly and permanently impact core forest areas by changing the overall percentage of large and medium core areas.

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INTRODUCTION

Interior forest habitats provide protection from disturbance and predation, food resources, and breeding habitat for wildlife. Clearing or fragmentation of interior forests creates more edge habitat and smaller forested tracts, which can impact availability and quality of feeding and nesting habitat for certain species, as well as isolate species populations (Rosenberg et al. 1999). Some species require large, un-fragmented blocks of habitat, and fragmentation can lead to reduced habitat quality. Habitat fragmentation can negatively impact habitat-specialist species, while having a positive or neutral effect to habitat-generalist species (Graham 2002). Utility corridors also can create a barrier to wildlife movement for some species and a travel corridor for others. Additionally, corridor widths and vegetation characteristics can have varying effects to different species. Abrupt vegetation transitions (e.g., mature forest to open land) often cause the greatest barriers, while a forest-to-shrub-to-grassland transition can have minimal-to-no effect to transiting species (Graham 2002).

Interior forests are important habitats for species that are sensitive to forest fragmentation. Interior forest dwelling species experience an added level of protection due to seclusion from edge effects. Species that are adversely affected by roadways, utility ROWS, or residential, commercial, and industrial developments, or other sources of fragmentation are most affected by the decline of large contiguous tracts of forested areas. Certain migratory birds, such as the cerulean warbler (*Setophaga cerulean*), are sensitive to the negative effects of fragmentation due to nest predation by species associated with land development, such as skunks, domestic cats, and raccoons. Other edge effects that may negatively impact forest interior dwelling species include the introduction of noise and light pollution from roads and developments, alterations to existing wind, heat, and other climate variables, as well as the establishment of invasive plant species.

For projects requiring a federal action, an environmental review under the National Environmental Policy Act (NEPA) must occur first. Section 102 in Title I of NEPA requires federal agencies to incorporate environmental considerations into their planning and decision-making. Further, there are federal protections in place that require consultations, permitting, and, in some cases, impose restrictions or mitigation measures for projects that will affect certain resources such as wetlands, waterbodies, prime farmlands, environmental justice communities, threatened and endangered (T&E) species, and air quality. However, there are no federal protections in place for interior upland forested areas or the interior forest dwelling species that depend on these areas. Through a cooperative effort, the Federal Energy Regulatory Commission (FERC) and the West Virginia Division of Natural Resources (WVDNR) developed a method for assessing and quantifying impacts on interior forests. A condition was then included in FERC's Order requiring the project proponent work with WVDNR to come to an agreement on practical mitigation measures to promote compatibility with the restoration and management of state-owned upland forest areas, which will help in the reduction of impacts on cerulean warbler habitat.

The Mountaineer XPress Project (MXP or Project), an approximately 273.5-kilometer (km) (170-mile [mi]), mostly 91.44-centimeter (cm) (36-inch [in]) diameter greenfield natural gas pipeline was proposed by Columbia Gas Transmission, LLC to move natural gas from the Utica and Marcellus basins to markets in the Midwest, Northeast, Mid-Atlantic, South, and Gulf Coast (Figure 1). The area of the MXP has undergone centuries of forest fragmentation due to human settlement, farming, mining, timber production, and other activities. From the 1780s through the 1830s, one of the key activities in the MXP area was the construction of roads and railroads. During the middle of the 19th century, the opening of coal mines further expanded the need for railroads. As the railroads became more active, towns began growing along the rail lines. As industry began to spread, the need for coal spurred the development of coal mines. Drilling for crude oil and natural gas began around the same time. After the Civil War, sheep ranching for wool, which was more profitable than cattle ranching, spurred wool mills. By the late 1880s, with the expansion of railroads and the depletion of timber resources in the northeast and Great Lakes areas, large lumber companies tapped in to the mountainous forests of West Virginia. The timber boom of the late 1800s through early 1900s changed the scale by which resources would be extracted from West Virginia. Timber production in West Virginia peaked in 1909, and by the 1920s, nearly all of the virgin timber was gone. The depletion of available lumber left the region needing an alternative fuel, and the cleared land was desirable to miners. From the end of the 1800s, mining of coal fields, mountaintop mining operations, and oil and gas extraction wells dominated the West Virginia landscapes through the 20th century.

FERC staff conducted a comprehensive environmental review of the Project, as required by the NEPA, and issued a Final Environmental Impact Statement (EIS) in July 2017 (FERC 2017). The WVDNR was one of several cooperating agencies who participated in the preparation of the EIS because of that agency's special expertise with respect to the environmental impacts associated with the proposed action. FERC issued an Order granting Columbia Gas a Certificate of Public Convenience and Necessity to construct and operate the MXP in December 2017. Construction of the MXP began in January 2018. The MXP utilized a 30-m (125-ft) wide temporary ROW for construction in non-agricultural uplands. In most areas, a 15.25-m (50-ft) wide permanent easement has been retained for operation of the pipeline.

Interior Forest

Traditionally, the FERC staff has categorized interior forests as forested areas greater than 91.44 m (300 ft) from the influence of forest edges or open habitat (Jones et al. 2001). For the MXP, FERC staff used this definition, but further refined the analysis of impacts on interior forests using a dataset produced by the Natural Resource Analysis Center at West Virginia University (Strager and Maxwell 2012), which ranks each interior forest as a Core Forest Area (CFA). Each CFA is based on the acreage of contiguous habitat, with a 100-m defined edge width. CFAs are differentiated into patch (small forest fragments), edge (continuous forest periphery), perforated (core forest containing a small clearing[s] within the forest), small core (less than 102 hectares [ha]; 250 acres), medium core (102 to 203 ha; 250 to 500 acres), and large core (greater than 203 ha; 500 acres). Figure 2 shows some of the pre-construction CFAs traversed by the MXP (in proximity of the Lewis Wetzel Wildlife Management Area, discussed further below).

Construction of natural gas pipelines and associated infrastructure can result in new, cleared corridors in forested areas. Interior forest, especially, provides valuable habitat for a variety of wildlife species and often has greater species richness and ecological integrity than surrounding areas. Assessing impacts on interior forests from large-scale pipeline projects is important, particularly since interior forests are not federally or state-regulated. Such is the

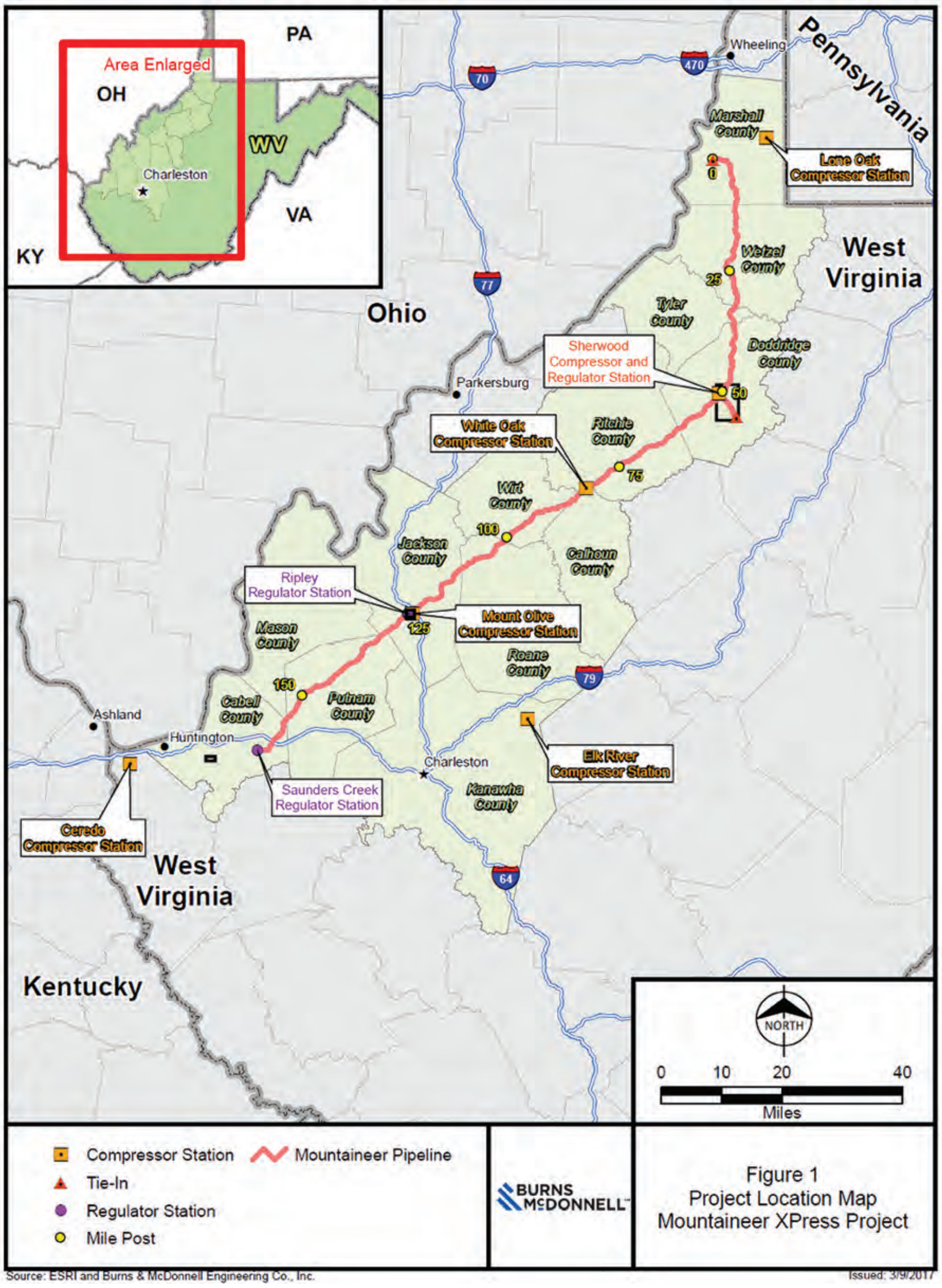

Figure 1.

case in West Virginia, where there are no state regulations limiting forest clearing, and activities such as oil and gas extraction and transportation/transmission operations can have a dominant presence in certain landscapes.

Clearing or fragmentation of interior forests creates more edge habitat and smaller forested tracts, which can impact the characteristics and juxtaposition of vegetation communities, including their suitability for some specialist wildlife species. The creation of a new corridor and forest edges could impact microclimate factors such as wind, humidity, and solar exposure, which could lead to a change in vegetation species composition and diversity. Forest edges also play a role in ecosystem functions, including the dispersal of plants and wildlife, the spreading of fire, movement of wildlife, and vegetation composition and structure. Impacts on interior forests from natural gas pipeline projects could contribute significantly towards cumulative impacts on interior forests in areas where other projects and actions involve forest clearing.

In West Virginia, state-owned lands, such as Wildlife Management Areas (WMAs) provide important habitat for forest interior birds, such as the cerulean warbler (*Setophaga cerulea*). The MXP pipeline crosses four WMAs in West Virginia. While most WMAs are managed for habitat and are not considered unique, rare, or significant, the Lewis Wetzel WMA contains core forest habitat that has been recognized as an Important Bird Area (IBA) for management of the cerulean warbler.

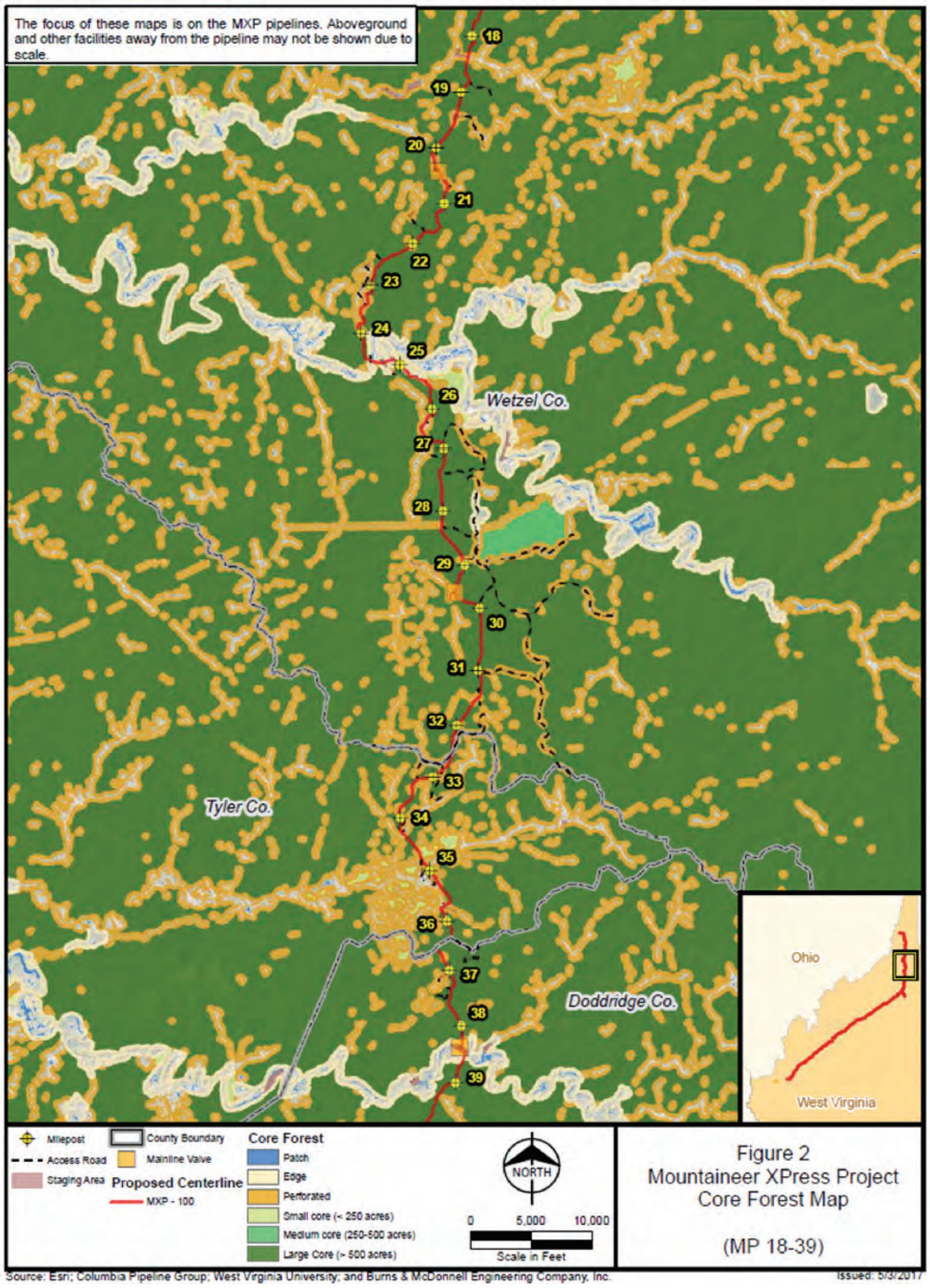

Figure 2. Core Forests (Pre-MXP construction)

IBAs represent a network of important sites needed to ensure the survival of global bird populations and are identified using internationally agreed upon criteria (BirdLife International 2015). While the WVDNR owns, manages, and controls surface land at the Lewis Wetzel WMA, mineral rights are largely controlled by private individuals. Thus, numerous natural gas wells and pipelines are already present or cross the Lewis Wetzel WMA and have contributed to the conversion of interior forest habitat to a more patchwork forested mosaic. Existing ROWs that bisect the WMA provide linear shrubland habitat scattered throughout the area (Figure 3).

Figure 3. Existing pipeline ROW in the Lewis Wetzel WMA

Cerulean Warbler

The cerulean warbler is a neotropical migrant warbler that breeds in eastern North America and winters in South America (Figure 4). Habitat for the cerulean warbler includes large tracts of mature deciduous forest with a closed canopy with many large, tall trees. West Virginia supports the highest densities of cerulean warblers anywhere in the species' breeding range (WVDNR 2003). Despite being a common breeding bird in West Virginia, cerulean warbler populations are in decline due in part to loss of breeding and wintering habitat, as well as habitat fragmentation (WVDNR 2003).

Figure 4. Cerulean warbler (*photo credit: Steve Shaluta, WVDNR*)

The cerulean warbler is listed as a Priority 1 species in the West Virginia State Wildlife Action Plan. Priority 1 species are those "Species of Greatest Conservation Need" within West Virginia (WVDNR 2015). Cerulean warbler populations have steadily declined at a rate of about three percent per year since 1966. In 2006, total populations were estimated to be approximately 400,000 birds (USFWS 2016). The MXP falls within Bird Conservation Region 28, where approximately 80 percent of the remaining population of cerulean warblers breed. While Conservation Region 28 is approximately 42,034,622.8 ha (103,869,815 acres) in size (NABCI 2017), breeding areas for the cerulean warbler have been impacted by clearing of more than 50 percent of historical forests within the region. Suitable breeding habitat for cerulean warblers includes structurally diverse canopies with a large enough forest patch size to reduce the risk of nest parasitism and predation (USFWS 2016). The minimum isolated forest patch size for detection of the cerulean warbler is 138 ha (341 acres) (Robbins et al. 1989). Although the cerulean warbler makes use of canopy gaps and can be found using thin forest edges and small perforated areas near narrow roads or ROWs, they are less abundant near these areas, and in West Virginia, have been shown to avoid edges of powerlines with ROWs that are roughly 23 m (75 ft) wide (Wood et al. 2013).

The cerulean warbler is also listed by the West Virginia Partners in Flight Working Group as a high-priority species of concern. The U.S. Fish and Wildlife Service (USFWS) is currently conducting a status review for the potential listing of the cerulean warbler as a threatened species as part of the Endangered Species Act.

RESULTS & DISCUSSION

Based on information in the dataset, FERC staff developed mapping that delineated each CFA ranking along the MXP pipeline route and locations of newly proposed access roads with the assistance of WVDNR staff. Existing private roads that would be used during construction were not included as a conversion or an impact on CFAs. Based on where the new project facilities traversed the different CFAs, the conversions were modeled by reclassifying the CFAs for post-construction acreages. After comparing pre- and post-construction CFAs, FERC and WVDNR staff were able to establish the impact from the difference of the two.

The analysis concluded that construction of the MXP would directly impact about 531 ha (1,311 acres) of small, medium, and large CFAs. This includes both the temporary and permanent ROWs (construction ROW). Of the 531 ha (1,311 acres) directly impacted during construction, about 493 ha (1,218 acres) would be to large core CFA. Permanent impacts on CFA (small, medium, and large) along the operation/permanent corridor of the MXP would total about 198 ha (490 acres).

Construction of the MXP has created a new, cleared corridor in areas of interior forest, which will, as discussed above, impact the characteristics of vegetation communities, including their suitability for wildlife. Review of CFA within approximately 16 km (10 miles) of either side of the MXP (as presented in the EIS) indicates that the project would traverse an area comprising approximately 233,740 ha (577,583 acres; 23 blocks) of large CFAs, 488 ha (1,206 acres; four blocks) of medium CFAs, and 653 ha (1,613 acres; 23 blocks) of small CFAs. Construction of the MXP would decrease large CFAs by 6,157 ha (15,215 acres; three percent) and create 21 additional blocks of large CFA (the newly created blocks would still be large enough to qualify as large CFAs). The MXP would increase medium CFAs to 1,514 ha (3,742 acres; 310 percent) and create nine additional blocks of medium CFA. The MXP would increase small CFAs to approximately 1,626 ha (4,017 acres; 249 percent) and create an additional 111 blocks of small CFA (Table 1). The decrease in suitable habitat (when large and medium CFAs are converted to small CFA and/or forest edge habitat) across the MXP would be about two percent. The MXP also would create forest edge where the pipeline traverses CFAs.

CFA Ranking	Pre-construction		Post-construction	
	Acres	Blocks	Acres	Blocks
Large Core (< 500 acres)	577,583	23	562,368 (-3%)	44
Medium Core (250-500 acres)	1,206	4	3,742 (+310%)	13
Small Core (< 250 acres)	1,613	23	4,017(+249%)	134

Table 1. Pre- and post-construction comparison of small, medium, and large CFAs resulting from the MXP Project

CFA Ranking	Pre-construction		Post-construction	
	Acres	Blocks	Acres	Blocks
Large Core (< 500 acres)	9,153	1	8,134 (-11%)	2
Medium Core (250-500 acres)	338	1	838 (+150%)	3
Small Core (< 250 acres)	-	-	241 (+241%)	5

Table 2. Pre- and post-construction comparison of small, medium, and large CFAs within Lewis Wetzel WMA resulting from the MXP Project

Lewis Wetzel WMA

The Lewis Wetzel WMA is traversed by the MXP for approximately five miles (from MXP mileposts 28.3 to 33.4). It includes approximately 3,704 ha (9,153 acres; one block) of large CFA and 137 ha (338 acres; one block) of medium CFA. The amount of suitable habitat for the cerulean warbler is estimated to be 3,841 ha (9,491 acres; large CFA plus medium CFA). The MXP components within the Lewis Wetzel WMA include an approximately 38-m (125-ft) wide pipeline construction corridor and the use of various existing access roads. The construction of the MXP will result in the creation of roughly 3,292 ha (8,134 acres; two blocks) of large CFA, 339 ha (838 acres; three blocks) of medium CFA, and 97.5 ha (241 acres; five blocks) of small CFA. The total amount of suitable habitat for the cerulean warbler in the Lewis Wetzel WMA in post-construction conditions is estimated to be 3,631 ha (8,972 acres; large CFA plus medium CFA), which is approximately a 5.5 percent decrease. Table 2 and Figure 5 provide a comparison table and map of pre- and post-construction forest impacts within the Lewis Wetzel WMA.

The Final EIS concluded that impacts on upland forest habitat from the MXP would be significant due to the three percent decrease in large core forests acres along the pipeline route (including a 5.5 percent large CFA reduction within Lewis Wetzel WMA), as well as the creation of medium and small core forest acres and blocks (in the case of the Lewis Wetzel WMA, creating small core forests where ones didn't previously exist). Likewise, the reduction to the cerulean warbler habitat and the existing CFA within 16 km (10 miles) of the MXP pipeline corridor, as a direct result of pipeline construction, would also be significant. The conclusion was based on the designation of the cerulean warbler as a Priority 1 species in West Virginia and the considerable reduction in an already limited amount of breeding habitat available.

As a result of the FERC staff's analysis of impacts on interior forest, the WVDNR, Wildlife Resources Section developed and applied a process for assessment of impacts on CFAs utilizing Habitat Equivalency Analysis (HEA) (NOAA 2000). The WVDNR developed habitat replacement ratios for the pipeline permanent ROW, construction ROW, and a 91.44-m (300-ft) buffer on both sides of the ROW based on a model of forest recovery using Visual HEA software. The resulting output for replacement habitat size resulted in the following ratios: 2.5:1 ratio for impacts to 15.24-m (50-ft) wide permanent ROWs and 1.8:1 for the additional 22.86-m (75-ft) temporary construction ROWs. A 91.44-m (300-ft) buffer on each side of the ROWs was assessed a 0.5:1 ratio. Visual HEA model calculations were not completed for new access roads, workspace, and additional temporary workspace. An additional assessment for forest cores less than 250 acres and perforated cores was prorated at 50 percent, resulting in ratios of 1.25:1, 0.9:1, and 0.25:1 for permanent, temporary and buffer impacts respectively. Mitigation and compensation for any state-owned or managed lands was determined separately for each property.

The WVDNR also developed criteria for replacement habitat that included a requirement for a core forest

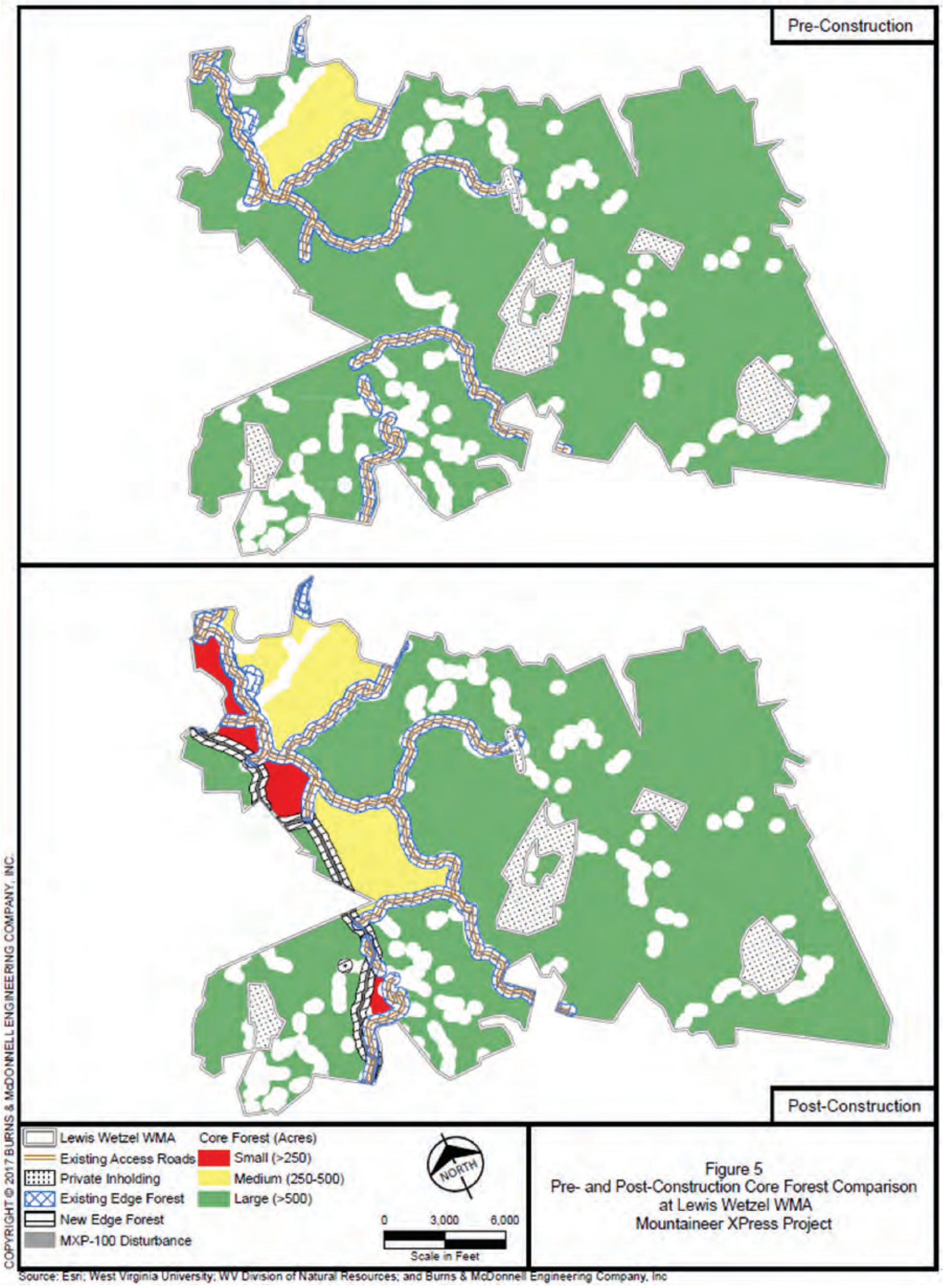

Figure 5.

component, as determined from the West Virginia University Natural Resource Analysis Center's forest fragmentation spatial dataset, and acquisition in one or more watersheds (using Hydrologic Unit Code 6) of the respective area of impact. The WVDNR gave priority for habitat replacement to fee acquisition of property, or acquisition of conservation easements that met a combination of the following parameters: property is within a WVDNR (Wildlife Resources Section) land acquisition priority area; property is within a State Wildlife Action Plan Conservation Focus Area; and/or property is within a high priority conservation area of one or more land trusts accredited by the Land Trust Alliance. All acquisitions must be open to perpetual access for wildlife-oriented recreation, including hunting. WVDNR developed a suitability index to prioritize potential property acquisitions. The WVDNR assessed suitability using landscape integrity, ecological integrity, biodiversity ranks, acres of public land available per hunter, and cerulean warbler density. Columbia Gas, working with the WVDNR, provided voluntary conservation measures in the form of avoidance, minimization, and habitat replacement for nearly 2,630 ha (6,500 acres) of CFA. Through implementation of Columbia Gas' Multi-Species Habitat Conservation Plan and payments to The Conservation Fund, as a fiduciary for the WVDNR, Columbia Gas has provided for replacement of interior forest habitat to benefit cerulean warblers and other Species of Greatest Conservation Need in West Virginia.

CONCLUSIONS

There are no federal protections in place that are intended to preserve large CFAs or other categories of interior forest. With the magnitude of oil and gas exploration and distribution projects occurring in West Virginia and other surrounding areas, a fair, reasonable, and consistent evaluation of the pre- and post-construction impacts should be considered in all NEPA documents. As a cooperating agency, the WVDNR was afforded the opportunity to participate in the NEPA process with access to FERC staff throughout development of the EIS for the MXP.

By closely collaborating with WVDNR on local, regional, and state-wide concerns over the loss of CFAs, FERC staff recommended special conditions that were eventually included in the FERC Order. These conditions directed the applicant to further work with WVDNR to devise and implement mitigation measures to promote compatibility with the restoration and management of state-owned upland forested areas, as well as to reduce impacts on cerulean warbler habitat.

One of the most common methods for minimizing impacts on environmental resources during the construction of linear features is by collocating with existing infrastructure and by reducing the width of the construction and permanent operational corridor. Accordingly, Columbia Gas made attempts to collocate and minimize its workspaces where possible; however, due to the steep terrain traversed by the MXP, industry-approved safe construction practices required a wider working ROWs. Other possible mitigation options that may be considered on future projects to reduce core forest fragmentation include placing conservation easements on large CFAs, funding state-wide stewardship programs, fee in-lieu payments to state-run programs that specialize in the preservation of CFAs, and the purchase and donation of CFAs to the state for conservation.

Because there are no federal protections for impacts on upland forested areas, FERC staff did not dictate to the applicant which mitigation or restoration methods to use. Columbia Gas and the WVDNR, without input from FERC staff, came to a reasonable agreement on what the appropriate mitigation and/or restoration measures should be. In working with the WVDNR, Columbia Gas agreed to provide for habitat replacement through funding to the WVDNR for the purchase and protection of additional CFAs. By combining these funds with those from other sources, including other pipeline projects, the WVDNR will acquire more than 12,000 ha (30,000 acres) of additional public lands during this fiscal year (2018). Developing a suitability index for CFA replacement and partnering with The Conservation Fund as a fiduciary, the WVDNR has provided for the acquisition and protection of habitat in areas impacted large-scale pipeline projects.

Disclaimer: Any views expressed herein are the authors' and not necessarily that of FERC, the Commissioners, or the Federal Government.

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Efficiently Addressing Climate Change as an Environmental Constraint in the Federal Permitting Process Based on Lessons Learned from Four Recent Case Studies

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Keywords: Government, Other.

Addressing a federally regulated resource in siting and permitting of rights-of-way (ROWs) can often create unanticipated project delays and expenses. This paper reviews lessons learned on how to move a project through the federal review process more efficiently by identifying and resolving potential constraints early in the planning process. This is based on the federal permitting processes of three recent transmission line projects and one renewable energy generation project in Colorado and Wyoming, respectively. The emphasis will be on addressing climate change as an environmental constraint. Additional potential constraints to be reviewed include early identification of environmental issues ranging from sage-grouse to potential air space violations; development of reasonable alternatives to satisfy requirements of the National Environmental Policy Act (NEPA); and addressing emerging and evolving federal regulations and associated case law as early as possible in the environmental permitting process, including the recent establishment of Executive Order 13807 and Department of Interior Secretarial Order 3355, both aimed at streamlining federal infrastructure decisions. Recent efforts to roll back climate change regulation on the federal level are likely to do little to stem the tide on climate change-related litigation. This paper offers a path forward on how to effectively and efficiently address climate change in federal permitting and NEPA documents in order to minimize the risk of associated litigation and costly delays.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

This paper first reviews federal permitting and National Environmental Policy Act (NEPA) review of right-of-way (ROW) projects, followed by early identification of constraints based on four recent projects. For context, an overview of climate change regulation and guidance, a brief discussion of litigation in the U.S. involving climate change, and recommendations on how to effectively and efficiently address potential constraints, including climate change, in right-of-way (ROW) planning, and NEPA.

Federal Agencies and NEPA

Planning, construction, operation, and maintenance of a utility ROW can require compliance with more than three dozen federal environmental laws and regulations, with several different federal agencies at the helm. As noted in Table 1, a few of the primary federal agencies with jurisdiction over resources affected by siting and developing a ROW include the U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers (USACE), the U.S. Fish and Wildlife Service (USFWS), the Bureau of Land Management (BLM), and the U.S. Forest Service (USFS).

Once a federal agency is involved with a decision to be made regarding a permit, federal land, or federal money (federal loan guarantees and grants) for a project involving a ROW, the NEPA of 1969 will apply to that decision. NEPA is codified under Title 42 of the U.S. Code (U.S.C.), in section 4331 et seq. (42 U.S.C. § 4331 et seq.). Under NEPA, Congress established the White House Council on Environmental Quality (CEQ) to ensure that federal agencies meet their obligations under NEPA. CEQ's Regulations for Implementing the Procedural Provisions of NEPA (hereinafter "CEQ NEPA Regulations") are in Title 40 of the Code of Federal Regulations (C.F.R.) section 1500 et seq. (40 C.F.R. § 1500 et seq.).

NEPA requires all federal agencies in the executive branch (40 C.F.R. § 1507.1) to consider the potential environmental consequences of proposed actions in their decision making. Key goals of NEPA are to help federal agency officials make well-informed decisions about agency actions and to provide a role for the public and other agencies in the scoping process.

Agency (Department)	Action	Implementing Laws
EPA (*Independent*)	NPDES Permit Compliance with NSPS and NAAQS standards Waste and Substance Management Compliance with noise standards	Clean Water Act Clean Air Act Resource Conservation and Recovery Act; Solid Waste Disposal Act; Toxic Substance Control Act Noise Control Act
FERC (Independent)	Certificate of Public Convenience and Necessity	Natural Gas Act; Energy Policy Act of 2005
USACE (DOD)	Section 404 Permit for activities in jurisdictional waters or wetlands, Section 9 or 10 Permit	Clean Water Act; Rivers and Harbours Act
Forest Service (USDA)	Activities on Federal (Forest Service) land	Federal Land Policy and Management Act
BLM (DOI)	Activities on Federal (BLM) land	Federal Land Policy and Management Act
USFWS (DOI)	Incidental Take Permit/Eagle Take Permit	Endangered Species Act/ Bald and Golden Eagle Protection Act
Rural Development (USDA)	Loans, Loan Guarantees, Grants	Rural Electrification Act
WAPA, SWPA etc. (DOE)	Interconnections to Power Administrations or Power Authorities; Permitting or Financial Assistance	Energy Policy Act of 2005 (Sections 216 & 1222); Transmission Infrastructure Program
ACHP, SHPO, THPO, NPS (DOI)	Archaeological, cultural, and recreational impacts	National Historic Preservation Act; National Trails Act; Native American Graves Protection and Repatriation Act

Table 1. Primary Federal Agencies Involved in ROWs

NEPA is an umbrella law, meaning that it addresses procedural or substantive requirements of other applicable federal, state, and local statutes and executive orders that bear on a decision collectively. NEPA also requires that a specific review process be followed, and legal challenges to federal decisions can be upheld if any steps of the process are omitted or determined to be insufficient. Legal challenges can also be lost if there are gaps in information or logic in the documentation; therefore, all analysis has to be well researched, documented, and reasoned.

Litigation challenging NEPA documents is the most common form of federal environmental litigation (Smith et al. 2014).

All discretionary federal decisions are subject to NEPA review, unless specifically exempted. There are three categories of NEPA review: Categorical Exclusions (CEs), Environmental Assessments (EAs), and Environmental Impact Statements (EISs). The lead federal agency will determine the level of analysis and type of NEPA document required for a specific action.

Generally, if a proposed action fits within a category of activities that an agency has already determined normally does not have the potential for significant environmental impacts, and the agency has established that category of activities in its NEPA implementing procedures, then a CE will be used. An EA is prepared to determine whether a federal action will have a significant potential impact, and an EIS is prepared when a major federal action is likely to have a potentially significant impact on the environment. The bottom line here is that an EA is required when a CE cannot be justified and it is unclear whether an EIS is required.

Federal agencies do not routinely track the number of CEs and EAs they complete on an annual basis, but CEQ estimates that about 95 percent of NEPA analyses are CEs, less than five percent are EAs, and less than one percent are EISs (GAO 2014). Projects requiring an EIS are a small portion of all projects, but are likely to be high profile, complex, and expensive (GAO 2014). Four agencies—USFS, BLM, USACE, and the Federal Highway Administration—are typically the most frequent producers of EISs, accounting for more than 50 percent of the EISs produced from 2008 through 2012 (NAEP 2013).

Early Identification of Constraints

Once NEPA review of a project is triggered, it is essential to identify and resolve potential constraints as early in the planning process as possible. Based on recent lessons learned from four NEPA projects, there are notable themes to the potential constraints in ROW development in the Rocky Mountain West region. The four projects which were evaluated include 1) EA for new transmission line in Park County, Colorado; 2) EA for rebuild of three existing transmission lines in the San Luis Valley, Colorado; 3) EA for new pipeline and associated transmission lines in Weld County, Colorado; and, 4) EIS for a wind energy development and associated collection and distribution line in Carbon County, Wyoming.

The environmental constraints that were determined to be the most time consuming to resolve for these four projects are summarized as follows:

- Impacts to federally or protected avian species, including sage-grouse and large, migratory raptors (requiring consultation and resolution with USFWS)
- Potential air space violations (requiring consultation and resolution with DOD)
- Visual impacts on federal land or to federally protected resources (requiring resolution with federal land management and/or SHPO)
- Tribal consultations
- Regulatory "gray" areas, including climate change

Additionally, for non-government organizations (NGO) seeking to halt or delay a particular project, litigation against the range of reasonable alternatives to satisfy requirements of NEPA and failure to adequately address emerging and evolving federal regulations are both key components of these groups' strategies.

Addressing Constraints

The following solutions are offered to address the constraints identified in the proceeding section:

- Include airspace designations and biological data in siting reviews
- Conduct early agency consultations and identify best management practices (BMPs) at the pre-construction (10-30 percent design) phase
- Complete visual simulations using BLM's Visual Contrast Rating methodology by default (use variations to the methodology if there may be impacts to USACE, FHA, NPS, or USFS properties)
- Conduct early tribal engagement and understand "meaningful opportunity" for consultations with lead agencies as part of the National Historic Preservation Act, EO 13175, and EO 12898
- Address regulatory "gray" areas, such as climate change, to avoid the risk of litigation, as discussed more below.

In terms of developing a range of reasonable alternatives, the use of specific Alternatives Screening Criteria in conjunction with a well-written Purpose and Need statement can be an effective tool to narrowing down a defensible list of alternatives. Alternatives Screening Criteria can specify that reasonable alternatives must:

- Meet the purpose and need
- Pose a clear choice for the decision-maker
- Be consistent with laws and regulations

- Be technically feasible (that is, would use commercially available technology)
- Be implementable by the project proponent

Climate Change as a Regulatory Gray Area

For the past several years, NEPA challenges based specifically on climate impacts have been a key component of many environmental groups' strategies, particularly when the challenged project involves energy development or transportation. Because federal agencies continue to vary greatly in how they address climate change in permits and NEPA documents, legal challenges to the way climate change is addressed in federal documents continue to increase. The litigation results in a discussion largely waged in the courts, leaving project proponents vulnerable to costly delays.

On an international level, the U.S. has no current abiding agreement to regulate greenhouse gas (GHG) emissions. Although the U.S. is a signatory to the Kyoto Protocol, the nation has neither ratified nor withdrawn from the protocol. The U.S. participated in the latest round of international climate negotiations focused on mitigation, adaptation, and financial assistance, which began in 2011 in Durban, South Africa, and concluded at the end of 2015 in Paris, France. The results of these negotiations are anticipated to go into effect in 2020. However, given the current political climate in the U.S., it appears unlikely that the U.S. will participate in any international agreement in the near-term.

Domestically, the EPA regulates GHGs as pollutants under the Clean Air Act (CAA). In 2009, the EPA finalized an endangerment finding that the following six GHGs constitute a threat to public health and welfare: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). However, EPA's GHG Reporting Program is not currently applicable to non-stationary emissions sources or mining, other than underground coal mining.

In 2010, the EPA set GHG emissions thresholds for permits granted under the New Source Review Prevention of Significant Deterioration (PSD) and Title V Operating Permit programs.

The EPA is largely in the process of rolling back recent initiatives targeting specific industries, including the first proposed carbon pollution standards targeting power plants, known as the Clean Power Plan, as well as a final carbon dioxide geologic sequestration rule.

Climate Change Guidance

The CEQ was established for the purpose of implementing NEPA and to provide written guidelines for the NEPA process. Additionally, most federal agencies also have department-specific and/or agency-specific regulations for implementing NEPA. NEPA assessments must disclose the impacts of a proposed project and its alternatives on the "human environment." The human environment includes the natural and physical environment and the relationship of people with that environment. Although economic or social effects are not intended by themselves to require preparation of a NEPA document, when a NEPA document is prepared, it should discuss all of the effects on the human environment (40 C.F.R. § 1508.14).

In 2010, CEQ issued draft guidance on the ways in which federal agencies can improve their consideration of the effects of GHG emissions and climate change within NEPA documents (CEQ 2010).

In 2010, CEQ noted that "action agencies need not undertake exorbitant research or analysis of projected climate change impacts in the project area or on the project itself…where agencies consider climate change modeling to be applicable to their NEPA analysis, agencies should consider the uncertainties associated with long-term projections from global and regional climate change models. There are limitations and variability in the capacity of climate models to reliably project potential changes at the regional, local, or project level, so agencies should disclose these limitations in explaining the extent to which they rely on particular studies or projections," (CEQ 2010).

On August 1, 2016, CEQ released *Final Guidance on the Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in NEPA Reviews*. This CEQ guidance advises agencies to consider the following in relation to climate change:

1.) The implications of the effects of climate change on a proposed action
2.) The potential effects of a proposed action on climate change as indicated by its GHG emissions (including assessment of projected GHG emissions and, when appropriate, potential changes in carbon sequestration and storage)

However, on April 5, 2017, CEQ withdrew its *Final Guidance on the Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in NEPA Reviews*, pursuant to President Trump's Executive Order 13783 on Promoting Energy Independence and Economic Growth. Executive Order 13783 directed all agencies to review existing regulations, orders, guidance documents, policies, and any other similar agency actions that potentially burden the development or use of domestically produced energy resources, with particular attention to oil, natural gas, coal, and nuclear energy resources, and to develop recommendations on how to alleviate or eliminate aspects of agency actions that burden domestic energy production.

Specific department- and agency-level regulation and guidance includes DOI Secretary Order 3226, *Evaluating Climate Change Impacts in Management Planning*, which requires that each "bureau and office of the Department… consider and analyze potential climate change impacts when . . . making major decisions regarding the potential utilization of resources under the Department's purview." Agencies under both DOI and USDA have incorporated adaptive management into their land-use planning regulations in an effort to plan for uncertainty, while DOD agencies have increasingly embraced preparedness and resiliency planning for proposed infrastructure. Though relevant agency-specific guidance documents are under review by the respective agencies, most have not been rescinded.

Climate Change Litigation

Litigation challenging the failure to prepare an EIS, or the adequacy of an EA or EIS, is the most common form of federal environmental litigation (Smith et al. 2014). Groups or individuals who disapprove of a federal action can, and often will, use NEPA as the basis for litigation to delay or halt that project. In 2011, CEQ reported 94 NEPA litigation cases were filed, down from the average of 129 cases filed per year from calendar year 2001 through calendar year 2008. The federal government successfully defended its decisions in more than 50 percent of the cases from 2008 through 2011 (GAO 2014).

Even though NEPA is not the preferred vehicle for regulating GHGs, in the absence of additional federal legislation, a key component of many environmental groups' strategies to delay or halt projects and curb nationwide GHG emission is challenging NEPA documents based on climate impacts. Legal challenges to the way climate change is addressed in federal documents continue to increase, resulting in a discussion largely waged in the courts.

- In recent years, approximately 711 lawsuits involving climate change and various permits and planning documents have been filed in the U.S. (Columbia 2018). The majority of these lawsuits have been filed since 2008. Even if a lawsuit is eventually dismissed, project costs and delays can be considerable. Lawsuits challenging inadequate consideration of the impacts of GHG emissions and climate change in permits and planning documents have come from a wide variety of environmental and public interest groups and have targeted every possible type of project and associated ROW:
  - *WildEarth Guardians v. BLM*
  - *Amigos Bravos v. BLM*
  - *Center for Biological Diversity v. BLM*
  - *WildEarth Guardians v. U.S. Forest Service*
  - *Northern Plains Resource Council, Inc. v. Montana Board of Land Commissioners*
  - *Animal Welfare Institute v. Beech Ridge Energy, LLC*
  - *Protect Our Communities Foundation v. Jewell*
  - *WildEarth Guardians v. BLM*
  - *Sierra Club v. Public Service Commission of State of New York*
  - *Brooks v. EPA*
  - *Sierra Club v. Wyoming Dept. of Environmental Quality*
  - *Sierra Club v. Moser*
  - *Appalachian Voices v. State Air Pollution Control Board*
  - *Blue Skies Alliance v. Texas Commission on Environmental Quality*

Challenges appear to be increasing on the grounds that a proposed change in land use (logging, filling in of wetlands, general development) has failed to account for GHG emissions due to carbon storage loss:

- *Center for Biological Diversity v. California Department of Forestry*
- *Center for Biological Diversity v. U.S. Army Corps of Engineers*
- *Earth Island Institute v. Gibson*
- *Coalition for a Sustainable Future in Yucaipa v. City of Yucaipa*

The inherent difficulty of assessing climate change impacts within NEPA documents stems largely from the cumulative, global scale of the issue and the limitations of being able to attribute the variable consequences of climate change to any single project. Even in the absence of federal climate change legislation, inclusion of climate change in NEPA documentation is unavoidable. The difficulty with the issue is how to analyze climate change in a way that is effective and meaningful to decision-making, while also avoiding litigation to the maximum extent possible. In the absence of both legislation and a federally supported system that puts a value on carbon emissions, such as a cap and trade market or federal carbon equivalence offset system, U.S. climate change regulation has a large void which allows for the latest court-endorsed protocol to be filled in. However, it is important to note that NEPA does not require that agencies reach a particular outcome, but only that they have considered the potential impacts of a project.

How to Address Climate Change

As noted above, considering climate change in federal permitting and planning documentation is now unavoidable. There are two broad categories of climate change considerations which need to be addressed, corresponding to CEQ's guidance (though the guidance has been rescinded, it serves as a useful reference tool):

1.) The implications of the effects of climate change on a proposed project

2.) The potential effects of a proposed project on climate change as indicated by its GHG emissions (including assessment of projected GHG emissions and, when appropriate, potential changes in carbon sequestration and storage)

Effects of Climate Change on a Project

The first part of any climate change impacts assessment consists of addressing the implications of the effects of climate change on a proposed project and the resources impacted by that project. This includes both examining the projected, probably future-affected environment due to climatic effects, and planning operations to account for changing environment due to climatic factors.

CEQ guidance previously specified that "the current and expected future state of the environment without the proposed action represents the reasonably foreseeable affected environment that should be described based on available climate change information, including observations, interpretive assessments, predictive modeling, scenarios, and other empirical evidence. The temporal bounds for the future state of the environment are determined by the expected lifespan of the proposed project" (CEQ 2016).

Information is published on almost a daily basis on the projected future-affected environment due to climate change in any given area. In large strokes for the U.S., projected future changes due to climate change include declines in soil moisture, increases in catastrophic events including landslides and fires, and altered surface water flows, water quality, and water quantity (BLM 2009). Good sources of information for characterizing the effects of climate change within federal permits and NEPA documents are readily available and include the U.S. Global Change Research Program's Third National Climate Assessment, as well as other reports from the U.S. Climate Change Science Program and the Subcommittee on Global Change Research; data sets from the Administration's Climate Data Initiative (climate.data.gov); EPA's 2016 Report on Climate Change Indicators in the U.S; USGS' National Climate Change Viewer; NOAA's State of the Climate Report and LCAT; myriad regional, state, and local assessments from research institutes and universities; and the United Nations' Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5).

As mentioned, the description of the affected environment or existing conditions of a project area should not be a static snapshot of the environment. The affected environment of a project should span the life of the project and, as appropriate, rely on trends that describe what the environment will look like for the life of the project.

Planning operations to account for changing environment due to climatic factors consists of incorporating both adaptability and resiliency into project design. Adaptability is defined as an "adjustment in natural or human systems in response to actual or expected climatic stimuli (variability, extremes, and changes) or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2014). Climate change resilience is the "capacity of an individual, community, or institution to dynamically and effectively respond to shifting climate impact circumstances while continuing to function and prosper" (IPCC 2014). Project proponents should explicitly state, when possible, what climatic factors they are considering and planning for in a project permit or NEPA document. Some examples relevant to ROW development could include:

- Protecting stream and river banks to ensure good water quality and safe guard water quantity
- Using new lighter weight and amphibious machinery where permafrost or ice may be lost
- Increasing use of dust control measures during droughts (EPA 2013; ICMM 2013).

Effects of a Project on Climate Change

The second part of an assessment of climate change impacts in federal permits and NEPA includes an assessment of all potential effects of a proposed action on climate change as indicated by its GHG emissions, including—when appropriate—potential changes in carbon sequestration and storage. Potential avoidance options (e.g., emissions control measures) and mitigation options, including sequestration, should be discussed in terms of their net offsets for the project emissions.

The inherent challenge of this type of assessment is associating specific actions with specific emissions- and climate-related effects in a defensible manner without engaging in endless speculation. Large-scale and speculative analysis are neither expected nor encouraged by climate change regulation and guidance.

A NEPA document should disclose and assess all quantifiable sources of GHG emissions from ROW development, including stationary and non-stationary sources. This calculation of emissions should include the release of stored GHGs as a result of destruction of natural sinks such as forests, coastal wetlands, and future sequestration capabilities. A NEPA document should disclose all changes in carbon sequestration capabilities and carbon stocks of affected land (CEQ 2016). For quantification of emissions and removals of carbon stock from land use changes, the USDA's estimation tools can be a valuable asset (*http://www.usda.gov/oce/climate_change/estimation.htm*).

NEPA documents should incorporate by reference, when possible, landscape scale or other programmatic studies and analyses, or should tier to relevant programmatic level NEPA reviews that have already considered potential changes in carbon stocks (CEQ 2016). Such analyses are readily available from the BLM and USFS.

CONCLUSIONS

Key to efficient constraint resolution is early identification and coordination with the appropriate entities in order to address the resolution in the federal permitting and associated NEPA process.

Challenging a project with a federal nexus on the grounds that the associated environmental impacts assessment inadequately addresses climate change or any other evolving regulation has become low-hanging fruit for special interest groups wanting to stop a particular project. In this day and age, all federal assessments involving ROWs should address climate change in one form or another. Addressing climate change in federal permits and planning documents is something that is, to a large extent, already being done across the U.S. as industries adapt and plan for future environmental and regulatory uncertainties. The greater issue is oftentimes how to present climate change considerations within permits and planning documents so they withstand regulatory scrutiny and legal challenges from special interest groups. Climate change discussion, in one form or another, should be woven into almost every section of a NEPA document. This paper offers the following path forward:

1.) Ensure that the affected environment described for a project takes into account foreseeable changes due to climatic changes for the duration of the project life; explicitly state which aspects of the affected environment are due to climatic changes.

2.) Incorporate adaptation and reliance into project design and planning. When meaningful, examine project alternatives with different design, adaptation, and resilience approaches. Explicitly state which aspects of project design are adaptation and resilience measures due to potential climatic factors.

3.) Assess the impacts of a project on climate change from emissions, land use changes, and mitigation measures as direct, indirect, and cumulative impacts. Assess both beneficial and negative impacts. When meaningful, examine project alternatives with different mitigation measures.

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AUTHOR PROFILE

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Lundin has managed NEPA and other planning projects and environmental compliance documents for a diverse range of international, federal, and private sector clients for the past 20 years. She has completed NEPA documents for an array of ROW projects, including multi-state pipelines and transmission lines. She holds a Master's in Environmental Engineering from Virginia Polytech Institute and a bachelor of science in Soils and Water Science from the University of Florida, as well as certifications from MSHA, OSHA, and the EPA. Her expertise includes addressing emerging regulations, facilities planning, and siting, and evaluating resource use conflicts.

Environmental Issues and Pipeline Abandonment: A Regulatory Perspective

Please note that the views, judgements, opinions, and recommendations expressed in this paper are those of the authors and do not necessarily reflect those of the National Energy Board (NEB), its Chair, or Members, nor is the Board obliged to adopt any of them.

Also note that, at the time of submission of this paper, the Government of Canada is proposing legislation that would replace the NEB Act and the NEB with the Canadian Energy Regulator Act (CER Act) and CER. Most legal abandonment provisions discussed in this paper are generally expected to be maintained, although ultimately, the actual legislation in force should be referred.

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Keywords: Abandonment-in-Place, Canadian Energy Regulator (CER), National Energy Board (NEB), Pipeline, Pipeline Abandonment, Pipeline Removal, Pipeline Retirement.

The National Energy Board (NEB) is Canada's federal regulator of more than 73,000 kilometers (km) of interprovincial and international oil and gas pipelines rights-of-way (ROW), a small fraction of all pipelines in Canada and North America. As a lifecycle regulator, the NEB's mandate is to promote safety and security, environmental protection, and economic efficiency in the Canadian public interest.

Although there were pipelines constructed much earlier, a boom in pipeline construction beginning in the 1950s means that some pipeline infrastructure is approaching the end of its initially expected life span. With this, the NEB is beginning to see more applications to abandon pipeline, and issues around abandonment are becoming increasingly important.

In Canada, companies seeking to abandon a federally regulated pipeline are required to apply to the NEB for authorization. The NEB conducts a review of that application and will typically attach conditions to an abandonment order. The NEB retains oversight of all pipelines that remain in place after abandonment.

Regardless of the reasons for the abandonment of a pipeline, the abandonment raises a variety of potential environmental impacts and trade-offs. Since abandonment-in-place can typically be expected to minimize land disturbance and reduce environmental effects, at least in the immediate term, this is often the conventional and preferred default method proposed for abandonment of most pipeline segments, if not all of a pipeline. Removal of pipeline is sometimes proposed to mitigate specific safety, environmental, and stakeholder concerns. These methods raise different potential environmental issues, as well as effects that necessitate appropriate and sufficient mitigation.

This paper provides context for emerging and ongoing issues around pipeline abandonment. It describes the phases of abandonment and discusses a range of challenges and environmental issues from a regulatory perspective, including trade-offs and appropriate mitigation strategies.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Canada has more than 840,000 kilometers (km) of oil and gas transmission, gathering, and distribution pipelines, of which about 117,000 km are large-diameter transmission pipelines (NRCan 2016). Although the first pipelines in Canada were constructed in the mid-1800s—a natural gas pipeline in Quebec in 1853—and the first oil pipeline in 1862 in Ontario—most of the pipeline infrastructure in Canada dates from after the 1950s, when a boom in pipeline construction began, following major finds of oil and natural gas reserves in Western Canada (Bott 2004). A similar boom in pipeline installation occurred in the 1950s and 1960s in the U.S. as well (Kiefner and Rosenfeld 2012).

Most pipelines in Canada are provincially regulated (state level). However, more than 73,000 km of pipeline rights-of-way (ROW) that cross borders, whether between provinces or internationally, into the U.S. are regulated federally by the National Energy Board (NEB).

For most NEB-regulated, large-diameter transmission pipelines proposed in recent years, the planned operational life is typically in the range of 40 to 60 years. This may often be more related to the expected commercial or economic life of a pipeline, rather than any physical limitations. Although some pipelines get removed from service due to their aging condition, nonetheless, with proactive integrity assessments, preventative maintenance, and other mitigation, it may be possible for pipelines to last much longer. As noted in a report on the age of pipelines and safety (in natural gas transmission pipelines), a well-maintained and periodically assessed pipeline can potentially transport product indefinitely when time-dependent degradation threats are neutralized and repaired (Kiefner and Rosenfeld, 2012). In addition, measures such as reducing the maximum operating pressure of a line may also prolong the safe usage of a pipeline.

Considering the extensive network of pipelines and much of it having been installed several decades ago, it is to be expected that with the passage of time, there are various reasons why a company may need or want to retire or cease operating a pipeline. Among these are:

- Engineering and safety concerns related to the condition and integrity of a pipeline
- Changing environmental circumstances, such as road or utility developments, or other encroachments resulting from land use changes or erosion (water or wind) that may expose the pipe
- Commercial or economic changes, such as reduction in upstream supply, or decreased downstream demand

Some of these factors may be interrelated and in addition, companies may sometimes no longer need or want to abandon only certain specific facilities (e.g., a compressor station) that are part of a larger pipeline system.

Taken together, the varied reasons for retiring a pipeline—along with the varied potential circumstances that may be encountered—means that even defining what abandonment is can be less than perfectly clear and pose some interesting challenges.

Regardless, in recent years, the NEB has started to see an increase in applications for pipeline abandonments, and with this comes a rise in interest around abandonment issues.

This paper examines environmental issues associated with pipeline abandonment from the perspective of the Canadian federal energy regulator—the NEB. As explained, the focus of the paper is on the abandonment of buried facilities rather than those above ground, and more on abandonments in place than on removals. The paper also focuses on the permanent abandonment of facilities rather than on temporary deactivations. Although the NEB considers other matters, such as socio-economic and financial matters, when assessing abandonments, and although it also regulates certain offshore facilities and powerlines, these are beyond the scope of this paper.

REGULATORY CONTEXT

The NEB's regulatory oversight spans the entire lifecycle of a pipeline—from project review and authorization, through construction, operation, and eventual abandonment.

With respect to abandonment, the NEB's regulatory oversight can be characterized as consisting of three stages:

- The physical abandonment activities—which includes any work conducted in the field and necessary to prepare the existing facilities for their permanent retirement and that may have an effect on the environment (e.g., clearing, excavation, soil remediation, reclamation, etc.)
- Reclamation monitoring—which consists of company monitoring of the ROW following the physical abandonment activities and reporting to the regulator on the progress of reclamation; it may also include remediation monitoring
- Abandoned pipeline monitoring—which is the indefinite, long-term monitoring of any pipeline segments abandoned in place, the purpose of which is to identify and resolve issues arising (e.g., subsidence, erosion, etc.); also, any maintenance activities (e.g., cathodic protection) retained for abandoned pipe may also require monitoring

Although regulated companies have had to apply to the NEB to abandon a pipeline for a long time, up until 2016, the NEB did not have regulatory oversight over a pipeline once the conditions of an abandonment order were met, and it was deemed abandoned. Prior to 2016, the NEB Act had no definition for an abandoned pipeline, and the definition of "pipeline" referred only to a line "used or to be used for the transmission" of product. Since the NEB's legal authority to regulate is set out in the NEB Act, the NEB therefore could not regulate a facility that no longer met the definition of "pipeline."

In the regulation of operational pipelines, however, since 1999, the NEB has had the Onshore Pipeline Regulations (OPR) that govern operating pipelines up to and including the physical activities associated with abandonment. Further, the OPR defines the term abandon as "to permanently cease operation such that the cessation results in the discontinuance of service."

The question of the continuation or discontinuance of service reflects an added detail, which has sometimes complicated the legalities around abandonment. As an example, in 1988, TransCanada Pipelines Ltd. applied to the NEB for authorization to retire multiple compressor stations that were part of a larger pipeline system. In its decision (NEB 1989), the NEB found that retirements of a pipeline, or part thereof, that did not result in a "discontinuance of service" did not require an authorization to abandon under the NEB Act.

This decision led the NEB to introduce "decommissioning" provisions in the OPR in 2008 to allow companies to retire facilities that are part of a larger pipeline system for which service is continued. Decommissioning was defined as "to permanently cease operation such that cessation does not result in the discontinuance of service." Although decommissioning was originally introduced to provide a clearer legal and procedural mechanism for "retiring" facilities where service continued, the similarities between decommissioning and abandonment have also led to confusion.

Companies have argued that the activities necessary for decommissioning a pipeline are no different than what is required for abandoning a pipeline in place. In the Line 3 replacement project, the company applied for authorization to essentially cease operation of one pipeline and replace it with a new one to be built (Enbridge 2014). Since the old pipeline is in a shared ROW with multiple operating pipes, and since the new pipeline would maintain service, the company applied for decommissioning with an understanding that it would one day return to apply to abandon the decommissioned pipeline. In this way, decommissioning has become an interim step towards eventual abandonment.

In 2008, the NEB led a Land Matters Consultation Initiative that included discussions with landowners and regulated companies on issues related to pipeline abandonment. Out of this initiative, the NEB developed a set of principles to guide its future decisions, one of which was that landowners will not be liable for the costs of pipeline abandonment. The NEB requires companies to set aside money for abandonment work, including for future activities to deal with unforeseen events, and the NEB periodically assesses that the amounts set aside are sufficient.

Although prior to 2016, the NEB did not have the regulatory oversight for "abandoned pipelines," companies were nonetheless required to apply to the NEB for leave to abandon the operation of a pipeline. The NEB requires that companies applying to abandon a pipeline must include relevant engineering and environmental information, as well as an abandonment plan developed in consultation with landowners, indigenous groups, and other potentially affected persons and groups. A company must demonstrate that it will abandon a pipeline in a way that protects the environment and the public. When the NEB issues an Abandonment Order, this comes with specific conditions designed to address any risks to public safety, property, and the environment.

In 2016, amendments were made to the NEB Act, including some relating to abandonment. These included:

- Addition of a definition for "abandoned pipeline:" a pipeline, the operation of which has been abandoned with the leave of the Board… and that remains in place.
- Clarifying that pipelines abandoned in place remain under the NEB's jurisdiction in perpetuity or until they are removed from the ground. Remaining under NEB jurisdiction has the effect of making pipeline companies remain liable for all their pipelines, including those abandoned in place.
- Authorizing the NEB to order pipeline operating companies to maintain funds to pay for the abandonment of their pipelines and for monitoring and maintenance of abandoned pipelines. Although the NEB had started requiring companies to set aside money for abandonment since 2013, this amendment formalized the requirement.
- Allowance for the NEB to make regulations governing abandoned pipelines, although the NEB has not yet exercised this power.

These amendments serve to reaffirm and strengthen the regulatory oversight of the NEB in regard to pipeline abandonments, as well as to hold companies responsible for their pipelines, as long as they remain in the ground. This is consistent with some other pipeline legislation, such as in the province of Alberta (Swanson et al. 2012). The NEB continues to regulate pipelines abandoned in place and requires companies to monitor and report on them as well as to address any concerns raised by stakeholders.

SELECTION OF ABANDONMENT METHODS

H2 level

There are basically two options or methods for dealing with pipelines that are to be permanently retired: removal or abandonment in place. While some sources may identify variations on these (e.g., CEPA 2007 identifies abandonment in place with special treatment as a distinct option), these are not necessarily different options so much as additional mitigation to deal with particular issues that may need to be addressed. Further, in the case of linear infrastructure like pipelines, the selection of either option is not all or none, and both options may be appropriate, depending on different circumstances encountered along the length of a pipeline. Indeed, sources also consistently recommend a site-specific assessment to determine an appropriate plan (NEB, 1985; NEB, 1996; CEPA 2007; DNV 2010; CSA 2015).

There are a few high-level factors or considerations that tend to influence which option is preferred or chosen for any particular segment of pipe: Land Use, Safety, Environmental Considerations, Affected Parties, and Cost. These factors can represent direct trade-offs or sometimes their details can be so intertwined as to make them difficult to categorize.

Factors Considered

Land Use

Existing and potential land use has been described as the most important factor to consider in whether a section of pipe should be removed or abandoned in place (CEPA 2007; Swanson et al. 2012) As linear infrastructure, transmission pipelines tend to cross long distances and are located in relatively less inhabited areas (subject to encroaching developments with time). As such, the majority of their route is often rural, whether across agricultural lands or on relatively less developed public lands. Often they may also follow and share ROW with other existing linear developments. Given these circumstances, the preferred default option identified in the literature and favored by industry is usually to leave the pipe in the ground. This may vary where there is more human activity or infrastructure, so that the chance for potential conflicts increases, whether in the present or in the foreseeable future. This often relates to safety issues or stakeholder concerns around potential environmental harms. Land use zoning designation could also potentially play a role in the selection of abandonment method for specific parcels of land.

Safety

Safety is a prime concern and often comes up wherever other infrastructure or activities may interact with a pipeline to be abandoned, or may constrain abandonment activities, especially removal.

Where multiple pipelines share a ROW corridor, safety may be an important driver for leaving a pipe in place. For example, a couple of recent Enbridge pipeline replacement projects, for Lines 3 and 10, both included retiring existing lines in shared corridors within three meters (m) of other active operating pipelines (NEB 2016; NEB 2017a). The risk of striking or damaging an adjacent operating pipeline, with consequent further safety, environment, or operational consequences, presents a constraint on how abandonment activities would need to be conducted. Although special practices and tools exist for working in constrained spaces, these may not necessarily be feasible for the removal of substantial lengths of pipeline. A 2013 analysis of pipeline incidents in Alberta between 1990 and 2012 found a strong correlation between the number of incidents and the level of industry activity. Although damage is infrequent on large-diameter pipelines, thanks in part to modern locating tools and methods, such as hydrovac excavation, the report noted that with increased density of buried infrastructure, excavation protocols must be of the highest caliber (AER 2013).

Furthermore, where there is existing infrastructure, then the potential benefits of removal may be relatively diminished and so the case for removal becomes less obvious when safety is also at stake. As an example, in the Enbridge Line 10 project, the NEB concluded that there was insufficient evidence to persuade it that the benefits of removing the existing Line 10 pipeline would outweigh the risks (NEB 2017a). Similar situations, where pipelines cross under roads or railways, also tend to favor abandonment in place with appropriate mitigation.

While concerns about safety around other infrastructure tend to favor leaving a pipeline in place, in contrast, concerns about the safety of other activities around abandoned pipes tend to favor removal. Examples would be where and when there may be foreseeable ground disturbance activities, such as excavating for planned developments or agricultural tilling in consideration of the depth of cover.

Environmental Considerations

Whatever method of abandonment is adopted, either one will have potential environmental effects associated, will require various physical abandonment activities, and varying degrees of mitigation depending on circumstances (see next section).

However, the method of abandonment proposed may itself be mitigation to the alternative. That is, where the potential impacts or risks associated with abandonment in place may be too great, then removal may be the most practical mitigation; and where the impacts of removal may be too great, then leaving the pipeline in place is often adopted as the best means of mitigation.

An example of removal being the optimal mitigation is where a segment of pipe has become exposed due to erosion and so can easily be removed, and should be removed, rather than applying further maintenance to it. Examples of other such environmental circumstances may include slope instabilities or soil contamination, requiring extensive excavation anyway, or pipeline buoyancy in settings such as wetlands, along with various other potential scenarios. The depth of burial or soil cover is often an important variable in these cases. These types of environmental issues are often about the effects of local environmental conditions on the pipeline to be abandoned and the risk of further public safety or environmental consequences that may need to be addressed. They present a risk and a liability—one that may have had to be managed or that required maintenance during the past operation of a pipeline, but for which, during abandonment, may be simpler to just remove.

Where there may be limited compelling reason to remove a pipe, however, the impacts of removal are a certainty (known from the construction of new pipelines), which abandonment in place can address.

As such, choosing which method of abandonment is focused on what is environmentally preferable, relative to the risks and advantages, and subject to any further mitigation associated with each alternative. In the U.S., federal assessments of abandonments follow a policy of considering alternatives that assesses whether an alternative method would be reasonable and environmentally preferable to the proposed action: does the alternative method have a significant environmental advantage over the proposed action (FERC 2017)?

Affected Parties

The NEB expects companies to prepare an abandonment plan tailored to the individual project in consultation with stakeholders (landowners, indigenous peoples, and other potentially affected persons and groups), so that their input is considered in the development and implementation of the abandonment plan. This includes seeking input on the proposed abandonment method, as well as on mitigation measures for potential impacts and on reclamation plans (NEB 2017b).

Stakeholders have typically advocated for removal of pipelines and have expressed concerns regarding the potential impacts of leaving pipelines in place, such as subsidence, contamination, crop loss, erosion, interference with drainage systems, corrosion and collapse, and safety concerns.

The choice of abandonment method should reflect any commitments made in contractual agreements (NEB 2013). For example, in the Peace River Mainline Abandonment Project (NGTL 2016), the company proposed to remove a nine-kilometer section of pipe that crossed through an indigenous group's reserve land. The decision to remove this section of pipe was based on obligations set out in the federal permit issued for the ROW on the reserve lands, on engagement with the indigenous group, and in consideration that the amount of reserve lands available for future development are limited.

Cost

Finally, it should be noted that the financial costs of removal or abandonment in place are different. In many circumstances, in the immediate term, it is usually less costly to abandon a pipeline in place than it is to remove it. As such, cost may often be the most obvious trade-off when other factors suggest removal. The cost of removal has been estimated to be 30 to 50 percent of the cost of installing pipe, assuming same size and setting (Swanson et al. 2012). However, potential future liabilities (e.g., related to safety or to interactions with the environment) and longer term monitoring also have their own costs. Depending on the potential consequences, the estimated probabilities, and the timing associated with these, companies may want to minimize the financial risk of potential future liabilities.

Guidance on Factors in Selecting Method

In order to weigh these different factors, companies' planning processes include technical evaluation, risk assessment, environmental assessment, consultations, and assessment of land use (Swanson et al. 2012). Nonetheless some basic industry guidance on starting assumptions is useful and available.

A common matrix has evolved within the last few years to provide a basic starting point on where and when to remove a pipe, abandon it in place, or abandon it in place with special treatment (CEPA 2007; DNV 2010). The simple matrix is based on three classes of pipeline diameter and 10 different land uses under broader categories of agricultural, non-agricultural, and other land uses. Pipeline diameter really only makes a difference to whether special treatment is applied to an abandonment in place where there are utility crossings. The matrix thus confirms the importance of existing and potential land use as the starting point for assumptions on method of abandonment. The recommendations apply to any hydrocarbon pipeline and it is assumed that cathodic protection would be discontinued on pipes remaining in place. According to some land categories (e.g., cultivated), where the primary option is assumed to be abandonment in place, more recent versions of the matrix (DNV 2010) also allow for up to 20 percent of the pipe to still be removed. As noted previously, site-specific or risk-based assessments are recommended and may override the default recommendation.

Steps in Abandonment in Place

Having identified what method of abandonment to use for what segments of pipe, there are typically five basic activities in abandoning a pipeline that is to be left in-place:

1. Removal of product from the pipeline
2. Clean the pipeline
3. Disconnect the pipeline and seal it off from active operational facilities to prevent product from re-entering the system
4. Permanent segmentation of the pipeline to prevent it from becoming a water conduit (and installing caps or permanent segmentation plugs)
5. Monitor the pipeline

Each of these actions also serves as mitigation for any potential environmental effects that could arise.

ENVIRONMENTAL EFFECTS & MITIGATION FOR ABANDONMENT IN PLACE

Pipeline abandonment projects have the potential to affect a number of different environmental elements, including physical and geological resources, water resources, and aquatic, wildlife, and vegetation resources. The effects on these resources can occur in a short, medium, or long period of time, with the effects from the physical abandonment activities (whether for removal or for abandonment in place) being mainly short- to medium-term, while the effects arising from a pipeline being left in place are longer in term.

Short-term effects are usually defined as effects that are less than, equal to, or slightly longer than the duration of the physical abandonment activities (e.g., weeks or months). Medium-term effects may last in the order of months or years, and long-term effects can last for a duration of years or decades (NEB 2016; and NEB 2018).

The physical abandonment activities for both removal or for preparing a pipeline for remaining in place entail physical disturbances that interact with and affect the surrounding environment. These activities and their potential environmental effects are very similar to those associated with constructing a new pipeline. The activities include clearing, soil stripping, excavation, backfilling, grading, etc., all of which may result in effects on soil, water resources, wildlife, and vegetation, among others. Although these effects are generally well understood, and with standard mitigation, most residual effects are minimized and are generally reversible within a few years, these interactions are certain to occur. One issue associated with pipe removal that is not encountered with new pipeline construction is the matter of pipe disposal, and especially if there is residual contamination (i.e., naturally occurring radioactive materials).

In contrast to the removal of pipe, abandonment in place is largely about leaving the existing pipeline and therefore the immediate surrounding environment as-is. This absence or general lack of physical disturbance means that there is not necessarily much interaction with the surrounding environment and consequently few apparent effects. Moreover, as time passes, potential future interactions and their potential effects become more uncertain in terms of where and when something may happen. Despite this uncertainty, however, it is still predictable that the pipe will eventually degrade and that there are long-term potential environmental interactions that can arise if not mitigated. These include ground subsidence, the pipe acting as a conduit for water and contaminants, and exposure of the pipe (CEPA 2007; DNV 2010).

Generally, preparing a pipeline for abandonment in place starts with isolating it from other operating pipelines, removing all surface facilities, and usually removing the cathodic protection from the pipe, which allows it to begin corroding with time. In some instances—for example, in the Line 3 replacement project, a company may choose to leave the cathodic protection in place in order to delay or slow down the rate of pipe corrosion (Enbridge 2014).

Corrosion will eventually allow soil and water to enter the pipe, with the pipe acting as a conduit allowing water and any residual contamination to move through the pipe and be deposited to another area. In addition, at a certain point in the future, the pipe may eventually collapse due to the corrosion. The timing in which this may happen is expected to vary from approximately 100 to 9,000 years, depending on the specific circumstances of the pipe and surrounding environment (DNV 2015). Collapse of the pipe would result in localized ground subsidence over that area.

The abandoned pipe could become uncovered and exposed with time due to soil erosion from wind and/or water. Each of these effects are discussed individually below.

Water Conduit

In areas where the pipe surface is in direct contact with water, pipe corrosion can occur through damaged areas of the pipe coating after the cathodic protection is removed (DNV 2015). When pit corrosion occurs, the water can enter the pipe and create a conduit within the pipe carrying the contents to a different area. This can mobilize any residual contamination within the pipe as well as mobilize soil (clean or contaminated) surrounding the pipe (CEPA 2007; DNV 2015).

There are a number of effects that may occur as a result of the pipeline becoming a conduit where water enters the pipe from a waterbody, and there is a slope or gradient change along the pipe. This may result in hydrological changes to both the water source and the receiving environment (AMEC 2017). Waterbodies that are small or that recharge slowly may become drained or experience a loss of volume that could impact the water source itself, or wildlife that use it. Depending on where the water exits the pipe, it may cause erosion of the surrounding soils resulting in potential sinkholes, flooding of low-lying areas or agricultural fields, or if it exits into or in the vicinity of a waterbody or wetland, turbidity and contamination of that waterbody may occur (AMEC 2017). The risk with respect to contamination is that contamination that may have initially been limited, localized, or possibly even confined could now be mobilized and spread to contaminate a larger area and additional receptors.

Two particular physical abandonment activities are relied on to address the potential impacts of a water conduit on hydrology and on the spread of contamination: the cleaning of the pipeline to reduce the potential for contamination, and segmenting (through the insertion of plugs) the pipeline to limit the length of conduit segments. After the contents of a pipeline have been purged, the pipeline must then be cleaned in order to remove as much residue and contamination as possible that may remain in the pipe. Current standards simply state that a pipeline, to be abandoned, must be cleaned (CSA 2015). A cleaning program could consist of mechanical or chemical methods, or a combination of both. However, there are no guidelines to indicate an acceptable method of cleaning, or the acceptable level of residual contaminants that may remain in the pipe once cleaning is complete (Alberta Innovates 2015). In the absence of clarity, companies have typically identified the effectiveness of pipe cleaning based on the amount of waste and material removed after each pig run, depending on pipe size. One abandonment application indicated that, based on previous in-line inspection data, it would repeat cleaning pig runs until two subsequent pig runs resulted in 10 liters or less of material for an NPS 20 pipe across distances of up to 153 km, and two liters or less of material for an NPS 4 pipe across two segments of 2.34 km, and 0.80 km (NGTL 2016; NGTL 2017).

Another mitigation measure to prevent or minimize water conduits include the removal of the pipe, or sections of the pipe could be isolated to stop the flow of water within the pipe. The local topography of the landscape can be used to identify the best sites to segment the pipe by cutting and capping the pipe. An example of this would be to cut and cap the pipe into shorter segments on the downgradient side of waterbodies. It has also been suggested that water discharge points could be created along a pipeline to divert water to areas that would not be negatively impacted (AMEC 2017).

Ground Subsidence

Ground subsidence can occur when the abandoned pipeline corrodes with time, and overlying soil enters the pipe through corrosion pits or perforations, or where pipe is collapsing. The first areas to corrode on a coated pipeline are areas where the coating has either disbonded from the pipe or there are defects in the coating (NEB 1996). This typically only occurs in one percent of the pipe, so it would be rare for corrosion to cover large areas of a pipe at one time. This makes it highly unlikely for significant lengths of pipe to collapse at once, but rather for collapse to be localized and gradual (NEB 1996).

Insofar as a pipeline does degrade and collapse with time, the depth of subsidence would vary based on factors such as pipeline diameter, burial depth, and soil type. One report estimates that the resultant ground subsidence from the collapse of an NPS 12 pipe or smaller would be negligible, the subsidence for a moderate-sized pipe (e.g., NPS 24) would be less than 10 centimeters (cm), and for a large pipe located in poor soil conditions and buried at shallow depths, subsidence could be as much as 40 cm (DNV 2015). The area of disturbance would also be much wider than the pipeline diameter due to the behavior of soil above the pipe.

Ground subsidence may potentially affect public safety if it should occur at a road or railway crossing. Soil subsidence may affect soil quantity in agricultural lands, which in turn may impact crops or the safe use of agricultural equipment. In addition, ground subsidence in the area of a stream or wetland may cause changes to the local hydrology and create ponding or linear flow out of a waterbody.

In order to mitigate the public safety issue at roads and railway crossings, the section of pipe under the road or railway can be cut, capped, and filled with a substance (such as concrete) that has the strength to prevent the pipe from collapsing (NEB 1996; CEPA 2007). Depending on the particular infrastructure and depth of burial, however, this may not always be necessary. For example, in one project, the company indicated that it would not fill the pipeline under any gravel roads with a depth of cover greater than 2.5 m, and it expected that any subsidence could be addressed as part of regular road maintenance activities (NGTL 2016).

In areas of minor subsidence, the placement of additional soil, or regular tilling on agricultural lands may mitigate the subsidence. In areas where the subsidence is more substantial, re-occurring, or poses danger to public safety, removal of the pipeline may eventually be warranted.

Pipe Exposure

Sections of a pipe abandoned in place may become exposed with time through a number of different factors. Pipes may become exposed at watercourses through erosion and/or slumping of watercourse banks, as well as through flood events or scouring of overburden due to watercourse dynamics with time. In areas of wet or saturated soils, pipes may float to the surface and become exposed once the product is removed from the pipe if no buoyancy control measures were installed, or if these measures become ineffective (DNV 2010; Stantec 2014). Pipes may also become exposed through frost heave or soil erosion from either wind or water. Frost heave is influenced by the length of the pipe section, depth of cover, soil type, and moisture (Stantec 2014). Erosion will reduce the depth of soil cover over the pipe until it eventually becomes exposed to the elements.

The potential effects of a pipeline becoming exposed in a watercourse and wet areas may include impacts to navigation and public safety, as well as changes to local hydrology, and impacts to fish and fish habitat through changes in sediment transport within the watercourse and potential barrier to migration. Pipe exposure on land may create a physical barrier and create issues with land uses, public safety, and wildlife movement.

Pipelines that were used to ship liquids products, if buoyancy control measures are not present, may need to be added at the time of abandonment; however, gas pipelines typically have buoyancy control mechanisms installed during construction. In the event that the buoyancy control measure fails, it may need to be replaced, or the pipeline removed if the risk of failure is high.

Assuming sufficient burial depth and subject to the flow regime of a watercourse, leaving the pipeline in place appears to be the preferred mitigation in order to avoid immediate disturbance to the watercourse bed and banks if a segment of pipe is removed. A similar situation might occur at locations where leaving the pipe in place may help maintain stability of the slope and removal would require extensive mitigation and slope remediation work (CEPA 2007).

Residual Effects

In assessing abandonment projects for these effects, there are several challenging aspects. In particular, assessing the proposed level of pipeline cleaning is challenging due to the lack of standards, guidance, or research literature on what levels of residual contaminants in the pipe would be considered acceptable. Due to this, in one case, the NEB conditioned the company to test a section of pipe slated to be removed to ensure that the predicted level of residual fluid indeed met the company's proposed standard. If not, then additional cleaning was required before any further work would be conducted (NEB 2018).

For potential ground subsidence and pipe exposure, the literature indicates that widespread, rapid structural collapse of the pipe is not expected to occur, but rather is expected to occur in localized areas and may take up to 9,000 years to occur (DNV 2015). The uncertainty of when and where both ground subsidence and pipe exposure would occur along an abandoned pipeline makes it challenging to assess. Due to this uncertainty, the NEB has conditioned companies to develop a plan for extended, long-term monitoring of the pipeline, until such time as it may be removed, to identify areas of ground subsidence and pipe exposures (NEB 2018).

RECLAMATION

The purpose of reclamation is generally to ensure that the surface soil, topography, and the vegetation of the project site is restored to an acceptable condition. Expectations and issues around reclamation might be expected to be similar to those that arise for new construction where ground disturbance occurs (e.g., for pipe removal and preparation of pipe for abandonment). However, the objective of reclamation after new construction needs to consider maintaining access and the capability for inspection activities for the operational life of the pipeline (CSA 2015) and this influences the type of vegetation that may be selected and managed. In contrast, the longer term reclamation for abandoned pipes does not have these constraints.

The extent of reclamation required for a pipeline left in place is generally much less than for a pipeline that is removed. However, the process could take many years—or even decades—depending upon the nature of the physical disturbance, the extent of contamination, the type of land use, the ecoregion and vegetation species, and the reclamation goal. In areas where the pipe is abandoned in place and no ground disturbance is required, the state and species composition of the vegetation on the ROW will depend on the nature and extent of the historic vegetation management (VM) and in some cases vegetation growth may already be advanced. However, where vegetation is dominated by certain grasses or where succession may be lagging there could sometimes be a need for more enhanced reclamation with additional vegetation planting or restoration treatments to ensure appropriate or more timely succession.

In Canada, there are no federal requirements for reclamation subsequent to the completion of physical abandonment activities. However, many provinces have requirements and criteria for reclaiming and restoring disturbed lands. For example, Alberta Environment and Parks has published several documents that set out the reclamation criteria and guidance for the upstream oil and gas industry to assess whether a site is reclaimed and eligible for a reclamation certificate (AEP 2018). The objective of reclamation is often to achieve an equivalent land capability, although translating this desired end into something more specific is not necessarily obvious. Some provinces require companies to reclaim land to a pre-development condition (i.e., to a state prior to constructing the pipeline), whereas others require reclamation to a state prior to the commencement of abandonment activities. These differing expectations parallel the sometimes contrasting perspectives of companies and stakeholders. For example, in one abandonment project, the company proposed that the objective of reclamation should be to reclaim the ROW to a condition comparable to the present surrounding environment, whereas some stakeholders argued that it should be reclaimed to a pre-construction condition. In addition to the requirements of any particular jurisdiction, factors such as zoning or land designation (e.g., national park), or adjacent land use may well influence the nature of the reclamation that should be done. This could influence, for example, what seed mixes are used, or whether reclamation might be passive and left to natural regeneration, or whether it may warrant more active restoration to enhance ecological succession. Reclamation activities also include monitoring, the purpose of which is to identify any locations or biophysical components that require additional reclamation activities, including corrective adaptive management actions, and to ensure that reclamation efforts are successful.

As such, while standards may vary between different jurisdictions, there exists a considerable body of standard best practices and guidance. Nonetheless, as with construction of new pipeline, there are often times when the regulator may still impose reclamation related conditions of approval.

MONITORING OF ABANDONED PIPELINES

Following physical abandonment activities and reclamation monitoring, the last stage in abandonment is the long-term monitoring of any pipe left in place. The NEB continues to regulate this phase of abandonment and expects companies to monitor and maintain any abandoned pipeline in a safe and environmentally sound manner for as long as it is in the ground.

As noted previously, it is predictable that there will eventually be environmental effects associated with the degradation of pipeline left in place. The nature of some of these effects are also reasonably identifiable. Despite these logical deductions, the limited past experience with pipeline abandonment means there is little in the way of long-term monitoring records about the impacts of abandonment in place. Further, since there are inherent uncertainties around when and where which specific effects may happen, it is therefore challenging to know what specific mitigative details are needed.

It may not be surprising then that companies currently do not tend to voluntarily propose long-term monitoring for unforeseen events or impacts that may arise in the future. For example, in the application for the Peace River Mainline Abandonment Project, the company did not propose any further post-abandonment activities, including monitoring, once equivalent land capability would be achieved following reclamation (NGTL 2016).

Monitoring, however, is a commonly accepted approach for dealing with uncertainty, even if determining what the details of monitoring should be for pipeline abandonment is not immediately obvious and raises a range of questions:

- For how long into the future should active monitoring of abandoned pipeline be required? Twenty, 50, 100 years, or in perpetuity?
- What methods of monitoring are needed and how frequently? What should be the mix of different methods (inspections, aerial patrols, remote sensing technologies, landowner reports, etc.) to ensure sufficient spatial coverage and level of detail to identify issues that could arise?
- How should monitoring change with time? (i.e., increased or decreased frequency using different means of monitoring)
- What records need to be kept?
- What information needs to be reported, and when, and to whom?
- What circumstances, or changing pipeline or environmental conditions, will warrant remedial action?

Notwithstanding these monitoring challenges, given the uncertainties inherent in trying to address issues that may arise in the future, and given that monitoring provides for the identification of issues and for future adaptive management, it is not surprising then that abandonment monitoring would be a common condition of abandonment.

In its decision report for the Peace River Mainline Abandonment Project, the NEB found that the company's plan to cease monitoring of the pipeline once equivalent land capability is achieved was insufficient, and that the effect of this is to rely on stakeholders such as landowners to report any issues, without any proactive measures by the company to identify and mitigate risks. The NEB, therefore, imposed a condition requiring the company to prepare a comprehensive and proactive Abandoned Pipeline Monitoring Plan for wherever the pipeline is abandoned in place. The condition requires the company to identify hazards (e.g., pipe exposure, ground subsidence, etc.), evaluate associated risks, develop controls, and to communicate identified hazards and controls with all relevant stakeholders. The company must also describe the methods and frequency for monitoring, and demonstrate how these will be effective in identifying any issues arising over time (NEB 2018).

The details of individual abandoned pipeline monitoring plans can be expected to vary from case to case, depending on the pipe, the hydrological and geophysical features traversed, and the land use and stakeholder concerns. Abandoned pipeline monitoring plans need to address all the foreseeable issues described previously, as the company remains responsible for the abandoned pipeline.

Given the relatively emerging nature of pipeline abandonment, there is limited technical and regulatory guidance. In addition, incomplete historical records for a pipeline can present a challenge at the time of abandonment (Swanson et al. 2012) and this could recur in the future.

Recommendations related to record-keeping (e.g., NEB 1996) include considerations that may be relevant to abandonment monitoring best management practices (BMP).

Abandonment monitoring records should contain:

- Regulatory authorizations and associated conditions (including reclamation certificates)
- Full particulars on the pipeline abandoned in place, including a physical description, location, and depth of cover, locations, and details of any mitigative measures implemented
- Copies of all past crossing agreements (e.g., road or railway)
- Records of all surveillance activities (whether aerial, remote imagery, site visits, etc.)
- Records of any monitoring findings, including but not limited to:
    - o Slumping over the pipe, or water flow through the pipe, that was noted during monitoring
    - o Any changes in pipeline state from the original abandonment plan (e.g., if pipe sections abandoned in place are subsequently removed)
    - o Any areas found contaminated after abandonment and reclamation activities
- Records of any remedial work performed on the abandoned pipeline.

In the long term, good monitoring records will help build a knowledge base from which to draw learnings on how to better address abandonment issues in the future, as well as provide adequate background context for whenever issues may arise that may need remedial work.

The last phase of abandonment may also include certain long-term maintenance activities, as distinct from monitoring activities. This is more likely to happen where an abandoned pipeline is in a shared corridor with multiple other adjacent operating pipelines. An example of this is the Line 3 replacement for which the company committed to continue applying cathodic protection on the retired line in order to reduce its rate of corrosion which, as previously discussed, mitigates against pipe degradation and eventual ground subsidence (Enbridge 2014). Other examples of long term abandonment maintenance activities include maintaining pipeline locator signage and remaining part of any applicable one-call program so that a line can be located by third parties. Maintenance activities will also require periodic monitoring.

In the absence of much experience or monitoring records related to pipelines abandoned in place, retrospective reviews might also be useful. Recently, the Pipeline Abandonment Research Steering Committee facilitated by the Petroleum Technology Alliance of Canada commissioned a review of a pipeline abandonment program conducted a few decades ago. The review looked at three segments of 20-inch pipeline loops totaling 12 km in boreal forest in northwest Alberta, and which were abandoned between 1972 and 1979 due to integrity concerns (CH2M Hill 2018). The surface level assessment did not reveal any evidence, after 40 years, that potential environmental effects of abandonment in place had yet started becoming evident. The review also included recommendations for additional sub-surface assessment and pipe excavation to examine a wide variety of parameters, such as the condition of the pipe, screw anchors, and the isolation measures used at the time, as well as soils, residues, contamination, and so on, and at different locations, including such as under wetlands. The review noted that there were no regulatory requirements around pipeline abandonment in the 1970s and that, perhaps consequently, no records for abandonment plans were found. While the findings and the circumstances in this review provide some reassurance for now after 40 years, it is not necessarily appropriate to extrapolate this longer term or to every abandonment, and more data remains desirable.

CONCLUSIONS

From a regulatory perspective, applications to construct and operate a new pipeline project present a question of whether to authorize a project, as well as how or what terms and conditions. In contrast, applications to abandon a project are almost entirely about the question of how to complete the abandonment.

Pipeline abandonment, and in particular, abandonment in place, is an issue that takes the consideration of effects further into the future than is often considered, and this raises a variety of challenges.

There are a number of practical technical challenges around abandoning pipelines in place that arise due to abandonment being an emerging issue for which there is very limited long-term experience and research or documentation. The challenges include:

- Lack of data and guidance—The relatively short time since pipelines have been abandoned combined with the limited number of them, means that the long-term effects associated with leaving pipes in place are not fully understood and there is little documentation for guidance. Research tracking individual abandoned pipelines as case studies, as well as collecting aggregate data would be useful.
- Uncertainty and monitoring—Despite the logical predictability of

certain pipe-environment interactions and effects, there remains the long-term uncertainties of where and when these effects may occur. Consequently, decisions around abandonment must necessarily rely on assumptions and best estimates, and on monitoring and adaptive management. The limited experience with abandonments also means that designing appropriate monitoring is difficult. Again, research will be beneficial.

- Cleaning—There is a need for more information, both in terms of research as well as standards, on methods of cleaning and on specific, acceptable, quantitative standards that should be met.
- Records—Good record-keeping will be important, both to address issues that arise on any individual pipeline over time, as well as to contributing to long-term experience, research, and learning.

In addition to these issues, there are others that are more strictly regulatory in nature.

- Weighing removal versus abandonment in place—Finding the right balance between the factors influencing whether to remove a segment of pipe or leave it in place is a complex weighing exercise. The relative weighing of the factors may be different for a regulator considering the broader public interest than it is from a company's interest or perspective.
- Regulations—Expectations on how to abandon a pipeline are largely set out on a case-by-case basis through the imposition of conditions on the authorization for abandonment. The regulator relies on conditions for its ability to oversee compliance. The recurring imposition of certain common standard conditions (e.g., for an Environmental Site Assessment, or for monitoring) suggests that the oversight of those issues might be more effectively replaced with a set of regulations.

Finally, given that decisions related to abandonment in place need to rely on assumptions, it is vitally important that there be wide and meaningful consultation, notably on validating assumptions, to be used in deciding on methods of abandonment, mitigation measures, and long-term monitoring. This is important both to address public concerns as well as to inform the best long-term decisions. Subject to future issues arising, consultation may of course need to be ongoing or may be reopened at any time. And pipe segments abandoned in place may always be removed later on.

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Footprint or Buffer?

A Comparison of Regulatory Approaches for Managing Historical Resources for Linear Projects

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Keywords: Construction, Pipeline, Other.

Historical resource features have a discrete footprint. Avoidance of these features may come down to a matter of inches (in) during right-of-way (ROW) planning and construction. The approach taken for investigating historical resources and applying for regulatory approval may influence the number of historical resource sites identified. In other words, a larger search area typically yields more sites. The approach selected also has implications for the approved area that is readily available to the project during construction—particularly when considering footprint additions or changes, such as extra temporary workspace or re-routes. This paper presents two case studies from Alberta. Two pipeline projects are used to compare two different approaches for obtaining historical resource approval. The first example highlights the advantages and disadvantages of requesting approval for only the design footprint (ROW) and anticipated temporary workspace), with no buffer to allow for immediate changes to the construction footprint. The second example reviews an approach that obtained approval for the project footprint and a buffer (*i.e.*, an anticipated area to account for changes to the footprint during construction). Scheduling, construction execution, and project management challenges associated with each approach will be compared.

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INTRODUCTION

Historical resource features, including historical, archaeological, and paleontological sites, have a discrete footprint. Avoidance should be the primary mitigation approach for these features as part of right-of-way (ROW) planning and during construction. Avoidance can physically come down to a matter of inches (in). Historical resources are regulated at the provincial or territory level in Canada. Obtaining regulatory approval to ensure compliance with applicable historical resource legislation can be a significant budget item and can create scheduling challenges. When developing linear projects, proponents are consistently challenged to compress schedules and reduce budgets. As such, it is imperative to be creative and challenge existing norms when developing a regulatory strategy to remain in compliance with legislated requirements.

A common approach to planning pipeline projects in Alberta includes obtaining historical resources approval using only the design footprint (ROW and anticipated temporary workspace [TWS]), followed by multiple approval applications during construction as additional footprint, such as extra temporary workspace (ETWS) or reroutes, is requested. In an attempt to mitigate both the budget and schedule impacts of this common approach, while allowing flexibility for anticipated, small-scale footprint revisions, Enbridge and one their consulting teams developed and applied for an alternate regulatory approach, which included obtaining approval for both the design footprint and a buffer (*i.e.*, an anticipated area to account for future changes to the construction footprint and ETWS). This paper presents a comparison of these two approaches.

Historical Resources as an Environmental Project Component

Historical resources and the legislation that regulates them have unique characteristics relative to other environmental components such as vegetation or wildlife. In general, "historical," "heritage," or "cultural" resources include archaeological sites, standing historic structures or features, and palaeontological (typically fossil) sites and locales (herein collectively referred to as historical resources). Historical resource sites may be evident on the ground surface or may exist only as a subsurface expression. They range in age from thousands of years old to just 50 years old, with the classification attributes varying between jurisdictions. In some jurisdictions, traditional land use sites may also be protected under heritage legislation.

Regulatory Variability

Each province and territory in Canada has created historical resource legislation specific to that jurisdiction, each administered by a ministry. Therefore, between the different jurisdictions, there are differences in regulatory process, project approval timelines, as well as the number and types of roles of stakeholder groups (e.g., Indigenous communities). Legislation can also differ in how historical resources are defined or what types of resources are covered. This is particularly true relative to inclusion or exclusion of palaeontological resources and the definition and protection of Indigenous traditional land use sites and locations.

Spatially Discrete

Historical resource sites are spatially discrete and fixed features. Typically, the presence and extent of historical resource features within a project footprint are defined after completing a field historical resource assessment (HRA). The boundaries of historical resource features can extend outside of the defined project footprint in some cases. The ability to spatially define a discrete and fixed resource means that avoidance of resource impact is usually feasible through modification of the project footprint—shifting the footprint laterally, reducing overall footprint width, and/or relocating TWS. This is usually easier to do earlier in the project schedule, when the footprint may be more flexible. However, at some locations, it is not feasible at all due to engineering, constructability, or landowner constraints. In addition, the costs of re-design may be greater than the costs of site mitigation.

Unpredictable

Although predictive modeling can be applied to the project footprint to identify target areas for field HRA, it is impossible to know what the extent, location, and/or relative value of each historic resource site will be without conducting a field HRA. This means that the extent of site mitigation—a costly and time-consuming process of hand excavation—is often unknown until later in the project schedule, which can impact the construction schedule and project budget. Furthermore, with the addition of ETWS during construction, additional heritage resource sites may be found, resulting in last-minute uncertainties. Having an experienced heritage resources team with solid working relationships with the regulator is critical to navigating around these types of situations.

Seasonally Restricted Assessment

Field HRA and mitigative excavation of sites are best conducted under snow- and frost-free conditions in Alberta and other northern areas. This introduces a seasonal limitation to project planning. In Alberta, the field season is typically from May to October. This often results in a minimum of two years of fieldwork for larger pipeline projects—the first to conduct field HRA and the second to conduct site mitigation if warranted.

Labor- and Time-Intensive

Both field HRAs and mitigative excavations are conducted largely by hand; these are labor-intensive and time-consuming tasks, with little option for increasing output and decreasing schedule.

CASE STUDIES

The Challenge

The regulatory process requires spatial data to define project footprints and historic resource sites. The project footprint for large pipeline projects must be reviewed by heritage resources regulators to evaluate the potential for impacts. The regulator then issues correspondence which—typically for large pipelines—results in requirements to conduct pre-construction field HRAs.

Field HRAs typically consist of foot survey and subsurface testing at identified target areas, selected as areas that have a greater likelihood to contain sites of high historical resource value and/or significance. Subsurface testing is usually conducted by hand and shovel, which can be complemented by deeper testing via mechanical means (e.g., backhoe) in areas of deeper sedimentation (e.g. valleys – floodplains/terraces). This is a time-consuming and labor-intensive undertaking, often in relatively remote areas. The results of the field HRAs are submitted in detailed reports to the regulator for review. The review period is typically a minimum of eight weeks in Alberta.

Any changes in the project footprint typically require additional field HRA and regulatory review. In addition, mitigation excavation may be required if significant historic resource sites are identified. Once a construction contractor in engaged on a project, they begin constructability reviews and construction execution planning. This may lead to the identification of areas where additional footprint is required. Contractors are typically not engaged until closer to the construction start date. As such, these footprint changes are identified later in the project lifecycle. They can be numerous and may include stockpile sites, laydown areas, log decks, shooflies, and/or access routes (herein collectively referred to as ETWS). Hundreds of new ETWS may be required depending on the size of the project. There is usually little time in the construction schedule to complete and report on field HRAs and then wait the minimum eight weeks of regulatory review and approval because these changes are late in the project lifecycle. Costs can also increase exponentially, with regulatory fees, field HRAs and reporting costs, contractor standby, and work arounds.

Enbridge executed two pipeline projects consecutively, each approximately 350+ kilometers (km) and roughly paralleling one another. Therefore, scope, landscape, and archaeological potential were roughly equivalent. An alternative regulatory strategy was undertaken based on real-time learnings during the first project. Further evaluation was conducted for the second project, for which the regulatory strategy was further modified.

Athabasca Pipeline Twinning Project

The Athabasca Pipeline Twinning (APT) project is an approximately 350-km pipeline in east-central Alberta, through parkland and boreal forest regions. The initial desktop review for historical resources was completed in early 2012, with receipt of regulatory requirements in spring 2012. The regulatory requirements for the field HRA were completed during the 2012 field season, with regulatory approval received for most of the line in spring of 2013. Specific heritage resources sites of high value were excavated in 2013 to mitigate the project impacts to the sites. While these sites were being mitigated, the project contractor was identifying locations where they required ETWS to support construction. This occurred on a piecemeal basis throughout 2013 and into 2014.

Undertaking field work and the regulatory process for each ETWS would have resulted in months of construction delay. This quandary required innovative problem-solving to minimize schedule impact. The archaeological/environmental team and Enbridge, in consultation with the regulator, worked together to develop an approach to effectively screen the ETWS requests on an as-needed basis. The approach required that the regulator was comfortable delegating a portion of the responsibility for evaluation and decision-making to the archaeological team.

The approach involved:

- A desktop evaluation of the pipeline alignment within 50 meters (m) of the original footprint to identify areas of low historical resource site potential or moderate-high site potential. The evaluation of heritage resource site potential was based on landscape attributes, results of prior assessments in the region, and the presence and extent of existing disturbance (e.g., cultivation, tree harvesting, etc.). The evaluation reflected the likelihood of significant historical resource sites being identified within the specific area.
- Areas with "low" historical resource potential were identified and mapped as green "go" areas and the "moderate-high" potential areas were identified and mapped as red "no go" areas.
- ETWS requests in green "go" areas did not require that the regulator be contacted for evaluation. The contractor was immediately advised they could proceed with work in those areas.
- ETWS requests in red "no go" areas were forwarded to the

archaeological team for desktop evaluation. The archaeology team would evaluate the footprint change at a finer scale and would determine next steps, which could have included:

- o No further work
- o Ground-truthing
- o Field HRA

In instances where further HRA was required, the construction team would then evaluate the necessity of the ETWS relative to time needed to wait for regulatory approval.

In total, 134 ETWS requests were screened, of which 52 were located in green "go" areas. The remaining 82 were located in red "no go" areas, of which 18 required field HRA.

Wood Buffalo Pipeline Extension Project

Despite the success in reducing schedule and cost with the red/green mapping approach, when a parallel pipeline, the Wood Buffalo Extension (WBE) project, was proposed shortly after completion of the APT project, alternate regulatory strategies were discussed. An idea was proposed based on the experience gained on the APT project and the intrinsic project management practice of improving efficiencies. Instead of individually addressing each ETWS request, the issue would be avoided by evaluating and assessing a larger, buffered pipeline footprint. Based on evaluating previous project data, the majority of ETWS requests occurred within 100 m of the ROW. Accordingly, this buffer was included for historical resources evaluation and field HRA.

The initial desktop evaluation was completed on this buffered footprint, followed by the identification of target areas for field HRA. The regulator then provided either approval or requirements for field HRA. The buffer footprint was increased in areas of anticipated construction complexity (e.g., watercourse crossings).

This buffer approach resulted in very little additional archaeological work during construction, as almost all the ETWS requests were located in the already approved buffer.

The Comparison

There were several advantages and disadvantages to each approach.

The advantages of the buffer approach were:

- Reduced complexity of record-keeping and tracking for numerous ETWS requests
- Minimal-to-no need for regulatory input following the completion of the field HRA prior to construction
- Greater understanding and certainty around archaeological constraints at an earlier stage in the project
- Increased ability to avoid impacts to significant archaeological sites by incorporating these constraints into the earlier planning phases of the project
- Decreased potential for non-compliance during construction

The disadvantages of the buffer approach were:

- Increased front-end field time—additional field time was required to assess the larger footprint
- Additional cost associated with the additional time needed for field work
- The regulator was concerned that the intensity of field HRA (i.e., the number of target areas) would be reduced due to the larger footprint

Generally, the advantages and disadvantages for the footprint approach were the inverse of the buffer approach. In addition to the complexity of record-keeping and tracking numerous ETWS requests using the buffer approach, there is an increased potential for non-compliance during construction. Managing large numbers of ETWS requests presents opportunities for miscommunication and misunderstanding, which may lead to work proceeding in areas that do not have regulatory approval.

CONCLUSIONS

Alternative methods of achieving the same objective are possible when teams are willing to work together and think outside the box. The success of both approaches was achieved as a result of:

- A positive working relationship with the regulator, including significant investment in face-to-face meetings and consistent communication
- An experienced and skilled archaeological team trusted by the regulator and the proponent
- A proponent willing to try a new regulatory approach

A key outcome of using an unconventional regulatory approach is that, based on the confidence the regulator had in the red/green mapping approach, it has now become an accepted approach for future projects and for other pipeline proponents.

The red/green mapping approach also highlighted that ETWS requests are not always necessary, even though they are requested. The contractor often indicated that they would find an alternate solution for the ETWS when they were advised that an area was located in a red "no go" area, which meant additional field work or an approval may be required.

Determining which regulatory approach is most appropriate for a project is dependent on project goals. If the project is cost conscious in the early planning stages, using the footprint approach may be most appropriate because the upfront cost is limited compared to the buffered footprint approach. The footprint approach, which requires less field time, would be more appropriate if the schedule is constrained during the planning stages.

However, the buffer approach would be most appropriate if a project is focused on understanding and mitigating potential risks in the planning phase because, in theory, all heritage resources features that could potentially be impacted would be identified in the early project stage. The buffer approach would also be more appropriate if a project is going to be schedule driven during construction execution, as the buffer approach generally eliminates the need to wait for approvals during construction.

In keeping with the good project management practice of creating efficiencies in scope, cost, and schedule, alternative regulatory approaches should be considered. Unconventional regulatory strategies can be achieved given a well-reasoned, defensible approach and a proponent-regulator-consultant team willing to collaborate and effectively communicate.

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Kate Peach is a senior archaeologist with more than 25 years of experience in survey, excavation, analysis, reporting, and project management. She manages and coordinates the historical resource component of a range of project development types, ensuring project completion with a focus on professional standards and quality. She has overseen and managed numerous Historical Resources Overviews (HRO), Historical Resources Impact Assessments (HRIA), monitoring and mitigative excavations, as well as traditional knowledge assessments. In addition, Peach has experience in the formulation of archaeological predictive models and constraints maps. She has worked throughout northwestern Canada, and has gained additional experience in Idaho and overseas.

Gray Areas: An Evaluation of Construction Activities Approved to Occur Outside of Approved Work Areas on FERC Regulated Natural Gas Pipeline Projects in the U.S.

Anthony Dalbec

Keywords: Federal Energy Regulatory Commission (FERC), Pipeline, Plan, Procedures, Right-of-Way (ROW).

The Federal Energy Regulatory Commission (FERC) is the lead federal agency responsible for regulating the siting and construction of interstate natural gas transmission projects in the U.S. FERC requires such projects to be constructed in accordance with the conditions set forth in the Order Issuing Certificate for any given project.

This examination will highlight the construction activities generally allowed to occur outside of approved work areas during construction, commonly referred to in the industry as "gray areas"." Such individual activities are generally permitted and defined by the FERC's Upland Erosion Control, Revegetation, and Maintenance Plan (Plan) and Wetland and Waterbody Construction and Mitigation Procedures (Procedures). FERC staff will be invited to validate the allowance of such activities, which often include—but are not limited to—siting of dewatering structures, out-letting of erosion/sediment control devices, off-right-of-way (ROW) retrieval and clean-up, implementation of mitigation measures for environmentally sensitive areas located off-ROW, and the use of pipe and contractor staging yards.

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INTRODUCTION

In the U.S., natural gas pipelines that transport gas in interstate commerce are regulated by the Federal Energy Regulatory Commission (FERC). As taken from its website, "The Federal Energy Regulatory Commission, or FERC, is an independent agency that regulates the interstate transmission of electricity, natural gas, and oil. FERC also reviews proposals to build liquefied natural gas (LNG) terminals and interstate natural gas pipelines, as well as licensing hydropower projects." Concerning interstate natural gas projects, the FERC "approves the siting and abandonment of interstate natural gas pipelines and storage facilities" and "oversees environmental matters related to natural gas and hydroelectricity projects and other matters" (*https://ferc.gov/about/ferc-does.asp*). A project is ultimately approved/authorized by the FERC's Order Issuing Certificate (Order or Certificate). This authorization includes conditions requiring a project's sponsor to follow the construction procedures and mitigation measures described in their applications and supplements, FERC staff's Environmental Assessment (EA) or Environmental Impact Statement, and special conditions within the Order itself.

To assist project sponsors in minimizing erosion, limiting the extent and duration of project-related disturbance on wetlands and waterbodies, and enhancing revegetation efforts, FERC has developed guidance documents known as the Upland Erosion Control, Revegetation, and Maintenance Plan (Plan) and Wetland and Waterbody Construction and Mitigation Procedures (Procedures), commonly referred to as the "FERC Plan and Procedures." The most recent versions of the Plan and Procedures were released in May 2013, and they provide the baseline environmental mitigation measures for project sponsors to follow in the absence of more stringent conditions and regulations imposed by FERC and other federal, state, or local agencies.

While the Plan and Procedures provide a concise and straightforward source of information for achieving compliance with the conditions of the Certificate, there are gray areas regarding how the measures outlined in the Plan and Procedures are implemented in situations that require temporary, or even permanent, activities/impacts outside of the Certificated right-of-way (ROW) or other approved project work areas. Such situations are not uncommon and can create challenges and unnecessary stress, usually at the most inconvenient of times, especially when gray areas are interpreted inconsistently from one project to the next.

This paper intends to highlight some of these gray areas and make interpreting them more black-and-white. This paper can serve as a guide for navigating the ambiguous portions of the Plan and Procedures, from the survey phase of a project through construction, post-construction monitoring, and line operation. These clarifications and guidance may also make a useful framework for updating future versions of the Plan and Procedures. The topics in the paper are generally ordered similarly to the Plan and Procedures to reflect the typical construction sequence of a project (i.e., survey, preconstruction, construction, post-construction monitoring). To provide visual context for this discussion, please refer to the attachment no. 1 for a visual characterization of the limits and layout of a typical construction ROW.

Guidance is provided based on the author's experience as a third-party compliance manager and rightfully may be interpreted as biased opinion. However, it is anticipated that the information presented herein will be found as both relatable and beneficial.

APPROVED AREAS OF DISTURBANCE

Section IV.A. of the FERC Plan, Approved Areas of Disturbance, states the following:

> Project-related ground disturbance shall be limited to the construction ROW, extra workspace areas, pipe storage yards, borrow and disposal areas, access roads, and other areas approved in the FERC's Orders. Any project-related ground disturbing activities outside these areas will require prior Director approval. This requirement does not apply to activities needed to comply with the Plan and Procedures (i.e., slope breakers, energy-dissipating devices, dewatering structures, drain tile system repairs) or minor field realignments and workspace shifts per landowner needs and requirements that do not affect other landowners or sensitive environmental resource areas. All construction or restoration activities outside of authorized areas are subject to all applicable survey and permit requirements, and landowner easement agreements.

At first glance, the information conveyed in this paragraph seems straightforward and is generally read as confining work only to authorized sites, getting permission in advance for changes to construction plans, and knowing certain activities can be performed outside of Certificated work areas with landowner permission and where environmentally sensitive resources will not be impacted. However, a closer look reveals that some useful details are missing and there is a disconnect between how a change is requested and how the information required to make that change is obtained and made available. For example, the second sentence of section IV.A.1. states, "Any project-related ground disturbing activities outside these areas will require prior Director approval." But what about activities that are not "ground-disturbing"? It also does not address the fact that the survey activities required to verify no additional resource impacts are the same that are causing ground disturbance and, potentially, impacts to sensitive resources. Since surveys are typically first in the construction sequence, they seem a logical place to start in evaluating gray areas of the Plan and Procedures.

SURVEY

Many surveys are required to verify the presence or absence of various resources on a proposed route. The most common include cultural and historic architectural resources, threatened and endangered (T&E) flora and fauna, geologic features and soils, wetlands and waterbodies, and paleontological resources. Many of these surveys cause ground disturbance by nature of how they are performed. For example, equipment used to perform certain geotechnical investigations must penetrate the ground to collect data and could cause rutting and/or mixing of soils while equipment and supporting vehicles travel to and from the site. Although not always causing ground disturbance, there may be additional impacts from clearing woody and herbaceous vegetation to access a survey location. Rutting is generally the most common, but there can also be potential impacts from hydro-vacuuming (hydro-vac) as part of daylighting utilities, soil morphology investigations, and the trampling of various surface resources from foot and vehicle traffic.

What then do the Plan and Procedures say regarding conducting surveys without impacting resources? Unfortunately, nothing. Since much of the survey work is conducted before the application is even filed with the FERC for Certificating a project, any survey mitigation for a resource would be dictated by its respective federal, state, or local agency. To be honest, though, some agencies do not always work well together or coordinate their activities. It is worth noting that many FERC staff consider ground-disturbing activities to include clearing of vegetation and, therefore, staff interpretation may vary between projects.

It seems logical that the order in which surveys occur should be dictated by using a top-down approach. For example, step one in performing a survey is getting to the area/site, so it would make sense that the first survey(s) to occur should be those evaluating resources that could be damaged or result in an impact on the surface (i.e. flora/fauna and the spread of invasives), as well as the pathway itself to access the survey site, which is often overlooked. Next would be to confirm the absence of cultural resources that could be damaged by equipment performing geo-technical investigations or a hydro-vac truck daylighting a utility.

The underlying thought has always been that FERC does not get involved until the project is under its review, which happens after surveys have been initiated, and so surveying is not a FERC action; however, one could argue that there would be no survey work occurring if not for the proposed project. While not entirely FERC's problem, as there are many other agencies involved, I believe that as the lead federal agency, all stakeholders and parties involved would be better served by adding a few brief and simple guidelines to the next version of the Plan and Procedures that outline a logical process for surveys.

Ground-disturbing impacts during surveys also raises the question of what defines sensitive resources in general. For example, the Plan alludes to topsoil being considered a resource when segregating it from subsoil (topsoiling), controlling loss through erosion, or when preventing mixing with subsoil or compaction (discussed in section II.B. on responsibilities of the environmental inspector), but it never directly identifies it as a resource, leaving it vulnerable to impact during survey (e.g., rutting and hydro-vacs). The same holds true for impacts to woody and herbaceous vegetation, including species living in/on them, that may need to be cleared for access and establishment of sightlines from off-ROW survey markers (work performed by the civil-survey crew), especially if the ground-disturbing work happens prior to any required flora and fauna surveys.

POST-CERTIFICATE, PRECONSTRUCTION

After FERC issues a Certificate for a project, but before a Notice to Proceed (NTP) is issued to commence actual construction activities on the ROW, the project is in a phase known simply as "preconstruction." This period is a large gray area since no actual "construction" on the ROW is allowed, meaning the ROW is not yet an approved area to work in. However, a significant amount of preparation for construction is occurring, including ground-disturbing activities. It is during this time that civil-survey is out staking the limits of the ROW and environmental inspectors (EIs) are installing limited signage such as "No Project Access" signs. Daylighting of existing-utility crossings by hydro-vac truck and remaining geotechnical work are often completed during this time as well. Pre-treatment of the ROW for noxious/invasive weeds before construction may also occur, which, although not always a ground-disturbing activity, can still be an activity of significant impact nonetheless.

Some of this work, especially ground-disturbing activities, are authorized by way of a limited NTP, but it is widely understood within the industry that limited Level 3 variances can be requested/approved in advance of an NTP being issued.

To briefly summarize, the FERC has a process for reviewing and approving changes during a project known as the "variance" program. Depending on the reason for requesting a variance or change, the nature of its impacts, how it affects landowners, and whether the project sponsor elected to participate in a third-party environmental compliance monitoring program (ECMP), an appropriate level of variance is assigned to determine the level of review needed to approve the change. The variance process uses a system of three levels to classify what information is required and who can approve it. The levels range from 1 (easiest to review and quickest to approve) to 3 (most scrutinized and time-consuming review). Per past experiences on FERC-jurisdictional projects, if no NTP has yet been authorized for the area where the change is requested, or the sponsor has not elected to participate in the ECMP, then only a Level 3 variance can be implemented prior to NTP authorization.

CONSTRUCTION

For the most part, off-ROW approved measures are well described in section IV.A. of the Plan. However, not all activities that are typically conducted during construction and the potential scenarios that develop during implementation of those activities are accounted for in the Plan and Procedures. The first significant activity to occur during the mainline construction phase is clearing. Clearing includes felling of trees and other woody vegetation, mowing of grasses or crops, and the removal of those materials from the ROW. However, tree clearing is only mentioned in passing in a section about residential construction, mowing is only discussed in association with post-construction maintenance of the permanent ROW, and clearing is only alluded to in a section describing the responsibilities of the Environmental Inspectors (EIs). Even though clearing is the first and most obvious activity for an off-ROW noncompliance to occur, and despite that it often causes ground disturbance, the Plan and the Procedures are basically silent on what is or is not acceptable when conducting this activity.

Another common question about clearing is what to do about woody vegetation and grasses that start growing or regrow (sometimes taller/thicker) outside of the permitted time of year for clearing, even though they were initially cleared within the allowed window for such activity. Additionally, what are the appropriate steps to remove a "danger" tree that could fall onto the ROW and injure or kill personnel, or remove a damaged tree from off-ROW?

Jumping back in the order of activities for a bit, spraying/removal of noxious and invasive plants often needs to occur prior to mainline construction for reasons of safety and effectiveness of the treatment. That said, it has been my experience that an NTP is required.

As discussed in section II.B. of the Plan, Responsibilities of Environmental Inspectors, the EIs are required to inspect perimeter erosion control devices (ECDs) of the ROW to verify no off-ROW discharges occurred during rain or snowmelt events, or as part of normal construction activities. If/when an off-ROW discharge does occur, the EI needs to verify how far off-ROW the material travelled but are prohibited from leaving the ROW since they do not have the same permissions that a surveyor would. The same issue is raised for spills and "frac-out" inspections during HDD operations. The reality is that EIs and other project personnel must sometimes go off-ROW to inspect impacts, so this is a significant gray area that must be addressed. This could potentially be solved by granting inspection staff limited "survey rights" for select incidents, which may mean simply having the ROW department or land agent discussing the need in advance with the landowner.

As discussed earlier, section IV.A. of the Plan, Approved Areas of Disturbance, states that the requirement to obtain prior Director approval:

> Does not apply to activities needed to comply with the Plan and Procedures (i.e., slope breakers, energy-dissipating devices, dewatering structures, drain tile system repairs) or minor field realignments and workspace shifts per landowner needs and requirements that do not affect other landowners or sensitive environmental resource areas. All construction or restoration activities outside of authorized areas are subject to all applicable survey and permit requirements, and landowner easement agreements."

The examples listed make sense and are justifiable (see Figure 1 – Approved Off-ROW Measures for visual context).

I would Include H-braces for fences, installation of protective measures for off-ROW ESAs, and grazing deferment (like-use only). For the containment, retrieval, and repair of abutting off-ROW sediment discharges, slips, spills, frac-outs, or trees that were cut on-ROW but fell off-ROW, it has been my experience that a variance is needed for off-ROW clean-up or containment, depending on how far off the material is and if there are any resource impacts.

Concerning snow removal, it has been my experience that sometimes no variance is needed for blowing or pushing snow off-ROW (being mindful of where it is blown or pushed) and other times it is needed. Regarding off-ROW ESA protection, ECD installation for construction can only be conducted post-NTP. While it is obvious that landowner permission would be required, it is less obvious how the permissions required to obtain access are acquired and how the information is distributed to those performing the work at off-ROW locations (e.g., karst or other ESA features). Alignments sheets do not typically show or define access to these areas. One should also keep in mind that landowners can say no to energy-dissipaters, slope breakers, dewatering structures, etc. proposed for placement off-ROW, as well as off-ROW access in general.

Section VI. of the Plan, Off-Road Vehicle Control, states that owners or managers of forested lands should be offered the option of installation and maintenance measures to control unauthorized vehicle access to the ROW. It would be beneficial to have the same offer extended to owners or managers of desert lands, tallgrass prairies, and even some unsaturated wetlands. While such mitigation can be implemented elsewhere on the ROW at the landowner's request, they may not know they can request it.

There are also questions with regards to section I.B., Definitions, of the Procedures. Item 1. of that section defines a waterbody as follows:

> "Waterbody" includes any natural or artificial stream, river, or drainage with perceptible flow at the time of crossing, and other permanent waterbodies such as ponds and lakes:
>
> a) "minor waterbody" includes all waterbodies less than or equal to 10 feet wide at the water's edge at the time of crossing;
>
> b) "intermediate waterbody" includes all waterbodies greater than 10 feet wide but less than or equal to 100 feet wide at the water's edge at the time of crossing; and
>
> c) "major waterbody" includes all waterbodies greater than 100 feet wide at the water's edge at the time of crossing.

This raises the questions of which construction activities are included in the definition of "…at the time of crossing" and how to proceed if the level of water (with respect to the water's edge) is below the ordinary high-water mark (OHWM) at the time of crossing? Keep in mind though that there are almost certainly other federal, state, local agencies with jurisdiction and the most stringent conditions or measures from any of the agencies is what applies.

Other gray areas in the Procedures include FERC regulation of public bridges requiring improvement or modification for construction and whether a variance is required, and whether pipeline construction vehicles are permitted to use ford crossings on public roads. Ford crossings on public roadways are likely not in-kind use considering the significant amount of traffic associated with a long-duration construction project. If clearing equipment and equipment necessary for installation of equipment bridges are allowed to ford the crossing once prior to bridge installation, then what about intermediate and major waterbodies (and their riparian areas) with sensitive resources? Concerning wetland boundaries, what is required of projects when conditions at the time of a wetland crossing extend that wetland well beyond the originally surveyed boundaries?

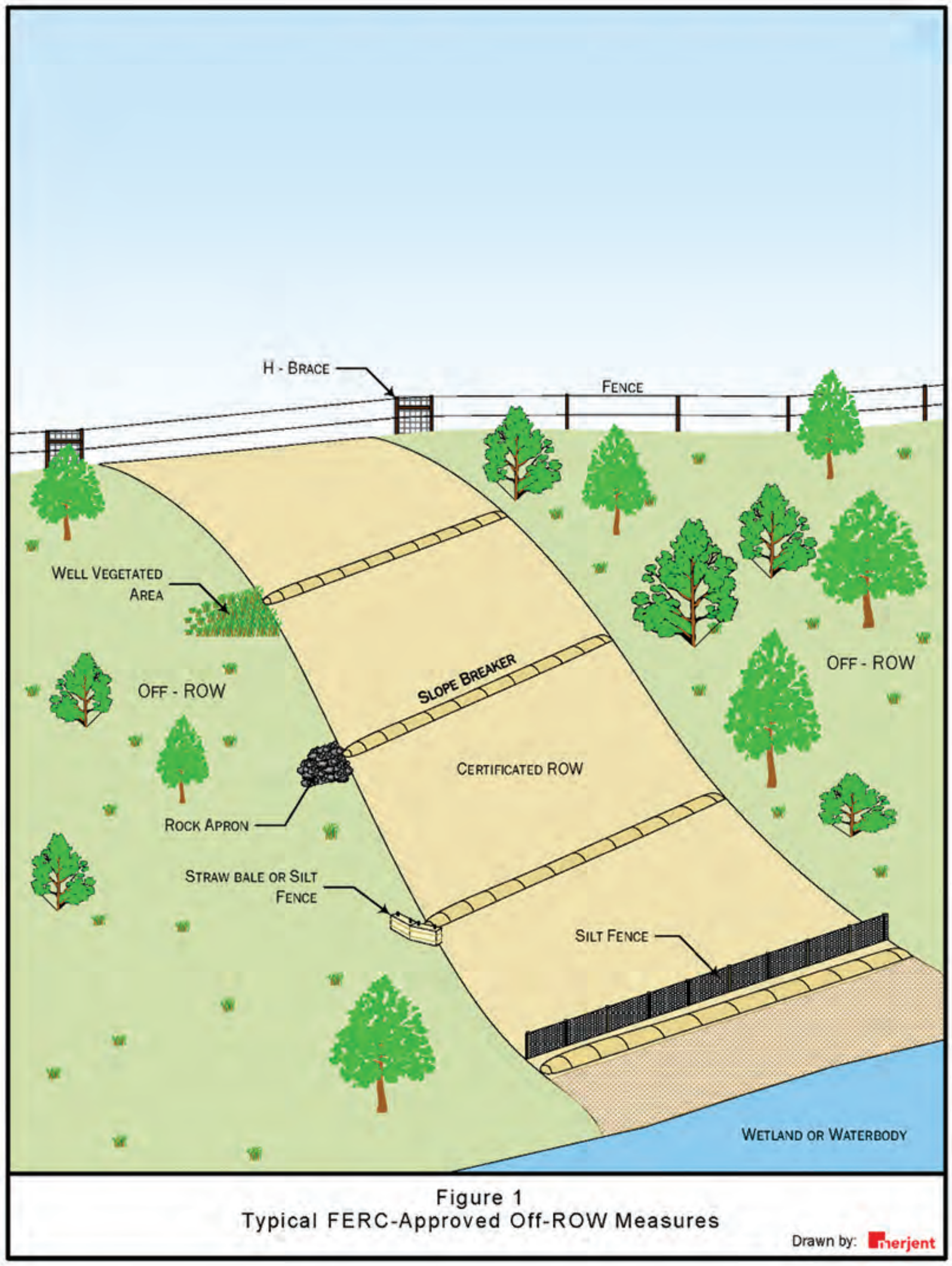

Figure 1. Typical FERC-Approved Off-ROW Measures

Where adjacent upland consists of cultivated or rotated cropland or other disturbed land, can an extra work area (ATWS) with no proposed fuel, hazardous, or spoil storage be sited abutting a wetland? Procedures section VI.B.1.a. states "Locate all extra work areas (such as staging areas and additional spoil storage areas) at least 50 feet away from wetland boundaries, except where the adjacent upland consists of cultivated or rotated cropland or other disturbed land." My own interpretation is that if spoils aren't stored in the extra workspace, then it is consdiered okay for that space to abut the wetland when the "…adjacent upland consists of cultivated or rotated cropland or other disturbed land."

POST-CONSTRUCTION

Post-construction monitoring of revegetation and overall conditions of the ROW is interesting in that despite coming into play after construction, compliance with its measures outlined in the Plan and Procedures is completely dependent upon decisions made during preconstruction planning and survey. Post-construction activities requiring off-ROW access include—but are not limited to—compaction/yield testing in cropland, drain-tile inspection/repair, parking, ROW access, erosional control (sediment discharge), revegetation monitoring and overall restoration success, drainage and irrigation systems monitoring, and monitoring waterbody banks and wetlands for sloughing, subsidence, and revegetation success. It is recommended that these areas be surveyed in advance to make it easier and more efficient to perform work in the future. Section III.A.2. of the Plan states that "project sponsors are encouraged to consider expanding any required cultural resources and endangered species surveys in anticipation of the need for activities outside of authorized work areas." Yet it remains unclear, from personal experience, how or if these activities are made known in advance to the landowner or adjacent property owners, and how such information is made available to those conducting the monitoring.

YARDS, DISPOSAL, AND OTHER RULES

No paper regarding gray areas in the Plan and Procedures should be without a discussion of pipe yards. From personal experience, there have been projects completed where all pipe yards were surveyed and permitted, no pipe yards were surveyed or permitted, and where some pipe yards were permitted while others were not. If there was no project, there would be no need for pipe or a yard to store it. The argument has always been that the pipe is not the property of the project sponsor until it is delivered to the ROW; therefore, the pipe yard is not part of the project, but rather property owned by one of its vendors. This could be true in rare cases. For example, it could be true when a landowner or business knows there will be several years of projects in an area requiring pipe storage, so they acquire permits, develop the parcel, and lease out the space. Typically, little investigation into ownership status occurs; and additional details in section III.A.1 of the Plan would be beneficial to ensure the pipe yards are fully compliant going forward.

This same concept holds true for mat storage yards, ancillary contractor/other yards, and borrow and disposal areas. Typically, the need for these yards is not determined until after the project has been certificated and the contractor has mobilized, so they are obtained through the variance process. This approach almost always creates unnecessary stress though, as not enough time is budgeted to conduct surveys and then wait for permits/concurrences and final FERC approval. Depending on how the job is bid, some contractors seem to struggle with estimating how much slash and rock must be disposed. Also, many sponsors and their contractors—and sometimes even their consultants—are stuck in the old habit of disposing excess mud from a horizontal direction drill (HDD) and/or the mud from the inadvertent release (frac-out) of an HDD, regardless of existing conditions, wherever someone will accept it. Mud containing additives may need to be disposed of at a licensed facility that can accept any potentially hazardous additive(s) that may be present. Mud should never be "thin-spread" on vegetated areas; however, thin-spreading material without additives in off-ROW gravel pits or even on cultivated agricultural lands is generally acceptable with landowner approval, but could vary by state.

Attention to these types of yards upfront during application preparation and National Environmental Policy Act (NEPA) review for these projects would provide considerable benefit to construction compliance staff once the project begins. It is worth noting that there have been various approaches to this pipe and mat yard dilemma on FERC-jurisdictional and non-FERC projects alike.

For a counterexample, contractor staging yards are often incorrectly scrutinized by pipeline opposition due to an incorrect assumption that they are project related. Contractor yards are private lands scattered around the U.S. in which contractors can stage and/or park their equipment in between projects to avoid having to haul the equipment back to their headquarters. These long-term equipment parking lots could be considered environmentally friendly based on reduced fuel consumption and associated air emissions. However, they are worth a windshield inspection from time to time to ensure they do not become storage locations for consumable project materials and testing welders.

Other issues to consider include whether portable toilets should be treated like materials that would require siting set-backs and secondary containment (I believe they should), and what is the definition of "bulk" in terms of fuel storage. Section V.B.5.a. of the Procedures states, "Only clearing equipment and equipment necessary for installation of equipment bridges may cross waterbodies prior to bridge installation. Limit the number of such crossings of each waterbody to one per piece of clearing equipment". Does this mean survey equipment and equipment used during post-construction activities are not allowed to cross without a bridge?

LANDOWNERS, CONDEMNATION, AND NON-LANDOWNERS

If we again take a close look at section IV.A.2 of the Plan, Approved Areas of Disturbance, particularly this sentence, "All construction or restoration activities outside of authorized areas are subject to all applicable survey and permit requirements, and landowner easement agreements." What if the property is part of a condemnation tract acquired using eminent domain? What if the adjacent off-ROW property is a non-landowner and so there is no easement? As pipelines are often routed along property edges or at the request of landowners to protect property value, trench dewatering or off-ROW flows of stormwater during or after construction, for example, may be out-letting off a temporary or permanent slope breaker to a landowner who is not officially crossed by the project ROW or other Certificated workspace. While it makes sense that no landowner approval is required for water to flow off-ROW, provided that no off-ROW erosion/sedimentation/flooding is occurring (no impact), it would also make sense that landowner approval be obtained, in writing, for installation/presence of off-ROW sediment controls. Off-ROW access and/or installation of sediment controls should be prohibited when the landowner denies permission, or the tract was acquired through condemnation. Additionally, if a new landowner would be affected, level 3 variance approval would be required.

The Plan and Procedures do not provide guidance for how landowners and non-landowners are to be notified of all the potential off-ROW activities that could occur on their property during and after construction, or if they should be notified of agreements for adjacent properties. The pamphlet provided to all landowners crossed by a project and abutting landowners not crossed directly only references the Plan and Procedures as additional information at the end of the pamphlet, making it unclear if crossed and abutting landowners are aware of the potential for off-ROW activity at all. The "line list," a document created by and for the project sponsor's land department to document information by parcel related to the easement agreement between the company and the landowner, is not required or controlled by the FERC. This is unfortunate because it is the opportune place to capture all the information needed to meet the landowner's requirements from survey through construction and into operation of the pipeline. When an applicant notifies landowners of a project, there is no template or standard for the information provided, including the system for landowners to make requests concerning their properties. For example, are they made aware that slope breaker outlets, energy dissipaters, trench dewatering, etc. are activities/structures that occur off-ROW, sometimes permanently? How are landowners made aware that construction debris (e.g., rocks, timber) can be left on their property for their use? It is also unclear how much of this information should be conveyed to a third-party compliance monitor who may not have access to the line list.

Another gray area occurs when permanent slope breakers are permitted to extend across the construction ROW, but the permanent easement is typically only 15 meters (m) (50 feet [ft]) wide. Can a landowner deny alteration to lands outside the permanent easement?

CONCLUSIONS

It is important to reiterate that the Plan and Procedures provides a quality, concise, and easy-to-understand source of information for achieving compliance with the conditions of the Certificate. This information is crucial to successful implementation of the FERC's environmental mitigation measures. The Plan and Procedures are essentially a set of best management practices (BMPs) and are, therefore, not fully prescriptive. The questions and criticisms in this paper are intended to be constructive and encourage FERC to consider updating the next version of the Plan and Procedures, future training sessions, and other conferences such as the International ROW Symposium. A few amendments to the Plan and Procedures may provide a good opportunity for reducing gray areas on projects.

The following is a list of suggested clarifications to gray areas in the Plan and Procedures and how these measures may be implemented:

- Provide a definition for the ROW boundaries, including the extent of off-ROW limits
- Add brief sections on the basic dos and don'ts for survey and clearing
- Grant inspectors and monitors surveyors' rights
- Require advanced planning for post-construction/restoration activities during permitting and preconstruction surveys, including off-ROW access for monitoring
- Standardize a minimum list of criteria given to affected and adjacent landowners that addresses access and concurrence with other activities likely to occur throughout survey, construction restoration, monitoring, and operation of the pipeline
- Compile landowner information into a modified version of the applicant's line list to keep it centralized and accessible. The line list could also be made an official document (privileged and confidential) that would be useful to compliance monitors
- Incorporate several feet of undisturbed ROW buffer into the design of the ROW, which would assist with ROW compaction testing, allow "blending" disturbed ROW with undisturbed ROW to help eliminate the "fault-line effect," create a stormwater run-off buffer, and provide a safe travel path for inspection during

construction. Additional footage should be included on the downslope side of the ROW, where possible, to site stormwater run-off discharge outlets, which would dissipate the energy of any potentially sediment-laden water before leaving the ROW.

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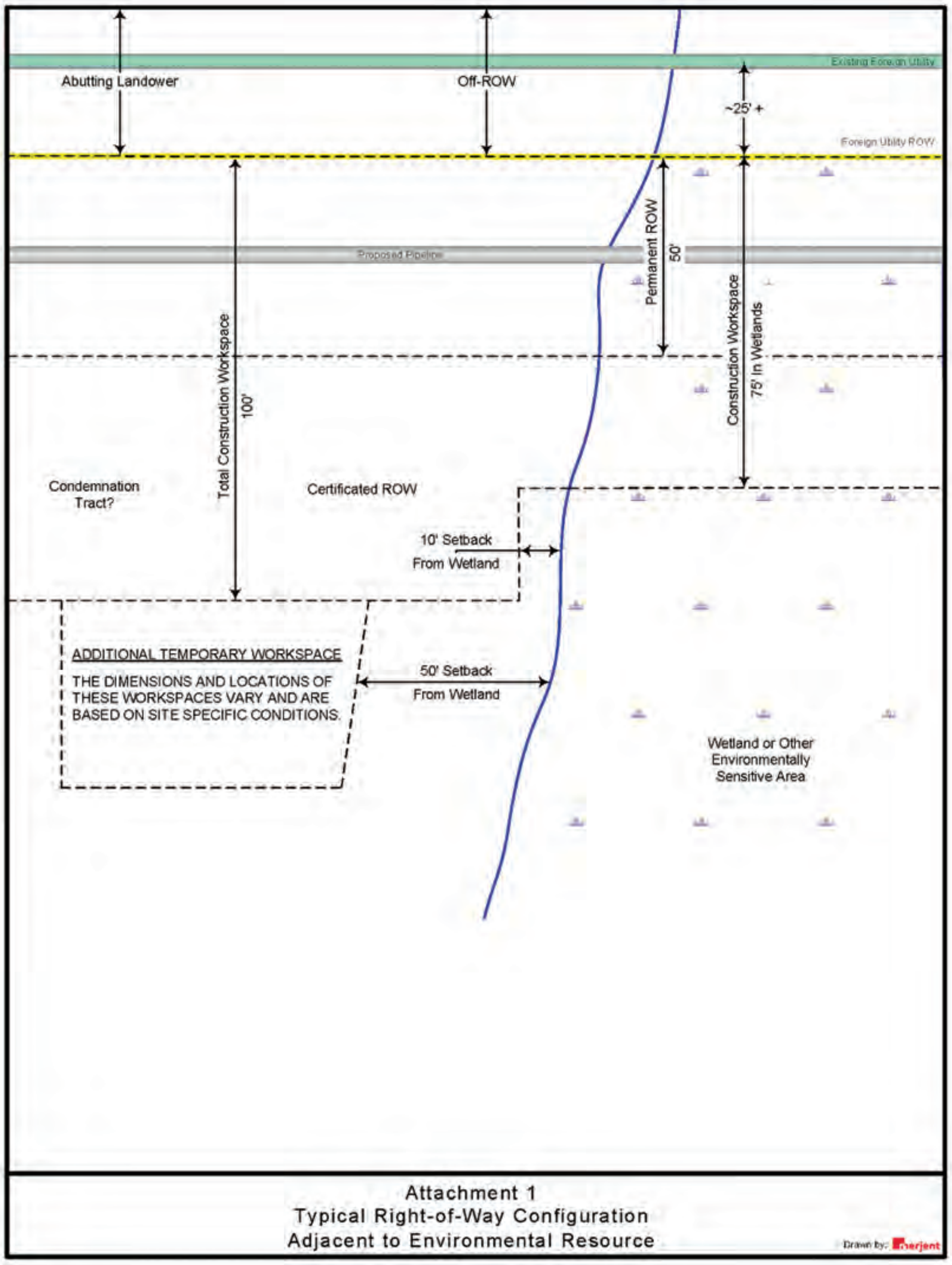
AUTHOR PROFILE

Anthony (Tony) Dalbec

Anthony (Tony) Dalbec earned a Bachelor of Science Degree in Natural Resources and Environmental Studies with an emphasis in Resource Assessment and a Minor in Forest Resources from the University of Minnesota—College of Natural Resources in 1999. Dalbec has more than 18 years of experience in the energy industry (pipeline and electric transmission), specializing in environmental feasibility and constructability analysis, management of environmental surveys, permit implementation, environmental inspection and third-party compliance monitoring, and post-construction restoration of pipeline and utility ROWs.



Attachment 1. Typical ROW Configuration Adjacent to Environmental Resources

Dalbec is a Senior Environmental Construction-Compliance Manager with Merjent, Inc., in Minneapolis, Minnesota, USA.

How Environmental Factors Affected the Design, Use of Helicopter Construction, and VM of a Transmission Line Rebuild Project

Leslie Knapp

Environmental constraints and land ownership affect not only transmission line routing, permittability, design, and construction on new projects—they also affect rebuilding transmission lines within existing rights-of-way (ROW). This case study describes how rebuilding 4.8 kilometers (km) of Dairyland Power Cooperative's Q 1 161-kilovolt (kV) transmission line in Wisconsin across the Black River floodplain and wetland complex, U.S. Fish and Wildlife Service (USFWS) Refuge land, and Department of Natural Resources (DNR) wildlife area affected this rebuild project. Located within the Mississippi River Flyway, the project area contains threatened and endangered (T&E) species habitat for Eastern massasauga rattlesnake (*Sistrurus catenatus catenatus*) and wood turtle (Clemmys insculpta), as well as habitat for other sensitive species. Numerous wetlands and waterways in the area presented permitting and construction access obstacles. Federal funding requested for the project triggered a National Environmental Policy Act (NEPA) review. This paper presents the design ramifications, construction timing and methods, and post-construction vegetation management (VM) requirements that resulted, including the use of heavy-lift helicopter for construction.

Keywords: Black River Floodplain, Construction Cost and Timing Benefits, Design Ramifications, Eastern Massasauga Rattlesnake, Migratory Bird Treaty Act, U.S. Fish And Wildlife Refuge, Wisconsin Department Of Natural Resources Wildlife Management Area.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Although it is widely recognized that environmental constraints and land ownership affect transmission line routing, permittability, design, and construction on new projects, these factors also affect rebuilding transmission lines within existing rights-of-way (ROWs). This case study addresses approximately 4.8 kilometers (km) of Dairyland Cooperative's (Dairyland's) Q 1 161-kilovolt (kV) transmission line 20.8-km rebuild project (herein referred to as the Project) that crossed the ecologically sensitive Black River floodplain. This included 1.4 km that crossed the U.S. Fish and Wildlife (USFWS) Upper Mississippi Wildlife and Fish Refuge (Refuge) and a little less than 0.5 km of the Wisconsin Department of Resources (WDNR) Van Loon Wildlife Management Area (WMA).

Dairyland is a not-for-profit generation and transmission cooperative headquartered in La Crosse, Wisconsin that provides wholesale electrical power to its 24 member utilities and 17 municipal utilities in the Upper Midwest, serving approximately 600,000 people. Electricity is delivered via nearly 5,150 km (3,200 miles [mi]) of transmission lines and 300 substations located throughout the system's 71,616 square km (44,500 square miles) service area in Wisconsin, Minnesota, Iowa, and Illinois. Dairyland's generation resources include coal, natural gas, hydroelectric, solar, landfill gas, and animal waste to energy. Dairyland is obligated to ensure reliable electricity service to its cooperative members and their customers to maintain compliance with North American Electric Reliability Corporation's (NERC) transmission planning standards.

Dairyland needed to replace approximately 20.8 km of an aging 161-kV transmission line in Trempealeau and La Crosse counties, Wisconsin, that was constructed in 1950s and was reaching the end of it useful life (Exhibit 1).

The Project was originally

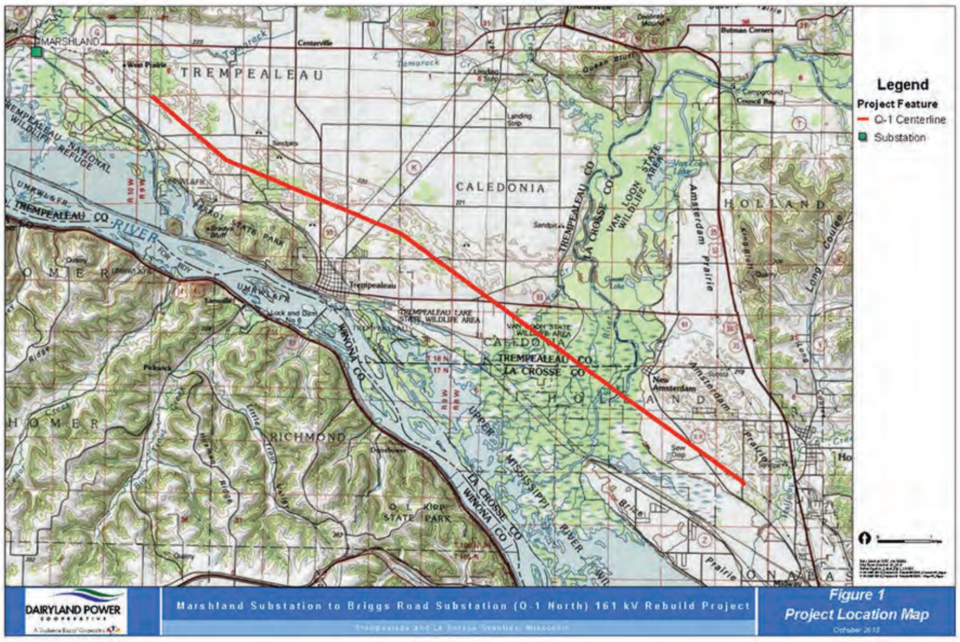


Exhibit 1. Project Location

Exhibit 2. Photographs of the Q-1 Transmission Line Construction in the 1950s

constructed with H-frame structures using butt-treated western red cedar poles. Exhibit 2 presents photographs of the original construction in the 1950s that demonstrate how difficult the line was to build initially, and how construction methods have changed.

The line had developed reliability issues due to its age and deterioration of the poles (Exhibits 3 and 4). Another contributing factor was that the line was originally constructed as a 138-kV line, but when upgraded to 161 kV, the original insulators had not been replaced and were undersized. As a result, there was a tendency for arcing to occur and cause pole-top fires. Access to structures in the Black River floodplain is very difficult and the need to conduct repairs and reinforce structures was becoming more frequent. In addition to electricity, the transmission structures also carry a fiber optic line from Minneapolis to Chicago, which presents the potential for outages to that service. Rebuilding the Project on its existing alignment was determined to be the only practicable alternative based on an extensive alternatives analysis.

The Project area contains threatened and endangered (T&E) species habitat for Eastern massasauga rattlesnake (EMR, *Sistrurus catenatus catenatus*), wood turtle (*Clemmys insculpta*), and habitat for other sensitive species. It is located within the Mississippi River Flyway that is under the requirements of the Bald and Golden Eagle Protection Act (BGEPA, 16 USC § 668, 50 CFR § 22) and the Migratory Bird Treaty Act (MGTA,16 USC § 701-712, 50 CFR § 21). Numerous wetlands and waterways in the area presented permitting and construction obstacles. Dairyland's plan to request federal funding from the U.S. Department of Agriculture (USDA) Rural Utilities Services (RUS) for the Project triggered the National Environmental Policy Act of 1969 (NEPA), the National Historic Preservation Act of 1966, and all applicable federal environmental laws and regulations. This included the preparation of an environmental assessment (EA). This case study presents the design ramifications, construction timing and methods, and post-construction vegetation management (VM) requirements that resulted, including the use of heavy-lift helicopter for construction.

Issues Affecting Design and Construction

Early in the planning process, Dairyland obtained input on the proposed Project through public notices, consultation letters, and agency meetings. For the portion of the Project crossing the Black River floodplain, the USFWS, U.S. Army Corps of Engineers (USACE), and WDNR were the key stakeholders. The USFWS and USACE became cooperating agencies in the federal EA due to actions these agencies would need to take if the Project were to be rebuilt, as described below. The Project was evaluated in two RUS NEPA processes. The Q-1 transmission line corridor had already been evaluated as an alternative route for a new 345-kV transmission line in an RUS Environmental Impact Statement (EIS) prepared for the CapX2020 Transmission Line Project, with the USFWS and USACE as cooperating agencies. The Q-1 corridor was not selected for the new 345-kV route, but the EIS determined that rebuilding the Q-1 161 kV transmission line route on its existing alignment was the best alternative for this Project.

Black River Floodplain

The Black River floodplain is characterized by wetland, riverine, and riparian habitats that support a variety of aquatic life, birds, and wildlife. The USFWS has identified the Black River Bottoms as a "Classification A" resource, which means that as a habitat for fish or wildlife, it is unique or irreplaceable on a national basis or within the ecoregion (USFWS, 2006a). In addition to "known or very probable federal endangered species habitat" and "essential habitat for state-endangered species," the USFWS considers lands that are essential production habitat or concentration areas for the wood duck (*Aix sponsa*), mallard (*Anas platyrhynchos*), ring-necked duck (*Aythya collaris*), canvasback (*Aythya valisineria*), tundra swan (*Cygnus columbianus*), osprey (*Pandion haliaetus*), peregrine falcon (*Falco peregrinus*), and bald eagle (*Haliaeetus leucocephalus*) as Resource Classification A. The area provides habitat for the state-endangered (federal candidate) EMR, the state protected Blanding's turtle, and the state-threatened wood turtle and other protected species.

Exhibit 3. Pole Deterioration

Exhibit 4. Structure Repairs

USFWS Refuge

The Refuge was established by an Act of Congress on June 7, 1924 "(a) as a refuge and breeding place for migratory birds included in the convention between the U.S. and Great Britain for the protection of migratory birds, concluded August 16, 1916, and (b) to such extent as the Secretary of Interior may by regulations prescribe, as a refuge and breeding place for other wild birds, game animals, furbearing animals, and for the conservation of wild flowers and flowering plants, and (c) to such extent as the Secretary of Interior may by regulations prescribe as a refuge and breeding place for fish and other aquatic animal life" (16 U.S.C. 723). The Refuge is approximately 97,124.5 hectares (ha) (240,000 acres) in size and spans 420 km (261 mi) along the Mississippi River in the states of Minnesota, Wisconsin, Iowa, and Illinois. The goals of the Refuge system are to conserve a diversity of animal and plant life and their habitat (including T&E species); maintain and develop a planned and managed network of habitats for migratory birds, certain fish and marine mammals; conserve important ecosystems, wetlands, and plant communities; and provide opportunities to participate in compatible wildlife-dependent recreation (hunting, fishing, wildlife observation, and photography, and environmental education and interpretation) (USFWS 2006b).

The Refuge encompasses one of the largest blocks of floodplain habitat in the lower 48 states. Bordered by steep, wooded bluffs that rise 31 to 183 meters (m) (100 to 600 feet [ft]) above the river valley and the Mississippi River corridor, the Refuge offers scenic beauty and productive fish and wildlife habitat (USFWS 2014). The Refuge is the flagship refuge of the Mississippi Flyway, where an estimated 40 percent of the North American continent's waterfowl and a substantial portion of its other migratory birds travel, rest, feed, and nest each year.

Wisconsin Department of Natural Resources WMA

The Wildlife Management Area (WMA) is a Wisconsin Bird Conservation Initiative, Important Bird Area noted for yellow-crowned night-herons, Acadian flycatchers, cerulean warblers, and prothonotary warblers that breed there (USFWS 2009). The WMA also supports red-headed woodpeckers, blue-winged warblers, and field sparrows. Waterbirds congregate in late summer, and land birds migrate through, particularly in the spring. The WMA is managed to provide opportunities for public hunting, fishing, trapping, and other outdoor recreation while protecting the qualities of the unique native communities and associated species found on the property.

Agency Actions and Input

In order for Dairyland to rebuild the transmission line, the USFWS needed to renew an easement on federally owned land and issue a permit for construction activities within the Refuge. The USFWS also had authority and trust responsibility under the Endangered Species Act (ESA), the Bald and Golden Eagle Protection Act (BGEPA), and the Migratory Bird Treaty Act (MBTA). At the time this Project was going through review, the USFWS had proposed the EMR as a candidate threatened species under the ESA, so ongoing consultation regarding potential EMR impacts and mitigation was conducted. The EMR has since been listed as federally threatened.

The Project required a permit from the USACE as part of Section 10 of the Rivers and Harbors Act for the crossing of the Black River, and a general permit in Section 404 of the Clean Water Act for activities that discharge fill into waters of the U.S., including wetlands.

Because Wisconsin passed its own endangered species law in 1972, the Project also required several actions on part of the WDNR to comply with state-implemented rules and regulations and identified species to be protected. The state law incorporates the Endangered Species Preservation Act of 1966 and the Endangered Species Conservation Act of 1969. Wisconsin State Statute § 29.604 and Wisconsin Administrative Code NR 27 establish, define, and guide Wisconsin's T&E species laws. In order to rebuild the Project, Dairyland would apply for an Incidental Take Permit (ITP) and prepare a Habitat Conservation Plan (HCP) for the state-endangered EMR and state-threatened wood turtle, and a general utility permit for wetland and waterway impacts. The WDNR would also need to issue a Wisconsin Pollutant Discharge Elimination System Permit and a Construction Stormwater Permit, and provide access to the existing easement within the WMA for construction.

Dairyland conducted ongoing coordination with these agencies. The agencies' concerns that affected the Project design, construction, and post-construction VM were the following:

- Renewal of the USFWS easement through the Refuge and related transmission line construction and maintenance issues.
- Impacts to the WMA.
- Potential for bird collisions with the transmission line due to its location in the Mississippi River Flyway, where an estimated 40 percent of the North American continent's waterfowl and a substantial portion of its other migratory birds travel, rest, feed, and nest each year.
- Impacts to the state-endangered EMR (at the time federal candidate, now federally listed), state-threatened wood turtle, and state-protected Blanding's turtle.
- Impacts to State special concern and MBTA and BGEPA bald eagle, state-endangered and MBTA loggerhead shrike (*Lanius ludovicianus*), state-threatened and MBTA red-shouldered hawk (*Buteo lineatus*), State special concern and MBTA black-crowned night heron (*Nycticorax nycticorax*), and prothonotary warbler (*Protonotaria citrea*).
- Impacts of 16 wetlands and 13 streams that would be crossed for construction access—17 in the Refuge and four in the WMA.
- Impacts to freshwater mussels in the waterways that would be crossed for construction access.

- Potential for tree clearing, if required, to impact big brown bat (*Eptesicus fuscus*) and Northern long-eared bat (*Myotis septentrionalis*) habitat.
- Potential for forested wetland clearing.
- Spread of invasive species—reed canary grass (*Phalaris arundinacea*) and common buckthorn (*Rhamnus*).

Dairyland also consulted with the Wisconsin State Historic Preservation Office (SHPO) and Tribes. Mississippi Valley Archaeological Center (MVAC) was retained by Dairyland to conduct a Phase I Archaeological Survey to identify resources eligible for listing on the National Register of Historic Places (NRHP) within the Project area. MVAC obtained a Wisconsin Public Land Field Archaeology Permit from the Office of the State Archaeologist, a Special Use Permit from USFWS to work in the Refuge, and a permit to work within the boundary of an uncatalogued burial site from the Wisconsin SHPO. A prehistoric mound group was previously recorded in the area. An archaeological survey did not identify any surface evidence of the mounds under the line. The location of the single pole that would be installed within the site was staked at the time of the survey, so a shovel test was performed. No evidence of human remains or mound fill was discovered by shovel testing, essentially mitigating the pole location. Some likely mounds were in the vicinity, but would not be impacted by the Project. In response to Prairie Island Indian Community's concerns and as part of Dairyland's responsibilities under Wis. Stat. § 157.70, an archaeologist was present to monitor any ground-disturbing activities near recorded burial sites during construction. If human bone or cultural resources had been discovered during construction, work would have been immediately suspended and Dairyland would have contacted RUS and the State Historical Society of Wisconsin, Burial Sites Preservation Office; however, no human bone or cultural material were found.

RESULTS & DISCUSSION

Design Ramifications

As part of Project design, Dairyland worked with the agencies and considered alternative transmission structure types for the Project. Dairyland selected Y-frame steel structures for the 4.8-km crossing of the Black River floodplain (Table 1) to:

- Limit new transmission line height to an average of 19.8 m (65 ft) in order to keep them at or below the average tree height, and install bird diverters as requested by the USFWS and WDNR, to reduce the potential for bird strikes
- Decrease the width of the ROWs to 19.8 m (65 ft) and allow for the unneeded portion of the ROWs to revert to native vegetation
- Reduce the number of structures needed in the Black River floodplain from 22 H-frame structures (44 poles) to 21 single Y-frame structures
- Reduce the number of poles on USFWS and WDNR land from 11 H-frame structures (22 poles) to eight single Y-frame structures

Construction Timing

Several factors that affected construction timing are discussed below, and Table 2 provides a 12-month schedule with required conservation actions and avoidance periods.

Bald Eagles

Bald eagles were known to nest near the Project; however, this is based on records from 1992 and 2001. An aerial survey for eagle nests was conducted on January 15, 2014, and no nests were observed. Dairyland resurveyed the Project area in April prior to construction. Had any new nests been observed, protection under BGEPA would have required USFWS consultation; however, no nests were found. Dairyland's construction fell outside of the avoidance period of February 15 through July 1. Also, there were no nests present within 201 m (660 ft).

Other Birds

Suitable habitat for state-endangered and MBTA loggerhead shrike was present in a small upland area adjacent to the Black River floodplain that was crossed by the Project. The avoidance period for loggerhead shrike is April 16

Structure Type	ROW Width	Average Structure Height	Number of Structures in Black River Floodplain	Number of Structures on USFWS- & WIDNR-Owned Land	Number of Poles in Black River Floodplain	Average Distance Between Structures
Existing Wood H-Frame	24.4m (80 ft)	16.8m (55 ft)	22	11	44	211.8m (695 ft)
New Steel Y-Frame	19.8m (65 ft)	19.8m (65 ft)	21	8	21	222.5m (730 ft)

Table 1. Comparison of Existing and Proposed Structures

Required Conservation Actions	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Avoidance Period	Notes
Bald Eagle Federally protected (BGEPA and MBTA); State special concern													Feb. 15 through July 1	—
Northern Long-eared Bat State threatened; Federal threatened													Early Apr. through Mid-Nov.	No tree cutting during avoidance period
Big Brown Bat State threatened													June 1 through Aug. 15	No tree cutting during avoidance period
Eastern Massasauga State endangered; Federal candidate													Mar. 15 through Oct. 31	ITP and HCP
Wood turtle State threatened													Mar. 15 through Oct. 31	ITP and HCP
Loggerhead Shrike, Bells Vireo, Red-shouldered hawk													Mar. 15 through Sept. 1	Avoid work in identified bird areas
Aquatic Species Spawning Period													Late Mar. through Aug. 31	Avoid work in Black River Floodplain
Mussel Species Four State endangered, including one Federal endangered, three State threatened													Mar. 1 through Oct. 31	Mussel survey and relocation at crossing from construction

Key: Red border Construction period (October).
Dates when WDNR requires that activities must be avoided.
Dates when WDNR requires that activities must be avoided unless identified mitigation measures are followed.
Overlap of planned construction period and avoidance period.

Table 2. Construction Avoidance Periods

Exhibit 5. Removing Existing H-Frame Structure

Exhibit 6. Transporting Steel Caisson and Equipment to Structure Locations

through August 15. Dairyland avoided working near that area during the avoidance period. Dairyland's construction within the Black River floodplain occurred outside of the March 15 through September 1 avoidance period for the remaining birds of concern.

Aquatic species

Dairyland implemented strict erosion and siltation controls during the entire construction period to avoid impacts to fish in the Black River and any neighboring water bodies and wetlands. Work in the Black River floodplain avoided the spawning period (late March through August 31). Other portions of the Project did not impact suitable habitat.

Construction in the Black River floodplain overlapped the avoidance period (March 1 through October 31) for mussels. The use of helicopter construction, an Argo-amphibious, all-terrain vehicle to transport personnel, and strict erosion control and runoff prevention measures reduced direct and indirect impacts to mussels. The Argo has a ground pressure rating of 1.5 pounds per square inch to minimize soil disturbance and compaction. As required by the WDNR and USFWS, Dairyland had a mussel expert conduct summer surveys and relocations of mussels from locations where the Argo would be used to transport crew members across waterways.

Bats

Since much of the ROW was cropland in the uplands and the existing ROWs had been maintained on a regular basis, limited to no tree clearing was anticipated. Dairyland was required to avoid directly impacting individuals, locations of maternity colonies, roosts, and areas of suitable habitat, and avoid clearing snags or dying trees from early April through mid-November, as well as to avoid impacts to the state-threatened big brown bat and state-threatened (at the time federal-candidate, now federally endangered) Northern long-eared bat.

Construction Methods

Dairyland also used specialized construction methods to minimize environmental impacts. The selected methods eliminated the need for concrete, avoided the need for dewatering, did not generate waste soil material, and did not require placing gravel or other fill for construction access. These methods are as follows:

1. The existing wooden H-frame transmission structures were cut at ground level and removed by helicopter (Exhibit 5). A heavy-lift helicopter then transported the steel caisson and associated construction equipment to the

structure location (Exhibit 6). Prior to erection, these structures were stored in a nearby staging area before being flown to the site. The heavy-lift helicopter then removed all equipment once installation was complete.

2. The helicopter then used a vibratory hammer (Exhibit 7) to vibrate the caisson to the required foundation depth at each structure location.
3. Once the caisson was installed, the heavy-lift helicopter transported the tubular Y-frame steel structure to the construction site, and the structure section was attached to the caisson foundation (Exhibit 8).
4. Wire stringing within the Black River floodplain used a helicopter to pull the wire. The final construction operation was to "clip in" and fasten the conductors to the insulators. Once the wire had been clipped in, the construction operation was essentially complete, and post-construction activities would follow.
5. Existing access routes within the Black River floodplain area were between 1.8 and 3.7 m (six and 12 ft) wide and would not require grading or vegetation clearing. Construction access for construction personnel within the Black River floodplain used access routes that have been used by Dairyland's maintenance crews since the early 1950s. Personnel would access the structure locations on foot, via an Argo, or by helicopter. Exhibit 9 shows the Argo used for this Project, and Exhibit 10 shows the helicopter used to fly construction personnel to the structure locations.
6. Areas within the Refuge and WMA disturbed by construction would be managed as described in the IVM Plan developed for the Project.

Exhibit 7. Placing Vibratory Hammer to Drive Steel Caisson

Construction Cost and Timing Benefits

Helicopter construction had cost and timing benefits. Conventional construction would have required:

- Access for heavy equipment across waterways and the wetland complex
- Four hectares (9.4 acres) or eight km (4.8 miles) of temporary matting
- Weeks to months to complete
- Would have resulted in greater environmental impacts, triggering more stringent permitting, and mitigation requirements.

Helicopter construction was costly, but only took five days to complete.

Post-Construction VM and Mitigation

Dairyland worked with the USFWS and WDNR to develop an IVM Plan. Also, the USFWS required mitigation in the form of clearing forested wetlands to improve habitat for EMR outside of their ROWs.

The goals of the IVM Plan include:

- Managing vegetation along Dairyland's transmission ROWs to meet FERC/NERC requirements

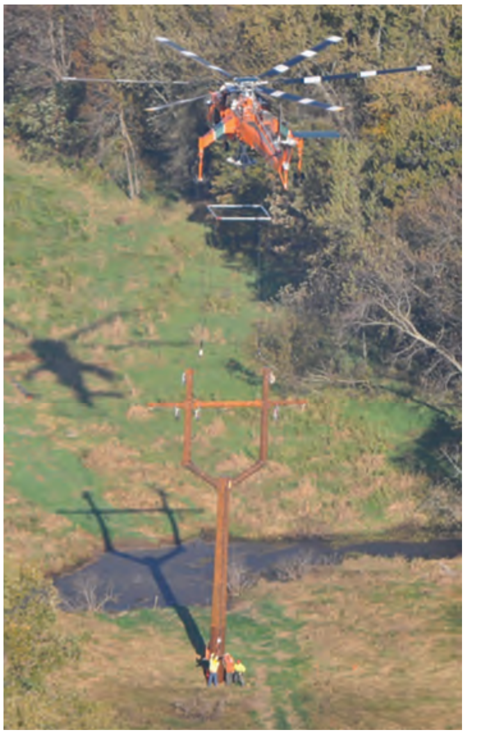


Exhibit 8. Attaching Steel Y-Frame Structure to Caisson

Exhibit 9. Using Argo Amphibious All-terrain Vehicle to Transport Personnel

Exhibit 10. Using Small Helicopter to Fly Construction Personnel to Structure Locations

- Working cooperatively with USFWS and WDNR staff to maximize the habitat goals of the Refuge and WMA
- Working cooperatively with USFWS and WDNR staff on special projects that benefit the stewardship of Refuge and WMA
- Meeting the land management conditions of the permit and easement agreements
- Promoting the use of IVM and best management practices (BMPs) to ensure proper VM, promotion of native plants, and the protection of the environment
- Maintaining a close communication between Dairyland VM, USFWS, and WDNR staff, and working cooperatively to expedite permitting of VM activities.

The IVM Plan includes the following key components:

- Promoting the conservation and encouraging the dominance of native shrubs, forbs, grasses, and trees. Dairyland will avoid the removal of these types of vegetation if they do not pose a threat to their service and safety goals.
    - o The "Wire Zone" is the area on electric utility ROWs directly beneath and between the energized conductors farthest out on the structure. This is the area where vegetation could potentially grow into contact with energized conductors and is typically used for access to the structures and conductors for repair, inspection, and maintenance. In the Wire Zone, maintaining low-growing, primarily herbaceous cover allows access to utility infrastructure for inspection, repair, and maintenance, and for inspection of vegetation on and off the ROW. In addition, the Wire Zone is often ideal for wildlife species that prefer a meadow-life habitat.
    - o The "Border Zone" is the area on the ROWs that are outside of the Wire Zone and extend to the outer edge of the established ROWs. In the Border Zones, incompatible vegetation is selectively controlled, and compatible vegetation that will not grow to maturity above a specified height (3.7 m [12 ft] for this Project) is conserved. The compatible vegetation is permitted between the transmission lines and the edge of the ROWs. By retaining a greater variety of vegetation types, wildlife habitat is improved, and the visual impact to the ROWs is softened. The USFWS and WDNR requested that shrub species be allowed to remain, reestablish themselves, and/or be planted within the Border Zone. In addition, the former 24.4-m (80-ft) wide ROW was reduced to 19.8 m (65 ft), providing an additional 4.6 m (15 ft) that would be allowed to revert to native vegetation.
    - o On a case-by-case basis, mowing ROW access lanes with a brush hog will be permitted to allow adequate clearance under conductors in the Wire Zone, as well as work crews' access through areas of dense vegetation. The mowing lane location will be pre-approved by the Refuge staff in coordination with Dairyland.
- Hazard trees are those located outside of the ROWs that are structurally defective and would cause an outage of the transmission circuit if they fell toward the conductors. Hazard trees are also trees with branches or trunk growing into the ROWs and approaching FERC-approved clearance standards. When hazard trees are identified, Dairyland will discuss them on an individual basis with Refuge staff to reach an acceptable resolution.
- Specified BMPs must be used to minimize the introduction of noxious weeds and invasive species (NWIS) on land surfaces disturbed by construction activities.
- Planting or seeding non-agricultural areas disturbed by transmission line work will use local, native seed mixes as indicated in the seed mix tables included in the IVM plan.
- Every effort will be made to conduct management activities during the dormant season (November to March) to avoid the breeding season (April 15 through August 15). Any disturbance in any endangered species or sensitive habitat area should be limited to outside of the breeding season of September to December, and disturbance should be as minimal as possible.
- Dairyland will notify the Refuge staff of intent to use herbicides and provide a list of intended herbicides 60 days in advance of application to allow time for all approvals.
- Debris from brush cutting or tree-top removal will not be left in large piles, but mulched in place or distributed so as not to cause an accumulation of thatch and produce a fire hazard or interfere with plant germination. Use of heavy equipment and vehicles will not be permitted on the transmission line ROWs during wet and/or muddy conditions, except when emergency access is required to repair overhead lines or towers.

CONCLUSIONS

Dairyland worked closely with the agencies to identify environmental constraints and how federal and state land ownership would affect the routing, permittability, design, and construction of this rebuild Project. This paper presented the design ramifications, construction timing and methods, and post-construction VM requirements that resulted, including the use of heavy-lift helicopter for construction. The Project was constructed October 12-16, 2015. Exhibit 11 shows a portion of the constructed transmission line. A video clip of the helicopter construction is available at: *https://www.youtube.com/watch?v=eW-pH_Zznd0.*

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AUTHOR PROFILE

Leslie Knapp

Leslie Knapp has a Bachelor of Arts degree in General Science and Biology and Master of Arts in Earth Science and Geology from the University of Northern Iowa. Knapp is a consultant with Tetra Tech specializing in the environmental review and permitting of complex projects. She has more than 37 years of project experience related to NEPA and state-level environmental review and permitting, assisting clients in the development of effective permitting strategies, and innovative mitigation measures. She has helped clients develop solutions to complex problems and has provided effective support in negotiations with regulatory agencies. Knapp has extensive experience in leading defensible siting and routing processes throughout the Midwest, resulting in projects that have been successfully permitted and constructed.

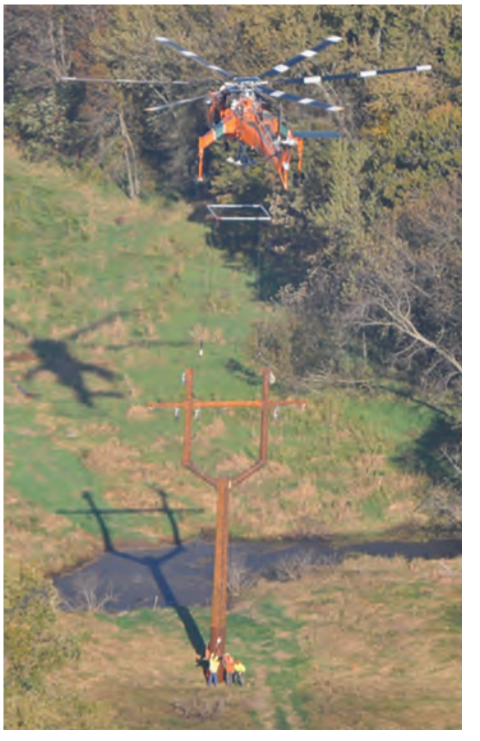

Exhibit 11. Constructed Transmission Line

Managing and Meeting Stakeholder Expectations in an Unpredictable Climate

Rachel E. Newton and
Mike Bonar

Keywords: Restoration, Stakeholder Engagement, Success Criteria, Vegetation Monitoring.

Stakeholder input and expectations are captured through the National Environment Policy Act (NEPA) and permitting processes and contribute to project mitigation requirements. Performance criteria for vegetation restoration are often developed using previously observed seasonal and climate scenarios and restoration successes. While historical accomplishments can provide a framework for developing criteria, the instability in precipitation and temperature can lead to extended monitoring periods and low levels of satisfaction among stakeholders. This paper presents a case study from the Ruby Pipeline, a 1,080-kilometer (km) (670-mile [mi]) natural gas pipeline traversing seven Bureau of Land Management (BLM) districts and two national forests in four states. Drought conditions in the years immediately following initial restoration efforts delayed vegetative growth, resulting in frustrated stakeholders and an extended monitoring period beyond the five years mandated by the Federal Energy Regulatory Commission (FERC). Continued monitoring to capture revegetation data has shown little progress in the right-of-way (ROW) condition, which has necessitated discussions with agency stakeholders about adjusting restoration practices and success criteria expectations. We effectively engaged agency stakeholders through in-person meetings along the Ruby ROW and presented supporting data to facilitate finding mutually agreeable solutions for all parties, including applying revised seed mixes and focusing on the quality of restoration activities rather than quantity. Restoration expectations now reflect on-the-ground conditions at micro- and macro-geographic levels. Targeted treatments have been put into place and the monitoring effort has been reduced by approximately 36 percent in the span of one year. Additional stakeholder meetings are expected to further reduce the monitoring effort through mutual agreement based on refined, site-specific success criteria and revegetation methods that reflect actual ROW conditions.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

The Ruby Pipeline (Ruby) is a 1,080-kilometer (km) (670-mile [mi]) long natural gas pipeline that crosses seven Bureau of Land Management (BLM) districts, two U.S. Forest Service (USFS) national forests, and multiple private land holdings as it traverses four states (Figure 1). The right-of-way (ROW) averages 35 meters (m) (115 feet [ft]) in width, for a total area of approximately 3,780 hectares (ha) (9,340 acres). Ruby was constructed in seven different spreads between July 31, 2010 and July 28, 2011. As stated in the Restoration and Revegetation Plans for the Ruby Pipeline Project (Ruby 2010), and in accordance with Federal Energy Regulatory Commission (FERC) guidelines, ROW reclamation started within 20 days following pipeline trench closure and final clean-up.

Short-term reclamation goals centered on soil stabilization and noxious and invasive weed control, while long-term goals focused on the establishment of a permanent vegetative cover with similar species densities and compositions as adjacent undisturbed lands, in accordance with 18 Code of Federal Regulations (CFR) 380.15. Vegetation restoration methods included seeding and planting of container-grown seedlings. Approximately 60 seed mixes were developed to accommodate the range of variability in elevation, soils, average annual precipitation, and terrain across the ROW.

The Long-Term Monitoring Plan (Plan) was developed to track the success of reseeding and transplanting as well as identify areas in need of supplemental restoration efforts (Walsh et al. 2012). General restoration goals consist of soil surface stability and the establishment of a desirable perennial plant community. Each agency developed specific performance criteria: Wyoming, Utah, and Oregon's seed mix performance criteria are relative percentages of the adjacent undisturbed areas (Figure 2), while Nevada's criteria are absolute, based on experience with previous revegetation efforts (Figure 3). Using a stratified randomization process, at least three permanent monitoring sites were established as representative for each seed mix type in each spread, resulting in 115 seed mix monitoring sites. Monitoring was stipulated to occur annually for five years after the completion of restoration efforts, and will continue until FERC and the supervisory agencies agree restoration goals have been met for specific stretches of the ROW.

At the time of construction completion (2011), none of the ROW was in drought condition (National Drought Mitigation Center 2018). From 2012 to 2015, conditions ranged from

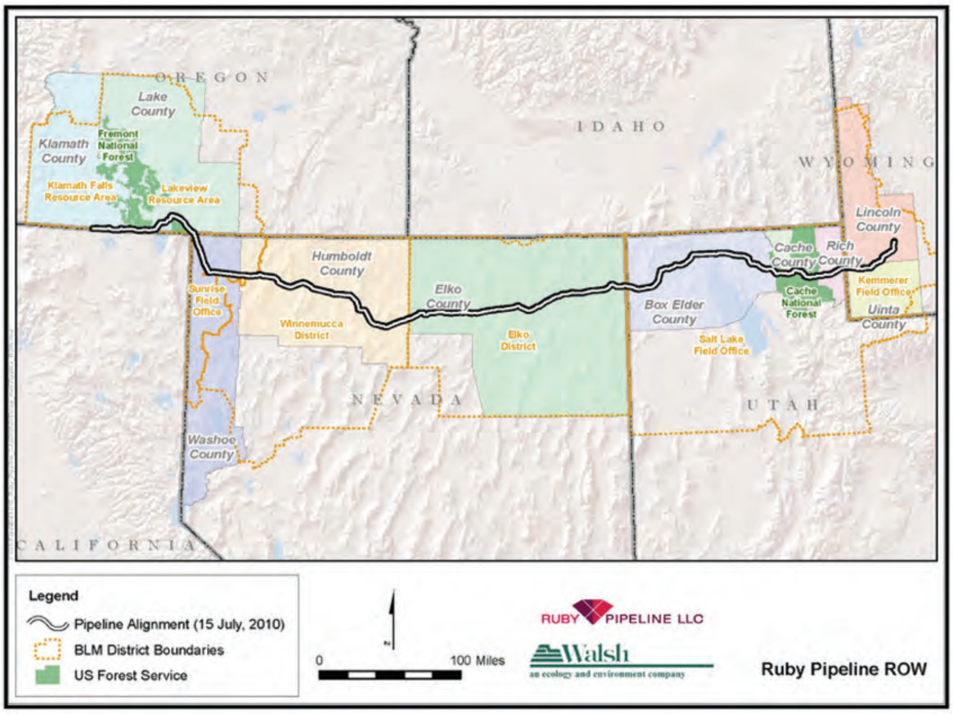

Figure 1. Ruby Pipeline ROW

Table 6.1-1 Wyoming, Utah, and Oregon Performance Criteria for Upland Revegetation

Federal Lands	Performance Criteria				
	Seeded		Seedling Transplant Survival (%)	Noxious Weed Relative Cover (%)	Soil Aggregate Stability Class
	Herbaceous (%)	Shrubs (%)			
KFO	Herbaceous and shrub canopy (foliar) plant cover ≥ 80 of control plot and presence of ≥ 4 desirable species	Herbaceous and shrub canopy (foliar) plant cover ≥ 80 of control plot	≥ 50	≤ 26	≥ 2
SLFO	Canopy (foliar) plant cover ≥ 80 of control plot and presence of ≥ 4 desirable plant species	Canopy (foliar) plant cover ≥ 60 of control plot and the presence of >1 species	≥ 50	≤ 26	≥ 2

Figure 2. Example of Wyoming, Utah, and Oregon BLM Performance Criteria

abnormally dry to extreme drought across the ROW, with the predominant conditions being moderate and extreme drought. This coincidence of prohibitive growing conditions during the critical initial establishment period set the tone for less-than-ideal progress along the ROW. At the close of the fifth year of monitoring (2016), vegetation establishment along the ROW had made good progress, but fell short of meeting the performance criteria stipulated in the Plan. An abnormally wet winter during 2016–2017 contributed to the growth and expansion of desirable species, but noxious and invasive species also benefitted from the increased moisture, leading to no net-gain toward meeting specified goals.

Table 6.1-2 Nevada Reclaimed Desired Plant Community Criteria Minimums for the *In Situ* ROW Vegetation and Soil

Seed Mix	Minimum Percent Basal and Crown Cover	Minimum Percent Canopy Cover	Minimum Plants per Meter	Minimum Plant Life Forms	Minimum Desirable Plant Species	Maximum Percent Annual Plant Foliar Cover	Minimum Aggregate Stability Class[1]
EDO/WDO Shadscale	10	15	3	2	4	15	>2
EDO/WDO Low precipitation Wyoming big sagebrush	15	20	5	2	4	15	>2
EDO/WDO High precipitation Wyoming big sagebrush	20	25	7	3	6	10	>3

Figure 3. Example of Nevada BLM Performance Criteria

This paper will detail our successful negotiation efforts during the sixth and seventh years of monitoring that incorporated vegetation monitoring data and on-the-ground discussions with agency stakeholders to reassess performance criteria in light of unpredictable weather patterns, determine targeted supplemental restoration efforts, and reduce monitoring efforts across the Ruby ROW.

METHODS

Use of Seed Mix Site Monitoring Data:

Data from paired monitoring and control plots were scrutinized to determine what (if any) trends were discernible, and what these trends meant for long-term restoration goals. Each seed mix site was assigned a color based on a combination of factors: the number of criteria it had met in the fifth year, its progression towards meeting these criteria since monitoring began (e.g., generally increasing vs. remaining constant), and the number of criteria the control plot had met during this time. Green sites were meeting the success criteria, or were similar to or outperforming the control plots, but not necessarily meeting the stated success criteria. Yellow sites were meeting the majority of the success criteria, and red sites were not meeting most criteria. Themes noticeable among control plots included noxious and invasive weed cover in the control plot similar to or greater than the monitoring plot, the inability of the control plot to meet the soil stability criterion, the inability of the control plot to meet basal cover criteria (Nevada), and the inability of the control plot to meet species diversity criteria. A technical memorandum with the color-coded list of each seed mix site, its representative ROW spread, notes regarding the performance criteria were sent to each agency, and the methodology used to develop the color coding was sent to each agency.

On-The-Ground Meetings

Following the submittal of the technical memoranda, each agency was contacted to set up a field meeting to discuss the results. These meetings followed a general format: a presentation of our assessment of each seed mix site (and its presentative spread) towards meeting the performance criteria, a discussion of how the site looked relative to the surrounding area, and a determination of what, if any, additional restoration methods were required so the particular site could meet a mutually acceptable state. These on-the-ground discussions were key because each stakeholder saw the same conditions, and was able to gauge ROW restoration against the adjacent areas. It was not uncommon for the monitoring plots in the ROW to be in better condition than the control plots, or for agency stakeholders to concede that, given the condition of the adjacent area, the monitoring sites looked as good as could be expected. Further, seeing successful species from seed mixes or those moving in from adjacent areas helped in the formulation of custom seed mixes for smaller stretches of the ROW.

RESULTS

As of August 2018, 23 of the initial 115 seed mix sites representing 210 miles of the Ruby ROW have been removed from monitoring. An additional 18 sites representing 136 miles will be removed after this fall's monitoring. This is a 36 percent reduction in the number of seed mix monitoring sites, and a 52 percent reduction in the number of ROW miles.

Four miles of ROW were seeded in Fall 2017 with a custom seed mix developed during our field visit, based on successful native species expanding from the adjacent area into the ROW. Focusing on the unique conditions of these 6.4 km (4 mi), as opposed to the general characteristics of the larger 80.5-km (50-mi) swath, helped us develop a boutique seed mix with varieties and cultivars better acclimated to the area.

CONCLUSIONS

Performance criteria for restoration efforts are developed with good intentions, based on the best available science, previous experience, and/or industry standards. These criteria often portray the best-case scenario, with ideal growing conditions and typical weather patterns. Our experience with restoration monitoring along the Ruby Pipeline tells us that some criteria are within reach of the restored areas, while others are unattainable. While there are a variety of reasons for this, the influence of drought on restoration progress cannot be ignored. Analyzing years of monitoring data to discern trends and identify shortcomings, then presenting these data to stakeholders *in situ*, has proven successful in reducing monitoring effort, tailoring additional restoration needs, and realizing the little victories in a drought-stricken region.

ACKNOWLEDGEMENTS

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AUTHOR PROFILES

Rachel E. Newton

Rachel Newton holds a Master's degree in botany and is currently one of the lead botanists with Jacobs. She has more than 12 years of experience in botanical studies, including rare plant and noxious and invasive weed surveys; vegetation monitoring design and implementation; habitat mapping; environmental assessment (EA) documentation; and wetland delineation. She has worked in upland and wetland plant communities in a variety of Western ecosystems, including the Great Plains, the Rocky Mountains, the Great Basin, the Cascades, and the Mojave Desert. Newton's comprehensive background in vegetation ecology, plant taxonomy, and vegetation monitoring ensures efficient data collection, dependable results, and thorough, data-driven analysis.

Mike Bonar

Mike Bonar is a Senior Permitting Compliance Specialist in the Kinder Morgan Colorado Springs office. In his 10 years with Kinder Morgan, he has worked on numerous FERC-regulated projects in the western U.S. Currently, he manages the Ruby and the Sierrita Post-Construction, Long-Term Monitoring Programs, as well as permitting of FERC 7c and Prior Notice projects. Prior to his time at Kinder Morgan, Bonar worked as both a consultant and in local government, where his experience includes threatened and endangered (T&E) species issues and development of an umbrella wetland bank and a conservation easement program. When he is not working, he enjoys spending time with his family, photography, hiking, and fly fishing.

Managing Permitting Commitments with the Realities of Construction

Gregory S. Liberman and Christopher DeRoberts

Keywords: Compliance, Construction, Impact Avoidance, Regulations.

During the environmental review and permitting phase of most electric transmission line repair or rebuild projects, there are often numerous regulations to comply with at the local, state, and federal level. Prior to issuance of a permit, most regulations require a project to demonstrate that sensitive resources (e.g., streams, wetlands, sensitive habitat) are avoided and/or impacts are minimized to the maximum extent practicable. To that end, numerous commitments are often made during the permitting phase, and typically become conditions of the subsequently issued permit(s). Examples of such commitments include strict adherence to the conditions within approved plans, using timber mats to cross sensitive resources such as streams or wetlands, installing buried electrical lines through use of directional bore methodologies, and hand-clearing in wetlands. However, it is not always possible to account for the complexities and unforeseen circumstances that occur during project construction. This presentation will provide a comparison of permit commitments to construction realities, given from the perspective of professionals experienced in both complex permitting and regulatory compliance during construction. In addition, this presentation will identify lessons learned from recent examples of project construction.

Environmental Concerns in Rights-of-Way Management
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INTRODUCTION

During the environmental review and permitting phase of most electric transmission line repair or rebuild projects, there are often numerous regulations to comply with at the local, state, and federal level. Prior to issuance of a permit, most regulations require a project to demonstrate that sensitive resources (e.g., streams, wetlands, sensitive habitat) are avoided or impacts are minimized to the maximum extent practicable. To that end, numerous commitments are often made during the permitting phase, and these typically become conditions of the subsequently issued permit(s). However, it is not always possible to account for the complexities and unforeseen circumstances that occur during project construction. With an understanding of typical construction realities, project owners and developers can plan accordingly during the permitting phase to avoid potential conflicts.

METHODS

The authors completed a qualitative assessment of construction projects located within the Hudson River Valley area of New York State from 2012 through 2018. Specifically, 56 kilometers (km) (35 miles [mi]) of electric transmission line rebuilds and replacements within Central Hudson Gas & Electric's service territory were evaluated to identify common themes in construction, which were often directly affected by permitting commitments and/or conditions. These lines were chosen to identify times where there were delays in the construction schedule, where permits needed to be modified and the lessons learned during that process. This review considered projects in various topographic areas (e.g., ridgeline, rolling hills, and flat agricultural areas). Additionally, the projects assessed were permitted under various state and local permitting thresholds, including Part 102 and Article VII of the New York State Public Service Law, various state environmental regulations, and local municipal review.

Figure 1. Matting: installation of construction matting over stream resources can be an effective way to minimize impacts

DISCUSSION

We found numerous commitments for each project made during the permitting phase of a project, which typically become conditions of the subsequently issued permit(s) including:

- Installation of matting at stream or wetland crossing
- Removal and/or restoration of construction access roads or lay down areas
- Strict adherence to the approved plans (Article VII projects)
- Use of only pre-approved landowner access agreements

Matting: Installation of construction matting over stream resources can be an effective way to minimize impacts. Matting can also be used to protect a variety of other resources areas (e.g., wetlands, agricultural land). However, construction costs associated with matting installation are often high.

While committing to matting can avoid or minimize impacts, thereby expediting the permitting process, project owners and developers should consider the following when planning a project:

- Early coordination with construction crews to establish a sequence for re-use can minimize mobilization and rental costs.
- Utilization of the right type of matting for each individual application. For instance, when used for lighter duty applications (i.e., protecting a landowner's mowed lawn) a thinner matting could be used, thus reducing mobilization and installation costs. Conversely, thicker matting may be needed for softer soils and wetland areas in order to keep equipment out of the resource.
- Planning for seasonal crossings (i.e., winter crossing on frozen soils) can reduce the need for matting at certain locations.

Removal and/or Restoration of Construction Access: A typical commitment, or more often a requirement, of state permitting regulations calls for newly constructed access roads to be temporary and are to be restored to pre-existing conditions and original profile. However, the benefit of improved access along certain hard to access rights-of-way (ROW) can be valuable. While the changes in grade associated with these new access roads, if left in place, can be accommodated for post construction, the new area of impervious surface may require post-construction storm water controls.

Project owners and developers can consider the existing condition of access roads in order to minimize conflicts with restoration requirements. For instance, a detailed evaluation of the following existing road conditions can guide the planning for long-term viability of access roads:

- Existing Temporary Access: No existing access route or it is so poorly maintained that dense vegetation has obscured it. Any permanent changes such as grading and/or stone application should be permitted.
- Existing Hard-Packed Dirt Roadway: (i.e., impervious) can receive minor grading and stone top dressing with the assumption that it is to be completed and left in place as improved access for future maintenance of existing facilities without the need for additional permitting.
- Existing Gravel Access: Maintain as needed, keeping within the confines of original design geometry. No additional permitting is needed.

Strict Adherence to the Plans: Contractor conformance to permit conditions is required; therefore, strict adherence to the project plans is critical. However, there will undoubtedly be times when field conditions vary from what was planned for and/or approved. As such, providing for some level of flexibility within the project plans and/or permit conditions can be beneficial. Therefore, project owners and developers should work to establish a balance in the project design and permitting to allow for flexibility. For instance, if the approved work areas are too discreet and/or inadequately sized/located, this can create challenges during construction. However, if the work areas are not adequately defined, substantial coordination between owner and contractors will be required to ensure sensitive resources are not impacted. To avoid these issues, project owners and developers can work with construction teams early in the regulatory process to make sure work areas are sized appropriately. Also, it is important to include clear language in the bidding documents limiting contractor access within the ROW, thus minimizing the amount of restoration required, and giving project owners adequate standing should resources be impacted beyond the scope of the approved plans.

Figure 2.

Landowner Access Agreements: Access to a ROW and infrastructure can be difficult and there can be kilometers of pipeline or transmission line in between access points or road crossings. These segments can contain resources (streams, wetlands, agricultural lands) that may be avoided if additional access agreements can be reached with landowners. Negotiating with landowners can be a lengthy process and agreements may not be finalized prior to permit issuance. A couple of items to consider in the permitting process include:

- Plan for the worst-case scenario and obtain stream and wetland crossing permits in the event that landowner agreements for access roads to avoid crossing resources cannot be reached.
- In agricultural areas, plan for matting and payment for crop loss, but hope for fields with rotational crops (matting may not be needed if they are tilling the following season).

CONCLUSIONS

Numerous commitments are often made during the permitting phase of a project, which typically become conditions to be met during construction. However, it may not always be possible to account for the site complexities and unforeseen circumstance that occur during project construction. Project managers prefer flexibility during construction in order to avoid change orders and delays, which could result from these site complexities or unforeseen conditions. Often times, the permit conditions do not allow for such flexibility. This paper presented various tools that project owners and managers can consider to expedite the permitting process while also ensuring flexibility during construction.

AUTHOR PROFILES

Gregory S. Liberman

Gregory S. Liberman has more than 15 years of experience in environmental impact assessment, permitting, and resource area restoration. Liberman has a Bachelor of Science in Landscape Architecture from the University of Massachusetts Amherst and has taken graduate coursework at the State University of New York College of Environmental Science and Forestry. He is a Senior Project Manager with EDR and in this role has managed the permitting efforts for numerous energy generation and transmission projects across New York State and the northeastern U.S.

Christopher DeRoberts

Christopher DeRoberts has more than 15 years of experience in environmental permitting, compliance, and remediation. DeRoberts has a Bachelor of Science in Environmental Science from the State University of New York at Plattsburgh and a Master of Science in Engineering Management from Clarkson University. He is an Environmental Coordinator with Central Hudson Gas & Electric and, in this role, he is responsible for all aspects of corporate environmental compliance; writing and obtaining federal, state, and local environmental permits needed for both maintenance on and construction of electric and gas transmission lines and facilities; coordinating SEQRA reviews and all associated environmental assessments needed for project; and monitoring construction crews to ensure compliance with permit conditions.

Xcel Energy's Minot 230-kV Transmission Line Project.

How state, local, landowner, and other stakeholder input affected ROW requirements, design, and construction of a 32-km, 230-kV transmission line and substation in North Dakota

Tom Hillstrom, Sean Lawler, and Leslie Knapp

Keywords: Government, Stakeholders, Utility Line.

Utilities must address regulatory requirements and consider input from a wide range of stakeholders in determining where and how to construct facilities. Xcel Energy's Minot Project is an example of how state, local, landowner, and other stakeholder input affected the rights-of-way (ROW) requirements, design, and construction of a 33 kilometer (km) (20.5-mile [mi]), 230-kiloVolt (kV) transmission line and substation in North Dakota. The North Dakota Public Service Commission requires applicants to minimize impacts to resources and obtain the majority of the needed land rights and local permits prior to completion of the state permitting process. Xcel Energy completed a route study, held a public meeting, met with landowners on an ongoing basis, conducted outreach to local governments and agencies, obtained several local permits, and acquired most of the land rights needed for the new transmission line and substation prior to submitting an application for the state permit required to construct the Project. Examples of how regulatory requirements and stakeholder input affected the Project are provided. These examples include constructing the transmission line as a double circuit due to landowner preference and rerouting the line for 6.76 km (4.2 mi) to meet Township ordinance requirements.

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INTRODUCTION

Utilities must address regulatory requirements and consider input from a wide range of stakeholders in determining where and how to construct facilities. Xcel Energy's Minot Project (Project) is an example of how state, local, landowner, and other stakeholder input affected the rights-of-way (ROW) requirements, design, and construction of a 33-kilometer (km) (20.5-mile [mi]), 230-kilovolt (kV) transmission line and substation in North Dakota (Figure 1).

Northern States Power Company, a Minnesota corporation doing business as Xcel Energy, provides service through an integrated generation and transmission system throughout portions of North Dakota, South Dakota, and Minnesota. Xcel Energy is authorized to conduct business in the state of North Dakota as a public utility subject to the jurisdiction and regulation of the North Dakota Public Service Commission (NDPSC) pursuant to Title 49 of the North Dakota Century Code (NDCC). Xcel Energy serves approximately 92,000 retail electric customers in North Dakota in and around the cities of Fargo, Grand Forks, and Minot, and serves 54,000 natural gas customers in the Fargo and Grand Forks areas. Xcel Energy owns a little more than 690 km (430 mi) of electric transmission lines and 20 substations of 69 kV and greater in North Dakota.

The Project was needed to meet the growing demand for electricity in the Minot area and to reinforce the reliability of the region's transmission system. Xcel Energy served its entire load for the City of Minot through the Souris Substation via two 115-kv transmission lines built in the late 1950s and early 1960s. These lines have been reaching capacity and occasionally experienced low voltage conditions when certain elements of the system were out of service. In addition, the McHenry Substation 230/115-kv transformer experienced overloads when certain elements of the system were out of service.

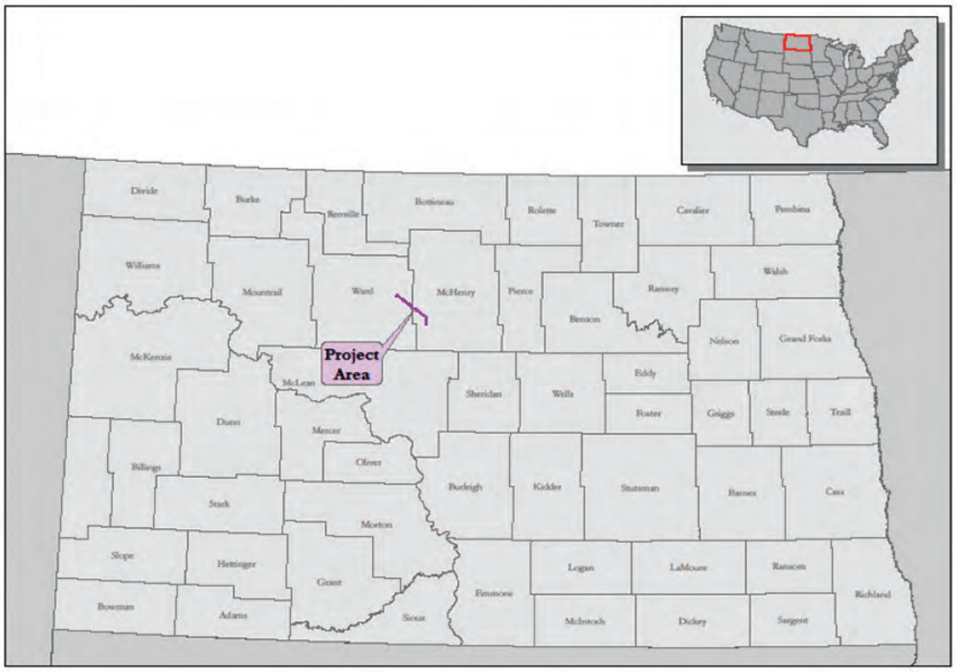

Figure 1. Project Location

To address these low-voltage and overload conditions in the Minot area, Xcel Energy, along with Basin Electric Power Cooperative (Basin), performed a joint electrical study (Minot Study) in 2015 to determine the most effective solution to address near-term voltage issues and long-term capacity issues. Two solutions identified in the Minot Study were 1) a new 230-kV transmission line from the McHenry Substation to a new 230/115-kv substation (eventually called the Magic City Substation), and 2) reconfiguring and upgrading existing infrastructure. As a result of the analysis provided in the Minot Study, Xcel Energy applied for and obtained a Certificate of Public Convenience and Necessity from the NDPSC on January 4, 2017.

Xcel Energy completed a route study, held a public meeting, met with landowners on an ongoing basis, conducted outreach to local governments and agencies, obtained several local permits, and acquired most of the land rights needed for the new transmission line and substation prior to submitting an application for the state permit required to construct the Project.

ISSUES AFFECTING ROW REQUIREMENTS, DESIGN, AND CONSTRUCTION

State Permitting Requirements

The North Dakota Energy Conversion and Transmission Facility Siting Act (Siting Act) requires applications for a Certificate of Corridor Compatibility and Route Permit to meet the criteria set forth in NDCC Chapter 49-22 and NDAC Article 69-06. The NDPSC requires applicants to minimize impacts to resources and obtain the majority of land rights and local permits prior to completion of the state permitting process. Xcel Energy completed a corridor and route study and conducted early and ongoing stakeholder outreach.

Corridor and Route Study

The Project's end points were determined based on the need to connect to the existing McHenry Substation, located approximately 32 km

(20 mi) southeast of the City of Minot, with the Minot area (Figure 2). Selection of the new Magic City substation site east of the City of Minot was primarily guided by the need to connect the new 230-kV transmission line to existing 115-kV transmission lines near the existing Mallard Substation. The selection of the proposed Magic City Substation site was based on the following criteria:

- Located near existing 115-kV transmission lines.
- Compatible land use: near wastewater treatment ponds and away from existing and proposed residential development.
- Engineering considerations: directly accessible from 37th Avenue and relatively level site, requiring minimal grading.
- Environmental impacts: no wetland, wooded area, or other habitat affected.
- Human/social impacts: no residences on land; willing seller.

Once the Magic City Substation site was selected, Xcel Energy examined the area between the existing McHenry Substation and the proposed Magic City Substation site to identify a corridor for the proposed 230-kV transmission line. Based on Xcel Energy's initial review of the potential corridors, the least impactful corridor would follow the existing Souris-McHenry 115-kV transmission line. Following the existing 115-kV transmission line meets the policy criteria of utilizing existing ROWs as listed in Part 4 of the NDAC § 69-06-08-02. Impacts to exclusion or avoidance areas and resources listed in Selection Criteria identified in Part 3 of NDAC § 69-06-08-02, including wetlands, could be avoided or minimized by placing poles outside these areas. After narrowing the focus to the existing 115-kV corridor, Xcel Energy identified the Project route within the Project corridor by considering the exclusion and avoidance criteria outlined in NDAC § 69-06-08-02 and after considering public input and agency input.

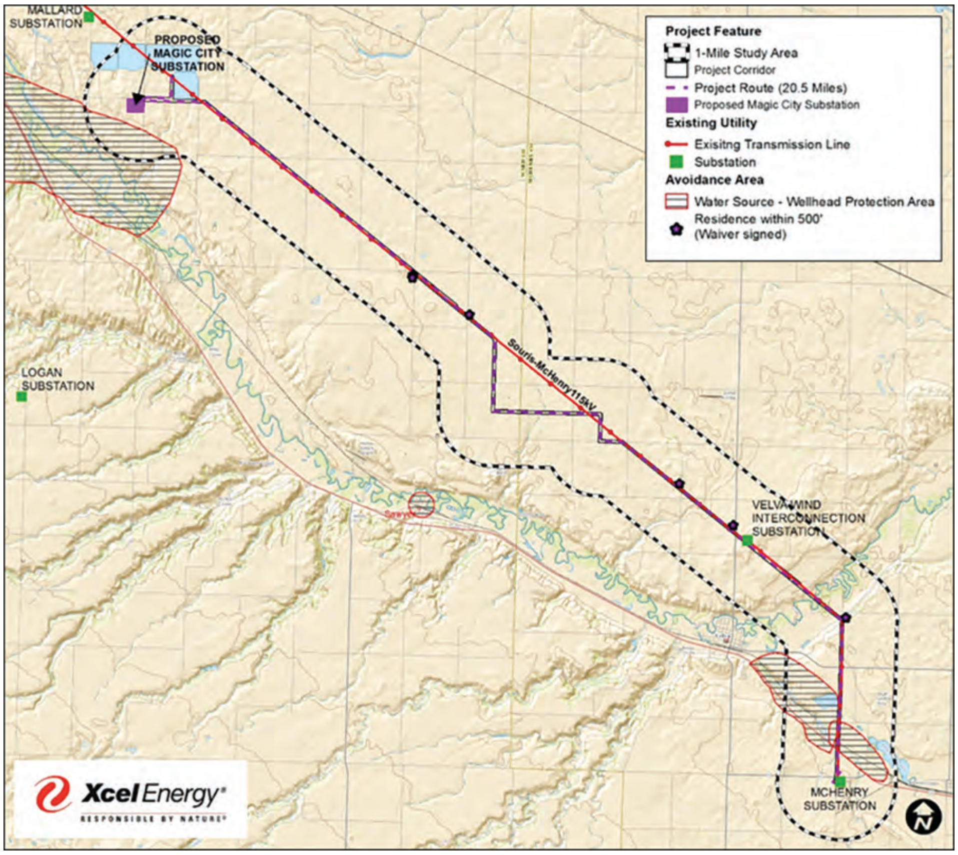

Figure 2. Corridor and Route Study

Figure 3. Photograph of the Existing 115-kV Transmission Line

Stakeholder Engagement

Landowner Input

Landowner input was sought in a public open house for the Project and in meetings with individual landowners. The existing 115-kv transmission line crossed farmland (Figure 3). An example of a 230-kV transmission line adjacent to a 115-kV transmission line, as proposed by Xcel Energy, was provided at the public open house (Figure 4). Most landowners did not support installation of a parallel H-frame line. Key issues that would add to their existing burden were 1) impacts to agricultural land use, and 2) the fact that construction of the new, 230-kV transmission line adjacent to the existing 115-kV transmission line would require them to farm around two transmission lines. The landowners preferred either a new, double-circuited or shared 230-kV and 115-kV transmission lines on single poles, or that the new 230-kV transmission line be located elsewhere.

Transmission Line Alternatives Discussed at the Public Open House

Based on the landowner input, the Xcel Energy team discussed the alternatives at the public open house and worked toward an internal cross-disciplinary consensus regarding Project design. Figure 5 is a table comparing the landowner impact, cost, and reliability of the three alternatives: parallel 230-kV and 115-kV transmission lines, double circuit 230-kV and-115-kv transmission lines on single poles, and a separate alternate route for the new 230-kV transmission line.

Although it was the costliest alternative, Xcel Energy listened to this feedback and revised the proposal to consolidate the 230-kV and 115-kV transmission lines on single steel pole structures (Figure 6). Xcel Energy proposed to construct the new transmission line as a 230/115-kv double circuit line adjacent to the existing 115-kV transmission line. The existing 115-kV transmission line would remain in service during construction and would then be removed after the new lines are energized.

Figure 4. Example of a 230-kV Transmission Line Adjacent to a 115-kV Transmission Line

Alternative	Landowner Impact	Cost (details attached)	Reliability	Comments
Parallel	Bad	Lowest	Good	Challenging to obtain ROW.
Double Circuit	Good	Highest (Add $8M to $11M)	Good	Landowner preferred.
Alternate Route	Questionable	Mid (Add $2M to $6M)	Best	Challenging to obtain ROW, many landowners will have same comments as parallel option.

Figure 5. Comparison of Route Alternatives.

Agency Input

The following summarizes Xcel Energy's coordination with various agencies:

- NDPSC: Regarding the required Public Convenience and Necessity, Certificate of Corridor Compatibility, and Route Permit for transmission lines more than 115 kV.
- U.S. Army Corps of Engineers (USACE): Regarding wetland mapping, avoidance, impacts, and crossing of Souris River.
- U.S. Department of Agriculture (USDA)/Natural Resources Conservation Service: Regarding agricultural land.
- U.S. Fish and Wildlife Service (USFWS): Regarding the following sensitive species and habitat requirements:
  - o Surveys for Dakota skipper habitat; no habitat was present in Project area
  - o Identification of raptor nests within one mile of the line
  - o Installation of bird diverters on the transmission line since it is located within the whooping crane migratory corridor
  - o Construction timeframe limits near an eagle nest
  - o Clearing and mowing be conducted outside of migratory bird nesting season
  - o Placing transmission structures outside of wetlands on USFWS wetland easements
- North Dakota Aeronautic Commission: Regarding airports and airstrips.
- North Dakota Department of Health: Regarding the requirement

for a construction stormwater permit and measure that must be taken to minimize noise, release of fugitive dust, and impacts to waterbodies.

- North Dakota Department of Transportation: Regarding utility permits that are required for work in highway ROWs.
- North Dakota Game and Fish Department: Regarding avoiding impacts to native prairie and wetlands, construction at the Souris River must be conducted outside of April 15 and June 1, requiring bird diverters on the line, and suggesting a half-mile construction buffer be implemented around two active bald eagle nest sites.
- North Dakota Parks and Recreation Department: Regarding the line crossing of two snowmobile trails and their impact to the locations of rare plant, animal, and ecological communities. None of the rare species range or habitat lies within the Project corridor and no impacts were anticipated for the snowmobile trail.
- North Dakota State Historic Preservation Office: Regarding the agency's review and concurrence with the Class I Literature Search and Class III Cultural Resource Inventory submitted for the Project, which had a finding of No Historic Properties Affected.
- North Dakota State Water Commission: Regarding the Souris River floodplain and floodway with a Sovereign Lands Permit for the Souris River Crossing, and requirement for a National Pollutant Discharge Elimination System General Permit for Stormwater Discharges Associated with Construction Activity and Stormwater Pollution Prevention Plan.

Figure 6. The 4.2 mile North Prairie Township Reroute in Relation to the Existing 115-kV Transmission Line

Local Permitting

Several county and township approvals were required to construct the Project. ROW Utility Permits, Approach Permits, Road Use Agreements, and Road Crossing Licenses were obtained where required. In addition, the approvals described below were also acquired.

Granted Substation Approval from Ward County: The Project included the construction of the new Magic City 230/115-kv substation located in Ward County. A subdivision plat was approved by the Ward County Board of Commissioners in August 2016 to facilitate the purchase of the Magic City Substation parcel. A building permit was obtained for substation facilities prior to construction. A Special Use Permit and Setback Variance were not required in the Agricultural Zoning District per the Ward County Zoning Ordinance, and confirmation of this was provided by the Ward County Planning and Zoning Administrator.

Approximately four hectares (ha) (10 acres) of the 20.24-ha (50-acre) Magic City Substation site was fenced and developed as part of this Project. Of the remaining 16.2 ha (40 acres), approximately four ha (10 acres) were used as a staging area during construction. The area that was not fenced as the Project was planted to prairie grasses after construction. Xcel Energy rerouted a short segment of the transmission line in Ward County to ensure that the proposed transmission line was 152 meters (m) (500 feet [ft]) away from an inhabited rural residence as required by NDCC § 49-22-05.1.

Conditional Use Permit for the Transmission Line from McHenry County: A Conditional Use Permit (CUP), necessary to construct a transmission line within the McHenry County Agricultural District, was approved by the McHenry County Board of Commissioners in December 2016. A Setback Variance was also approved by the McHenry County Board of Commissioners in February 2017 to permit the placement of transmission structures within setback areas. A permit for transmission structures located within the Souris River floodplain was required.

North Prairie Township-Required Modifications before granting a CUP for the Transmission Line

Xcel Energy sought to obtain a CUP and Setback Variance from North Prairie Township. North Prairie Township's Zoning Regulations state that, "Above-ground utilities shall be placed in a manner which will not place undue hardship on normal farming operations. Utility placement shall conform with section lines, highway (state and federal), and railroad ROWs." While the proposed route following the existing 115-kv transmission line did not follow section lines within North Prairie Township, Xcel Energy conferred with North Prairie Township officials who indicated that this route complied with the intent of the regulation of minimizing impacts to farming operations. Xcel Energy therefore submitted a CUP and Setback Variance application to North Prairie Township for the double circuit option on October 18, 2016.

The North Prairie Township Board considered the application at a December 19, 2016 hearing. At this hearing, several landowners opposed the use of the existing corridor, regardless of whether the new line was consolidated with the existing line. Rather, these landowners requested that the new 230 kV transmission line as well as the existing 115-kv transmission line be located on section lines or half-section lines to minimize impacts to agricultural operations. Xcel Energy also presented its position at this hearing, noting that consolidating these two lines along the existing 115-kv route is the shortest route and reduces land use impacts from the existing condition.

After deliberation, the North Prairie Township Board denied Xcel Energy's application, citing the Township's Zoning Regulation requiring new utilities to be sited to conform with section lines. The North Prairie Township Board clarified that a route along half-section lines would also be acceptable, and that any new application must include removal of the existing 115 kV and consolidating this line with the new 230-kV transmission line. Given this denial, Xcel Energy revised the portion of the route within North Prairie Township to follow section and half-section lines (Figure 6). While the North Prairie Township reroute added approximately $1.5 million in Project costs when compared to the double circuit route following the existing 115-kv transmission line corridor, this reroute gained verbal approval from nine of the 11 landowners along the proposed alignment. Verbal approval had been provided for all parcels located within North Prairie Township limits. Two landowners, both of whom own properties outside of North Prairie Township limits, were opposed to the reroute. Xcel Energy submitted a revised CUP and Setback Variance application to North Prairie Township on February 17, 2017 with this reroute, and it was approved.

Pollinator Planting at New Substation

Xcel partnered with the USFWS through their Partners For Fish and Wildlife program. The USFWS designed a flower-heavy prairie mix, ordered the seed, and paid for a portion of the seed. USFWS also provided a seed drill to plant the seed. In return, Xcel planted the seed and agreed to at least 10 years of management of the land to the target plant community.

DISCUSSION

Utilities must address regulatory requirements and consider input from a wide range of stakeholders in determining where and how to construct facilities. State, local, landowner, and other stakeholder input affects the ROW requirements, design, and construction of this 33-km (20.5-m), 230-kV transmission line and substation Project in North Dakota. Because the NDPSC requires applicants to minimize impacts to resources and obtain the majority of land rights and local permits prior to completion of the state permitting process, and as part of the public and agency stakeholder process, key routing, design, and construction included the following actions:

- Xcel Energy modified the Project design based on landowner input from having the new 230-kV transmission line parallel the existing 115-kv transmission line on wooden H-frame structures to combine the new 230-kV transmission line with the 115-kv transmission line on single pole steel structures.
- Xcel Energy rerouted 6.76 km (4.2 mi) of the new 230-kV transmission line in North Prairie Township as required to meet the County ordinance and obtain a CUP from the Township.
- Xcel Energy installed bird diverters on the transmission line because it is located within the whooping crane migratory corridor.
- Xcel Energy created construction and clearing and mowing timeframe limits.
- Xcel Energy placed transmission structures outside of wetlands on USFWS wetland easements.
- After construction, Xcel Energy planted approximately 12 ha (30 acres) of the new Magic City Substation, outside of the fenced area, to prairie grasses.

CONCLUSIONS

It is critical for project proposers to understand what the permitting entities will require. Early and ongoing input from all parties help to lead to a successful project. The Certificate of Corridor Compatibility and Transmission Facility Route Permit application was submitted to the NDPSC in March 2017. At the time of application submittal, almost 70 percent of the landowners had signed easements, and most permits required for the Project had been obtained. The NDPSC held a hearing on the Project in

August 2017, which included a presentation of the North Prairie CUP process and related modifications. North Prairie Township expressed support for the Project. The NDPSC granted the Certificate of Corridor Compatibility and Route Permit in October 2017, and the Project was constructed as shown in Figures 7 through 9.

ACKNOWLEDGEMENTS

Xcel would like to acknowledge the landowners along the new transmission line for their negotiating prowess and integrity.

Xcel also acknowledges its consulting team of Jared Brandell Douglas, Leslie Knapp, and Mark Rothfork.

Figure 7. Drilling Structure Foundation

Figure 8. Placing Single Pole Steel Structure

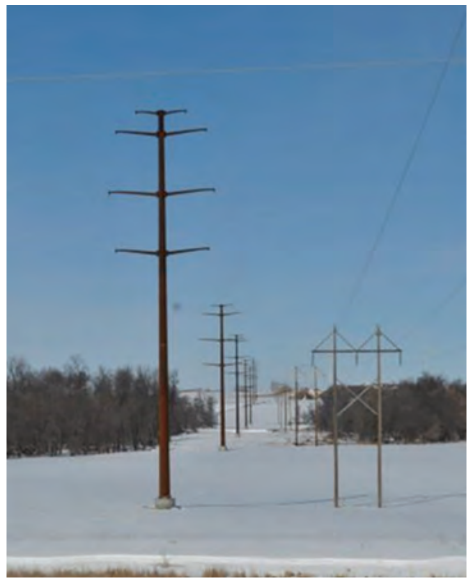

Figure 9. New 230/115-kV double circuit line (left) prior to removal of existing 115-kV transmission line (right)

AUTHOR PROFILES

Tom Hillstrom
Tom Hillstrom has a Bachelor of Science in Biology and has more than 25 years of experience in the consulting, transportation, and energy fields. Hillstrom has worked for Xcel Energy for 13 years and is responsible for siting and permitting of large transmission projects in Minnesota, Wisconsin, and the Dakotas.

Sean Lawler
Sean Lawler has more than six years of experience in planning, siting, and land rights acquisition for major electric transmission, gas, wind, and solar utility facilities across the upper Midwest. His experience includes land rights acquisition, state and local permitting, asset management, permit compliance, and construction liaison support. Lawler received his Bachelor of Arts degree in Planning and Community Development from St. Cloud State University.

Leslie Knapp
Leslie Knapp received a Bachelor of Arts (General Science/Biology) and Master of Arts (Earth Science/Geology) from the University of Northern Iowa. Knapp is a consultant with Tetra Tech, specializing in the environmental review and permitting of complex projects. She has more than 37 years of project experience related to National Environmental Policy Act (NEPA) and state-level environmental review and permitting, assisting clients in the development of effective permitting strategies and innovative mitigation measures. She has helped clients develop solutions to complex problems and has provided effective support in negotiations with regulatory agencies. Knapp has extensive experience in leading defensible siting and routing processes throughout the Midwest, resulting in projects that have been successfully permitted and constructed.

The Oroville Dam Spillway Incident—Beyond the Headlines in Oroville, CA

M. Bernadette Bezy, Steve Pelletier, Michelle Cross, Leah McNearney, Ryan Martin, Jim Hall, Gail Kuenster, Chris Kasiewicz, and Jacqueline Wait

Four years of drought were followed by an unprecedented deluge in California in 2017. The Oroville Spillways Incident is known around the world; however, here we want to share lessons from a little told story about powerline issues and solutions below the Oroville Dam. Flows over the Emergency Spillway eroded the foundation of powerlines coming from the California Department of Water Resources Hyatt Powerhouse. These powerlines needed to be rerouted quickly as a temporary solution and within a few months as a permanent solution. The permanent reroute was a collaborative effort between engineers, environmental scientists, archaeologists, contractors, and State and Federal Regulatory Agencies. The quandary was how to reroute these powerlines quickly amid multiple cultural and biological environmental constraints. How do we thread the needle between an eagle nest, the remnants of an historic gold mining camp, potential tribal resources, and prominent recreation trails? The solution: collaboration and communication.

Keywords: Biological Resources, California Environmental Regulations, Cultural Resources, Emergency Response, Fast-Track Permitting, Oroville, USFWS Take Permit.

Environmental Concerns in Rights-of-Way Management
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INTRODUCTION

On February 7, 2017, erosion was discovered on the lower chute of the main Flood Control Outlet Spillway at Lake Oroville. With an onslaught of winter storms, releases down the damaged main spillway were unable to prevent the reservoir from overtopping the concrete weir. Water cascaded down the Emergency Spillway, triggering the evacuation of more than 180,000 people downstream of Lake Oroville on February 11.

Here we tell the lesser-known story of the California Department of Water Resources (DWR) Spillway Incident Emergency 230-kiloVolt (kV) Powerline Reroute Project (Powerlines Project). The Powerlines Project is one that required collaboration among DWR and Pacific Gas and Electric Company (PG&E) engineers, biologists, archaeologists, Native American tribal representatives, environmental regulators, and California State Parks managers to solve interwoven and complicated fast-track design and environmental regulatory issues.

Damage resulting from the Oroville Spillway Incident and use of the Emergency Spillway compromised transmission structures that supported the 230-kV line that connected the Hyatt Powerplant to California's bulk electrical grid, prompting immediate design and installation of temporary powerlines (shoofly lines) and fast-track design, permitting, and construction of permanent reroutes by DWR and PG&E—all in the face of summer power demands and the next anticipated winter rain season.

Key spatial limitations (Figures 1 and 2) forced creativity in design, while key timing constraints (Figure 3) triggered construction sequencing solutions.

Specifically, the Powerlines Project development constraints included the following:

- The PG&E Temporary Line (shoofly) was positioned such that the DWR powerline could not be installed near or over it. The PG&E shoofly had to be de-energized prior to DWR installing an energized powerline above it, which constrained the start date for this segment until after June 2017.
- New powerline towers in the PG&E Permanent Alignment needed to be constructed and the lines in service by July 2017 to respond to peak mid-summer power demands. This required installing tower footings on a promontory ridge near known cultural resources. The DWR Permanent Alignment required use of the same promontory, with adequate separation between the two lines, and also had to take into consideration the cultural resources. Prior to construction, cultural resources surveys, consultations with tribes and the State Historic Preservation Officer, and the development of protection measures were required.

Photograph 1. Oroville Spillway Incident. Photo credit: DWR, 2017 (https://pixel-ca-dwr.photoshelter.com)

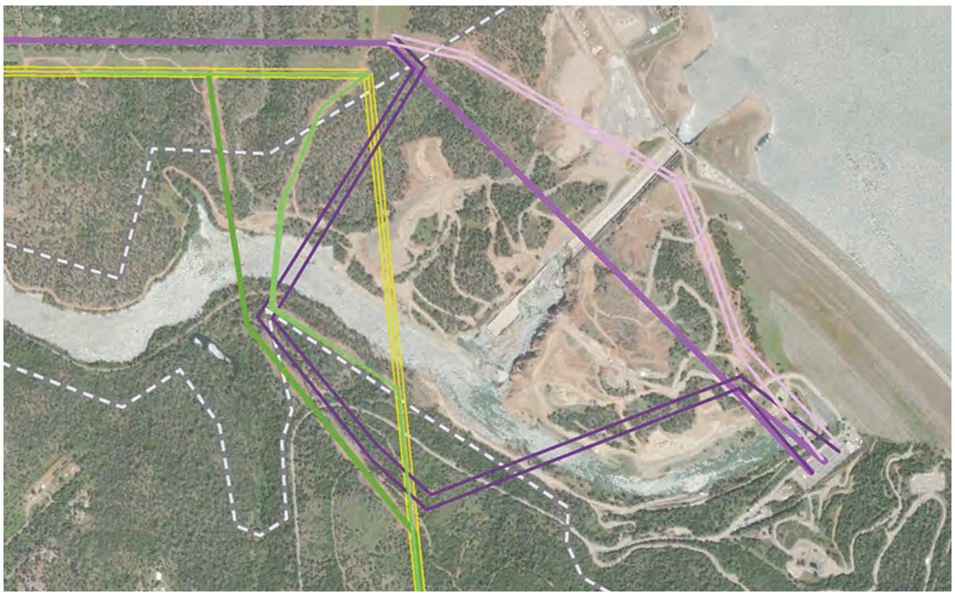

Figure 1. Powerlines Projects Relative to the Oroville Dam (Green = PG&E, Purple = DWR). Source: Stantec.

Additionally, because the PG&E reroute was completed *prior* to DWR's permanent powerline installation, the DWR route was further constrained by the presence of the adjacent PG&E line and the cultural resources to the west.

- The DWR Permanent Alignment was also located in proximity to an active bald eagle nest, necessitating measures in the design layout and construction schedule. The DWR powerline was thus constrained to the east by the active eagle nest AND construction could not begin until the eaglet had fully fledged in July 2017.

Regarding completion dates, several constraints were paramount.

- The DWR Temporary Powerline needed to be de-energized prior to October 2017 so the Emergency Spillway secant wall could be completed prior to the upcoming rainy season. The secant wall is a cantilever wall installed below the Emergency Spillway to help control erosion in the event of another heavy rain event. Cranes were required for the secant wall installation, but could not operate with the temporary (DWR Shoofly) high-voltage powerline overhead. Consequently, the DWR Powerlines Project had a hard completion date of September 2017.
- The anticipated heavy winter rains were another primary constraint, dictating powerline completion and erosion control installation prior to their expected October arrival, as well as a construction completion in autumn 2017.

The physical and environmental constraints surrounding the powerline reroute areas are steeped in a mix of pre-history, history, ecology, recreation, water, and energy interests. This dynamic project and associated fast-track permitting, design, and construction succeeded because of the urgent need for consistent coordination and collaboration between archeologists, ecologists, tribal representatives, State Parks managers, DWR and PG&E engineers, and regulatory agency staff.

Figure 2. Powerlines Project Relative to the Spillway and Dam. Photo credit: Drone Footage, DWR.

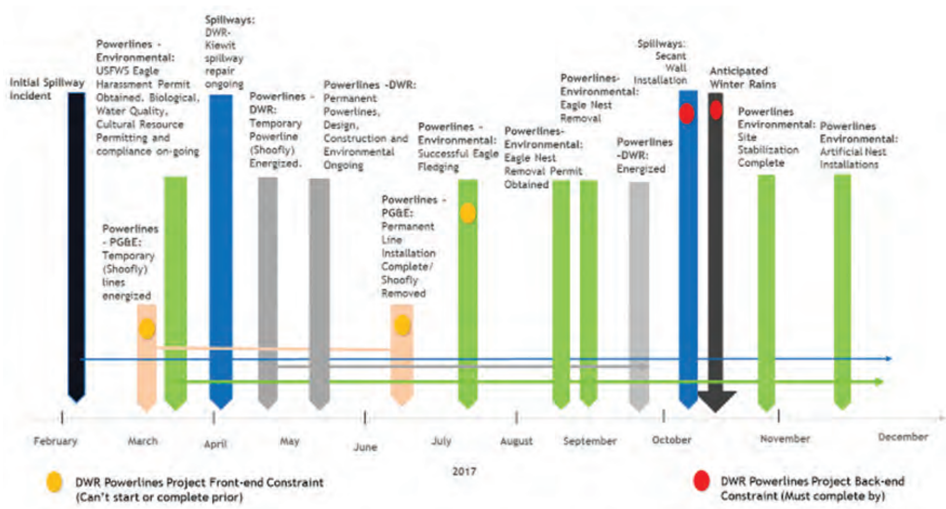

Figure 3. Approximate Fast-Track Powerline Installation Timeline. Source: Stantec.

BACKGROUND

The Oroville Dam is one of the key components of the State of California's water and bulk electricity systems and the headwaters of the California State Water Project (SWP). The Project is in the southeast portion of Butte County in the City of Oroville at the DWR-operated Oroville Dam and associated hydroelectric facilities. Elevation at the site ranges from approximately 65.5 to 195.1 meters (m) (215 to 640 feet [ft]) above mean sea level. The Project is in the Oroville Dam and Oroville U.S. Geological Survey Quadrangles at Township 20 North, Range 4 East, Sections 34 and 35, and Township 19 North, Range 4 East, Sections 2 and 3 (Figure 4).

National View of Oroville

The U.S. likely knows the Oroville Dam Facilities from some key facts. For example, at 235 m(770 ft) tall, Oroville is the tallest dam in the nation. The Feather River and Lake Oroville are the source waters for the SWP, providing much of the agricultural and drinking water for northern and southern California.

These details were augmented by headline news indicating that January and February 2017 were the wettest in 110 years of Feather River hydrologic records. Rain on snow events caused Lake Oroville to receive an entire year's average runoff of 4.4 million acre-feet in about 50 days during those two months. On February 7, 2017, erosion was discovered on the lower chute of the main flood control spillway at Lake Oroville. With an onslaught of winter storms, releases down the damaged main spillway were unable to prevent the reservoir from overtopping the concrete weir. Water cascaded down the Emergency Spillway, triggering the evacuation of more than 180,000 people downstream of Lake Oroville. On February 11, California Governor Brown declared a State of Emergency (Brown 2017) and everyone downstream was evacuated in a matter of hours. During that same time, more than 3.6 million acre-feet volume of reservoir inflow (equivalent to the entire storage capacity of Lake Oroville) continued to be safely released from Lake Oroville, despite the significantly damaged Flood Control Outlet Spillway (DWR 2017a).

However, what didn't necessarily hit the national headlines is that erosion resulting from the Flood Control Outlet and Emergency Spillways compromised two transmission structures that supported the 230-kV line connecting DWR's Hyatt Hydroelectric Generation Facilities to California's bulk electrical grid.

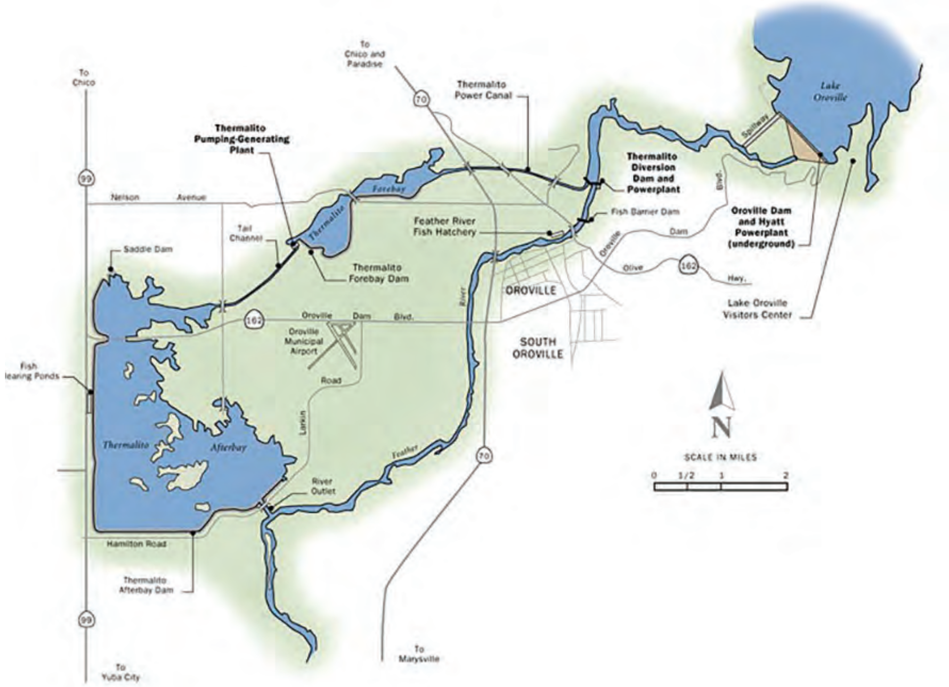

Figure 4. The California Department of Water Resources Oroville Facilities. Source: DWR (*https://water.ca.gov/Programs/State-Water-Project/SWP-Power/HLPCO-Oroville-Facilities-Project-2100*)

The State Water Project and Oroville Facilities

The existing SWP energy facilities are unparalleled in terms of regional, infrastructural importance. Planned, constructed, and operated by DWR, the SWP is the nation's largest state-built, multi-purpose, user-financed water project, supplying water to more than 27 million people throughout California. The SWP water also irrigates about 303,514 hectares (ha) (750,000 acres) of farmland, mainly in the San Joaquin Valley (DWR 2017b).

Lake Oroville, created by Oroville Dam, was completed by DWR in 1967 after five years of construction. It conserves water for distribution by the SWP to homes, farms, and industries in the San Francisco Bay area, the San Joaquin Valley, and portions of Southern California. The Oroville facilities of the project also provide flood control and generation of clean hydroelectric power in addition to recreation (DWR 2017b).

The SWP, and specifically the Lake Oroville Facility, was designed to provide many additional benefits:

- Flood Control and Public Safety: The flood of 1955, which submerged Yuba City, was the impetus for the construction of Lake Oroville.
- Power Generation: The SWP produces hydroelectric power to operate pumping facilities required to move water from Northern to Southern California.
- Recreation: The Lake Oroville State Recreation Area (SRA) surrounding Lake Oroville is a state park unit of California. The 11,917-ha (29,447-acre) park was established with the commissioning of the dam in 1967. The SRA includes Lake Oroville and its surrounding lands, recreational facilities within the project area, as well as the downstream land and waters in and around the Diversion Pool and Thermalito Forebay. The park and lake support outdoor recreation such as camping, picnicking, hiking, sail and power-boating, water-skiing, fishing,

swimming, boat-in camping, floating campsites, and horse camping.

- Fish and Wildlife Habitat: The SWP is operated to protect fish and wildlife with fish hatcheries, fish screens and passages, mitigation agreements, fish surveys and monitoring, a fish salvage facility, habitat restoration, and restricted pumping schedules. In addition, the area provides habitat for many common and protected wildlife species, including multiple pairs of resident bald eagles and large influxes of over-wintering migrants (DWR 2017b).

Relative to pre-historic and historic resources, the Feather River region has been occupied by Indigenous peoples for at least 3,000 years, with use continuing up to and beyond the mid-1800s arrival of Euro-American immigrants. Three months after gold was discovered at Sutter's Mill near the town of Coloma, John Bidwell found gold on the Feather River at what became known as Bidwell's Bar. The Feather River was a major gold-producing area, with all the social, economic, and environmental consequences found elsewhere in the mining West (DWR 2012).

THE CONUNDRUM

Immediately after the Oroville Spillway Incident, DWR needed to thread a 230-kV powerline right-of-way (ROW) through water infrastructure, power generation, and biological, cultural, and recreational resources within the fast-track demands and seasonal constraints.

METHODS

All of the following activities were required to deliver an on-time and environmentally compliant Powerline Project. In addition, all the activities were conducted under an Incident Command scenario within the backdrop of critical and much larger Oroville Spillway Incident Emergency Recovery activities.

Given the wide variety of constraints on this project and the need for fast-track permitting (Figure 1), DWR employed collaborative and iterative coordination punctuated by weekly in-person meetings and frequent on-site collaborative deliberations among DWR and Stantec engineers and environmental specialists, contractor (Barnard) managers, State Parks management, and DWR real-estate, among others.

Baseline Data: Baseline data and information collected by DWR on bald eagle territories and nest histories, for example, became immediately valuable at the onset of the Powerlines Project emergency response activities. Immediately following the Incident onset, DWR worked collaboratively with U.S. Fish and Wildlife Service (USFWS) to obtain an eagle harassment permit (No. MB22883C-0) (USFWS 2017a), should it be necessary to cause activities that might otherwise be considered "take" during the remaining 2017 breeding season (February through August). A harassment permit meant that if construction was necessary near an eagle nest that caused the eagle nest to fail that one year (2017), DWR would not be in violation of the Bald and Golden Eagle Protection Act. Regardless, from the Powerlines Project inception, DWR made every effort, as a priority, to avoid any eagle harassment and nest abandonment. Similarly, baseline data on wetlands and cultural resources also informed the ongoing design efforts.

Engineering Meetings: While engineering considerations are almost always the ultimate driver for a Powerlines Project alignment, environmental input was weighted heavily by DWR to facilitate the fast-track schedule. This was accomplished through an iterative process between the engineers and environmental/cultural teams to put forth a design that minimized impacts and accelerated the permitting process to the extent feasible. This began with engineering meetings between DWR and PG&E to better understand concurrent timelines and target alignments. PG&E needed to permanently reroute their powerlines prior to the peak demand period in July 2017. DWR coordinated with PG&E throughout the process as they assessed engineering and environmental/cultural constraints and defined solutions. DWR engineers also met internally on a minimum weekly and often more frequent basis to develop a preliminary design within weeks of the initial Incident.

Field Meetings: Field meetings were held with project engineers, biologists, archaeologists, water quality specialists, and tribal representatives. The best alignment was initially defined based on desktop constraints and biological, cultural, water quality, and recreation field information.

Weekly Collaboration Meetings: Once the route was defined, additional adjustments to the footprint were made to further accommodate environmental and cultural resources constraints and regulatory agency requests, a process that continued throughout construction. For example, the physical location of many natural and cultural resources and their boundaries were often obscured by the presence of thick underbrush and poison oak, and were discovered in the field as the ROW was cleared. This meant that for the duration of the project, the design, construction, and environmental permitting were dynamic, often changing weekly. DWR managed this change with weekly in-person meetings among project engineers, environmental scientists, archaeologists, real estate specialists, State Parks representatives, and tribal outreach specialists. Daily monitoring logs from tribal representatives, biologists, water quality specialists, archaeologists, and the contractors, as well as regular coordination with the environmental regulators, informed the weekly meeting adjustments and decisions were made proactively. The key elements of these meetings were:

(1) Prioritize safety.

(2) Bring your creativity to help DWR meet the dual imperative of completing the Powerlines Project

by September 2017 and minimize environmental impacts.

(3) Come to the meetings with issues *and* solutions.

(4) Think like your counterparts (i.e., if you are an archaeologist, try to understand the engineer's needs and vice versa).

(5) For complicated issues, detail the options and ramifications for DWR management to make informed decisions.

Specific examples and results of the constant conversation are listed in the results section below.

Photograph 2. Use of Mats to Distribute the Weight of Equipment in Areas with Potential Sensitive Surface or Subsurface Resources. Photo credit: DWR.

RESULTS & DISCUSSION

The identification and final selection of the permanent alignment route required review and analysis of numerous logistical and technical siting constraints as part of the emergency response conditions. The analysis included identification and assessments of ecological and cultural features known and expected to occur within the affected area in conjunction with design and construction engineering requirements for the construction of the three parallel 230-kV circuits.

Water and Energy—The Powerlines Project is an energy project. The purpose was to temporarily, and then permanently, re-route the compromised 230-kV powerlines that connect DWR Lake Oroville Hyatt Hydroelectric Facilities to the California bulk power grid. The reroute alignment was needed to ensure the powerline infrastructure was outside the spillway discharge zone. The project also needed to be installed prior to the next rainy season and could not interfere with PG&E's similar re-route process, which needed to be installed by the peak summer demand season in July.

All potential impacts were assessed in a National Environmental Policy Act (NEPA) compliant Environmental Assessment (EA) (FERC 2017), which occurred in parallel with design, permitting, and construction activities. In addition, DWR was exempt from the California Environmental Quality Act (CEQA) due to the Governor's declaration of a State of Emergency (Brown 2017). Regardless, to meet the energy restoration goals of the project, many environmental factors, including potential cultural, biological, and recreation resource impacts, had to be considered.

Prehistory and History—DWR utilized baseline data from the ongoing FERC relicensing process to inform the Powerlines Project footprint. In addition, archaeologists surveyed the proposed route and suggested design and construction method refinements during both the pre-design and construction phases, including those needed for permanent and temporary access roads.

DWR included Tribal representatives from the Enterprise Rancheria during field surveys and throughout the construction monitoring process. These individuals provided a tribal perspective on the local resources. Adding to the dynamics of this project, there were newly identified historic resources located during surveys and construction.

A Programmatic Agreement (PA) was executed between the California State Historic Preservation Officer and the Federal Energy Regulatory Commission (FERC) that defined a process for compliance with Section 106 of the National Historic Preservation Act. The PA allowed for a more streamlined approach and confirmed a delegation of authority to DWR to consult directly with the State Historic Preservation Officer.

As new project activities were identified, adjustments were made in the field to avoid cultural resources and were summarized by addendum to the Pre-Construction Report.

The goal throughout the project was to avoid impacts to cultural resources. If avoidance was infeasible, measures to minimize impacts were employed. Examples included re-routing access roads, adjusting tower footings, and hand-felling trees away from resources. Examples of construction method adjustments to avoid adverse effects included placing temporary plates over historic canals or track mats to distribute the weight of equipment on top of possible historic properties **(Photograph 2)**.

Biological Resources—Similar to cultural resources, every effort was made to avoid and minimize ecological impacts. For example, the parallel alignment was confined to a single corridor to the extent feasible to minimize the patchwork of tree removal and flora/faunal impacts associated with habitat fragmentation. The general environmental compliance process and associated design modifications can be defined by the individual resources:

Potential Wetlands and Waters of the U.S.: The project area was primarily located on dry Sierra Foothill hillsides. The primary water crossing was over the Thermalito Diversion Pool, which is part of the Feather River. However, all powerlines footings and poles were located upslope and out of federal Clean Water Act jurisdiction and the powerlines themselves were strung by helicopters. As such, impacts to the Feather River were avoided. In addition, drainage surveys were completed by biologists early in the design process, thus allowing engineers to avoid encroaching on drainages during the placement of a key tower. As another example, a previously unmapped seep was identified as brush was removed during construction, prompting biologists and contractors to cooperatively identify new access road locations in the field to avoid impacts to the seep. These types of design modifications allowed project deadlines to be met while avoiding resource impacts. Communication with the U.S. Army Corps of Engineers was ongoing and DWR was able to avoid placement of any dredge or fill material into potential waters of the U.S.

Rare Plants and Wildlife: Initial surveys for protected species were conducted prior to construction. Apart from a nesting bald eagle and migratory birds, described below, no additional rare plants or wildlife were identified within the bounds of the Powerlines Project, thus requiring no additional avoidance and minimization measures. Although not mandated by a regulatory agency, DWR nonetheless ensured that fulltime biological monitors were on site during every aspect of construction to verify avoidance of natural resource impacts.

Photograph 3. (Left) Juvenile Bald Eagle Successfully Fledged in July 2017. (Right) Drone Photo of 1,000-pound Eagle Nest After the 2017 Nesting Season. Photo credits: Stantec (left) and DWR (Right).

Nesting Migratory Birds: Early in the process DWR obtained a Migratory Bird Treaty Act (MBTA) Take Permit from the USFWS (MB30372C-4) (U.S.FW 2017b) and coordinated accordingly with the California Department of Fish and Wildlife (CDFW). The MBTA Take Permit allowed for a total of 25 bird nests to be removed during the emergency response and recovery process. This total was for all aspects of the larger Spillway Incident Emergency Recovery Project, including the Powerlines Project. DWR also needed to enlist the support of approved regulatory agency biologists who would initially survey the entire construction area to determine nest locations, establish no-work zones if necessary, and provide information used to determine construction sequencing. To the extent feasible, the contractor would then delay construction near active bird nests to allow for successful fledging. In the few cases where construction could not be delayed, the nests were removed and relocated immediately to the wildlife rescue center, where all relocated nests successfully fledged.

Bald Eagle: The Bald Eagle is protected by the USFWS as part of the Bald and Golden Eagle Protection Act. In addition, the species is fully protected under California State Fish and Game Code. From the project onset, DWR communicated with the USFWS regarding the Glen Pond Bald Eagle Nest (eagle nest), which DWR had monitored for more than a decade. During the 2017 nesting season, for the duration of the PG&E and DWR construction process the eagle nest had a full-time monitor. . . A no-work buffer was implemented, and the Powerlines Project construction sequencing was subsequently defined by the eagle nesting season. Despite DWR's permit (U.S.FW 2017c) for bald eagle harassment and nest failure and the need to maintain the construction schedule, DWR voluntarily delayed construction around the area until the young bird was ready to leave the nest, thus helping ensure fledging was a success **(Photograph 3)**.

Concurrent with DWR's nest protection efforts was an assessment of "danger trees" for compliance with the North American Electric Reliability Corporation (NERC) regulations. Danger trees, or hazard trees, are trees outside the clearing boundaries that could affect safe operation of the lines should they fall. Identification is based on safe clearance from 1) falling trees to an "at-rest" position; 2) swung conductors to standing trees; 3) trees growing into the conductors (estimated 6.1 m; 20 ft in 10-year period for all species). NERC is the electric reliability organization for North America, subject to oversight by FERC. As a transmission owner, DWR is required to follow regulations developed and enforced by NERC. There are many standards developed by NERC which apply to

DWR facilities, however, FAC-003 Transmission VM describes the requirements by which DWR needs to maintain the vegetation in and around their transmission facilities ROW.

Specifically, DWR must ensure all vegetation conforms with the Minimum Vegetation Clearing Distances (MVCD), or minimum required clearances from an energized part/facility to adjacent trees or other vegetation to prevent a flashover, as well as to inspect vegetation off the ROW for danger trees or other potential off-ROW hazards.

DWR engineers and environmental staff worked diligently to avoid the potential classification of the eagle nest tree as a danger tree. The alignment route was adjusted on three occasions by DWR engineers in coordination with environmental staff to gain maximum buffers for sensitive resources, with the eagle nest being the highest priority for protection. Light Detection and Ranging (LiDAR) data were reviewed and nest buffers were again adjusted to minimize tree removal in the area (Figure 5a). The LiDAR profile was shared with the USFWS and CDFW. The transmission design was also adjusted to place all circuits on the western sides of the Q tower alignment (Figure 5b), thereby allowing for more flexibility when ultimately defining the width of the clearing and grubbing area near the eagle nest.

With the alignment fixed, a forester reviewed the corridor for danger trees outside the initial clearing boundaries that could pose reliability and safety risks to the powerlines. Clearing standards for ROW construction and maintenance were based on NERC requirements and included the identification and removal of trees located outside the clearing boundaries that pose a potential risk to the transmission lines (i.e., danger trees). Individual danger trees were initially identified via LiDAR data and Powerlines Systems Computer Aided Design and

Drafting (PLSCADD) modeling analysis and then verified in the field.

Photograph 4. Bald eagle nest in tree deemed as a danger tree. Photo credit: Steve Pelletier, Stantec.

Factors for selecting danger trees for removal included tree species, overall height, form (e.g., excessive branching and/or leaning), and vigor, as well as adjacent slope aspect and gradient. Despite efforts, the eagle nest tree was ultimately identified in the modeling analysis process as a danger tree and then subsequently confirmed in the field **(Photograph 4)**.

Final field verification indicated the eagle nest tree needed to be removed to comply with NERC because the liability of a hazard tree along a powerline is great. The USFWS has a mechanism for conducting the lawful removal of an eagle nest. As such, DWR proceeded with another round of fast-track permitting with the USFWS. Importantly, because DWR had kept the USFWS abreast of all the adjustments to ensure successful fledging and design modifications to attempt to preserve the tree, the USFWS was able to immediately determine that all alternatives had been exhausted and issued a nest take permit on September 7, 2017 (MB53028C). Seven days later, DWR removed the 1,000-pound nest intact **(Photograph 5)**.

The nest proved too large for feasible relocation into nearby trees. Therefore, DWR worked with the USFWS to obtain permits for the placement of the nest at the visitor center and museum, and the use of nest materials for construction of four artificial nests within the territory. The nest designs were based on interviews

Photograph 5. Eagle Nest Removal Process. Photo credit: Bernadette Bezy, Stantec.

and discussions with specialists nationwide who had developed similar alternative nests. Alternative nest site locations were selected in accordance with the surrogate tree location (proximate to the Feather River and former Glen Pond breeding territory), prominence, form, and condition, as well as experience gained from years of bald eagle behavior monitoring, and also considered cultural resource impact avoidance for the subsequent tree access and nest installation activities.

Four alternative eagle nests were installed in November 2017 and mid-December 2017 (Photos 6a-c). In

California, Bald Eagles typically begin the nesting process in November and early December. The delayed installation may have influenced the 2017/2018 nesting season as the resident eagle pair did not select any of the alternative nests, but instead built a new nest on the north side of the Thermalito Diversion Pool in direct sight of their prior nest.

DWR, the USFWS, and CDFW had nevertheless made every effort to avoid impacts and facilitate successful fledging, which occurred during both years of the Spillways Incident Emergency Response and Recovery Process 2017 and 2018. Future use of the nesting structures will continue to be monitored with time.

Recreation: DWR must consider safety first and heavy construction and recreational uses are not safely compatible.

Multiple trails pass through the Powerlines Project area, some of which were widened and used for access, while others were crossed by the Powerlines corridor. DWR is presently working to re-open trails and add additional safe access trail routes.

CONCLUSIONS

The Oroville Spillway Incident was unprecedented in many aspects. However, the little told story of the Powerlines Project demonstrates a path to success for fast-track ROW projects set to the backdrop of complicated Federal and California environmental regulations and myriad environmental resources. Urgent collaboration and creativity were among the most important team characteristics. Inclusion and transparency with tribal representatives, local regulators, environmental scientists, and design and construction engineers facilitated a solution-focused process that successfully addressed a dynamic and evolving design process, in parallel with permitting, and synchronized with

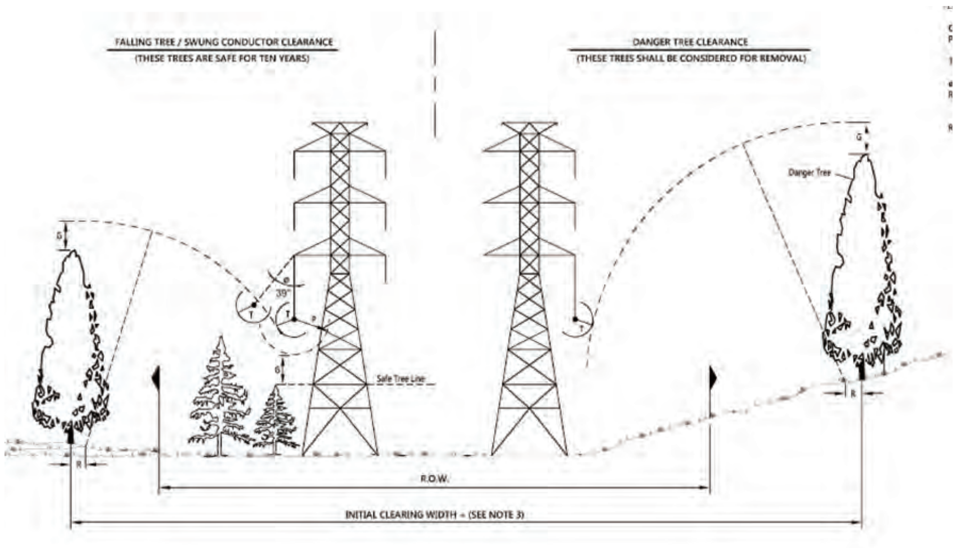

Figure 5a. Hazard Tree Conceptual Model. Source: Stantec 2017.

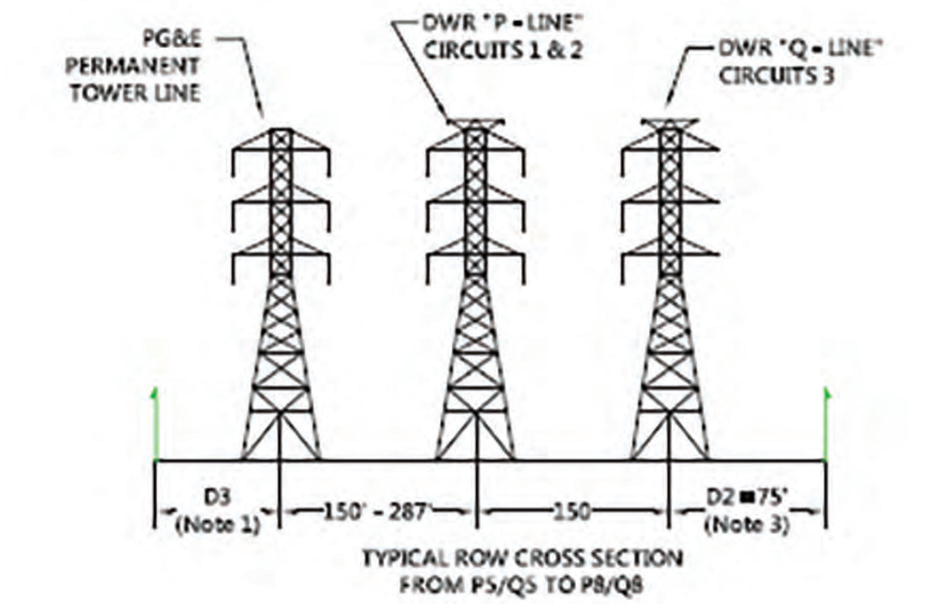

Figure 5b. Powerlines Project Alignment and Wire Location Adjustments for Sensitive Area Protections. Source: Stantec 2017.

construction (Photo 7).

ACKNOWLEDGMENTS

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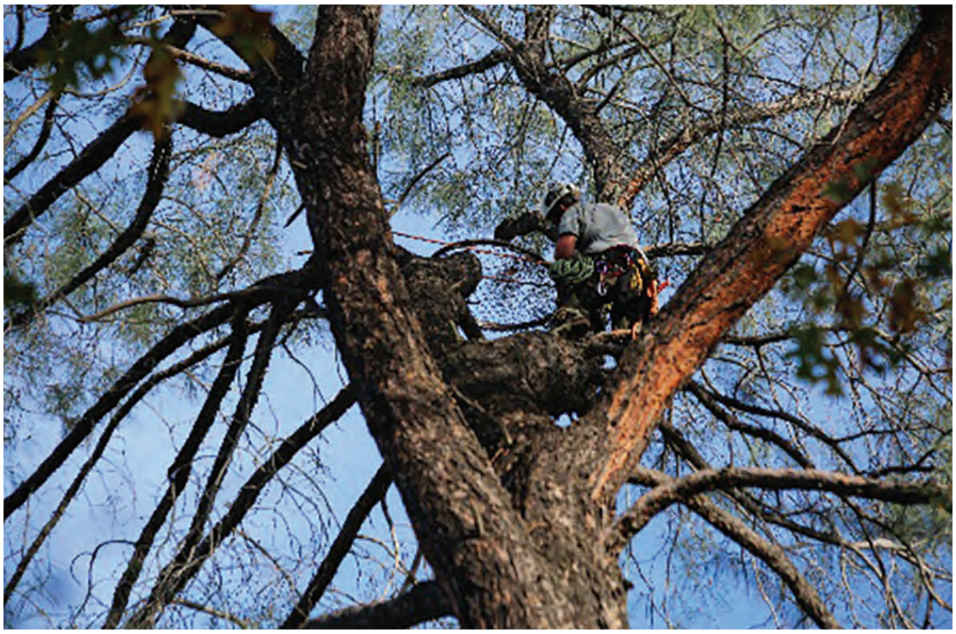

Photograph 6a. Alternative nest installation. Photo credit: Steve Pelletier, Stantec.

Photograph 6b. Nest diameters = 3 and four feet, nest materials came from original BAEA Nests. Photo credit: Steve Pelletier, Stantec and Josh Littlepage, Davey Trees.

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Photograph 6c. Alternative nest Within A Half Mile From the Original Nest Location and Spillway. Photo credit: Steve Pelletier, Stantec and Josh Littlepage, Davey Trees.

Photograph 7. Bald Eagle Nest on a Flatbed Truck, DWR and PG&E Powerlines, and Protective Covering Mats on Sensitive Cultural Resources. Photo credit: Bernadette Bezy, Stantec.

The Transco Dalton Expansion Project: An (Un)mitigated Success

James Mathis and Joe Thacker

Keywords: Bats, Cherokee Darter, Cherokee Syllabary, Etowah River, Etowah Darter, Federal Energy Regulatory Commission (FERC), Georgia, Large-Flowered Skullcap, Mitigation, MtDNA, Mussel, Outreach, Raccoon Creek, White-Nose Syndrome.

Williams' Dalton Expansion Project is a 185-kilometer (km) (115-mile [mi]) natural gas pipeline project in west central and northwest Georgia, U.S. that was placed into service in August 2017. Through close collaboration with the U.S. Fish and Wildlife Service (USFWS), a unique mitigation portfolio focusing on specific projects generated targeted results for a number of protected species, resulting in a reduction in overall mitigation.

During routing discussions, and during preparation of the USFWS's Biological Opinions for the Project, a number of high-priority conservation projects and goals were identified in the Project area. By earmarking funds for specific conservation projects, a number of these high-priority goals were met using the Project's mitigation dollars.

The mitigation portfolio included a white-nose syndrome research project that has major implications for treatment of this disease; mitochondrial deoxyribonucleic acid analysis of fish, which supported a wet, open-cut crossing of the 152-meter (m) (500 feet [ft]) Etowah River; purchase of significant acreage of priority land tracts/inholdings in ecologically sensitive areas; aquatic species population studies; protected plant species conservation; a mussel reintroduction study; installation of a cave gate to protect bat hibernacula and a Cherokee syllabary; and construction projects to improve fish passage and reduce stream turbidity.

Specific and major quantifiable benefits to the Project included removal of northern long-eared bat time-of-year clearing restrictions; approval from the USFWS and U.S. Army Corps of Engineers (USACE) for a wet, open-cut crossing of a 152-m (500 ft) waterbody; removal of time-of-year-restrictions from a large number of waterbodies; and a significant reduction in direct mitigation costs. In addition, the Project obtained both the USACE authorization and completed formal USFWS consultation prior to issuance of the Federal Energy Regulatory Commission's (FERC) Certification of Public Convenience and Necessity.

Environmental Concerns in Rights-of-Way Management
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INTRODUCTION & PROJECT DESCRIPTION

The Williams Dalton Expansion Project (Project) is a 185-kilometer (km) (115-mile [mi]) natural gas pipeline located in west central and northwest Georgia (see Figure 1). The Project was constructed to provide natural gas service through a new pipeline lateral (Dalton Lateral) to interconnections on the Dalton Lateral in northwest Georgia. The Project included installation of a new compressor station and three new meter station facilities in Georgia, as well as modifications and supplemental odorization equipment at existing facilities in North Carolina and Virginia. The Project was constructed by Transcontinental Gas Pipe Line Company, LLC (Transco), a wholly owned subsidiary of Williams.

The Dalton Lateral originates at Transco's existing Compressor Station 115 in Coweta County, Georgia, about 9.6 km (six mi) west of Newnan, Georgia. It extends to the north, through Carroll, Douglas Paulding, Bartow, Gordon, Murray, and Whitfield counties, Georgia. The Dalton Lateral terminates at a power plant in western Murray County. A small pipeline lateral (the Atlanta Gas Light [AGL] lateral) extends from approximate Milepost 105.2 of the Dalton Lateral, about 3.2 km (two mi) to the north of an AGL metering interconnect facility.

This case study focuses on Transco's efforts to mitigate potential Project impacts to federal- and state protected plant and animal species as well as several unique ecological features. It describes the communications and cooperation that took place between Transco and the agencies, how the resulting mitigation agreements benefited the project, as well as the sensitive resources. These species and features include those identified during consultation with the U.S. Fish and Wildlife Service (USFWS) under Section 7 of the Endangered Species Act and with the Wildlife Resources Division (WRD) of the Georgia Department of Natural Resources (GDNR). Although

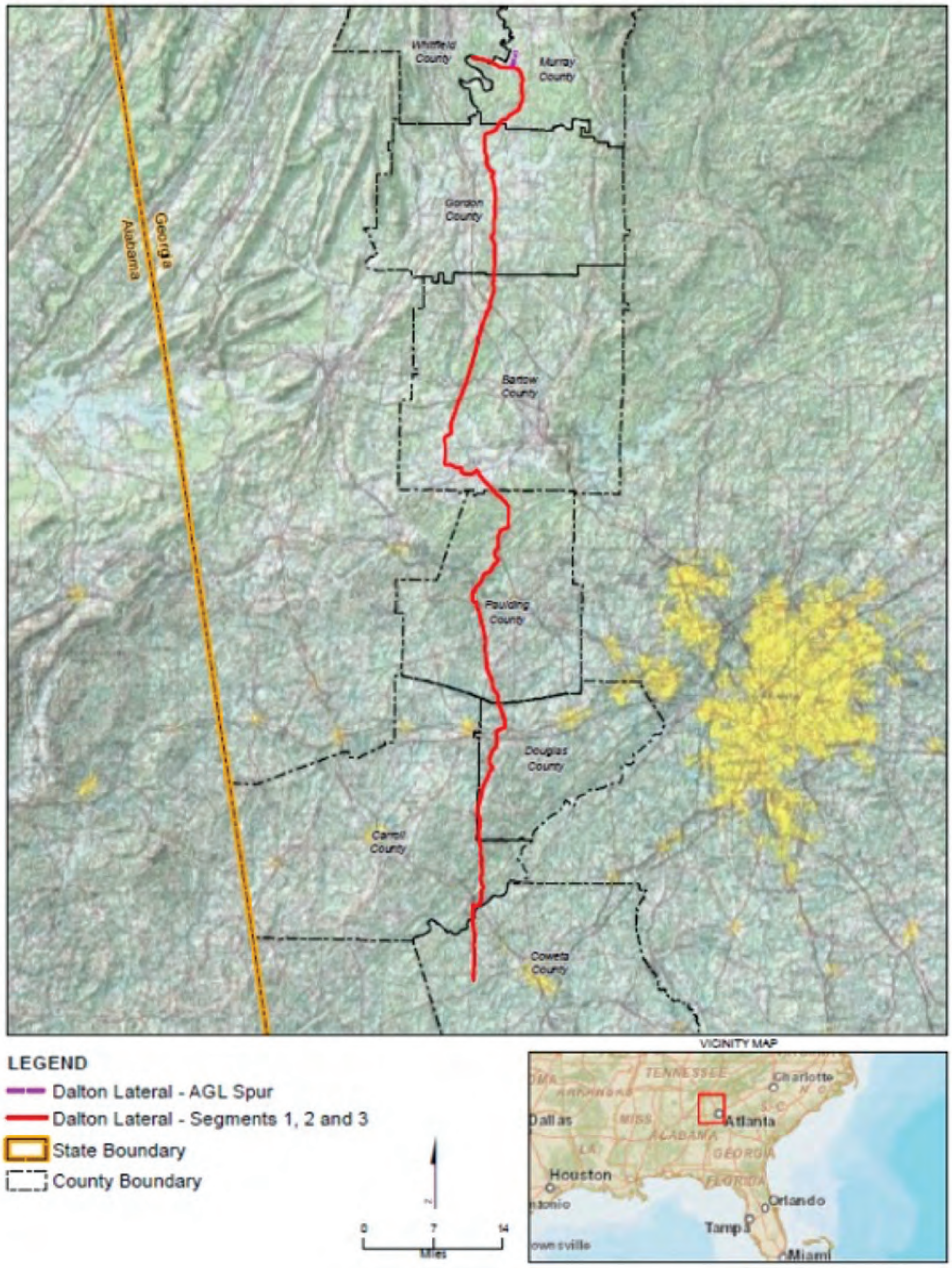

Figure 1. Location of the Dalton Expansion Project

Transco also provided mitigation for cultural resources through the Georgia Historic Preservation Division of the GDNR, mitigation for stream buffer impacts through the GDNR-Environmental Protection Division and mitigation for impacts to wetlands and waterbodies through the U.S. Army Corps of Engineers (USACE), these mitigation efforts are not discussed herein.

Regulatory Background

The Project was regulated by the Federal Energy Regulatory Commission (FERC) under Section 7(c) of the Natural Gas Act. Pre-filing drafts were submitted to FERC in August 2014, the Final FERC Application was submitted in March 2015, and the FERC Order was received in August 2016. The Project was placed into USFWS in August 2017. A Section 404 permit from the USACE was required, as was formal consultation with the USFWS, and informal consultation with several other federal agencies. Major state permits were required, including a National Pollutant Discharge Elimination System permit and a Stream Buffer Variance from the GDNR-Environmental Protection Division. Transco completed formal consultation with the USFWS and received two separate Biological Opinions (BOs) prior to receipt of the FERC Order.

Project History and Outreach

The Project was initiated in 2012 with the commissioning of a feasibility study and identification of a preliminary route. In the first quarter of 2014, Williams' Land Group identified and acquired survey access for approximately 1,200 landowners and within one year, obtained survey permission from 990 landowners. Based on engineering, environmental, and cultural resources; field data; and discussions with landowners and other stakeholders, the preliminary route was modified to a "finalized route" in 2015. The finalized route included more than 750 tracts to be acquired prior to receipt of the FERC Order in August 2016. Through the negotiation process, Williams was able to purchase easements from approximately 90 percent of the landowners on the project before the FERC Order was received. This included negotiations with the GDNR and other high-profile landowners.

Public outreach for the Project was initiated during the FERC pre-filing process in mid-2014, when the Project team held meetings with local public officials in each affected county. Simultaneous outreach efforts were made with other stakeholders, including state and federal officials. Nine open houses were held during the second quarter of 2014 and in early 2015. These open houses included an overview of Williams' role in the Project, and an explanation of the FERC process and regulations, project scope, and location. Williams used these meetings as an opportunity to listen to questions and concerns from landowners, public officials, and other stakeholders to better understand the communities and people affected by the project, and to find ways the project team and the community could work together. As a result, Williams was able to address these questions and concerns, and significantly modify the pipeline route to minimize impacts to landowners and the environment while accomplishing project goals.

During the early outreach period, Williams partnered with the University of West Georgia Center for Economic and Business Research to develop an economic impact study to highlight the economic benefits of the Project. This study provided detail on the economic benefits to the affected counties during construction, as well as long-term economic benefits provided during operation of the Project. The economic impact study is available to the public through the FERC website as part of Resource Report no. 5.

As part of the public outreach strategy, Williams partnered with non-profit organizations in several of the project communities. These relationships continue today as part of the long-term commitment Williams has made with the communities the Dalton Lateral serves. Some of the organizations include the Coosawattee Foundation, the Douglas County Community Schools, the University of West Georgia, the City of Whitesburg library (part of the Carroll County Regional Library system), the Food Ministries in the City of Whitesburg, and the REACH Foundation.

Transco was required to obtain a Revocable License Agreement from GDNR's Real Estate Office for construction of the Project and a Permanent Easement for operation of the Project across lands owned by the State Properties Commission. At the December 2015 meeting of the Board of the GDNR, Transco presented a summary of the Project, which was approved by the Board at that meeting, and later in legislative session. At the meeting, the head of the Real Estate Office and several members of the GDNR Board acknowledged and commended Transco's outreach efforts to the state and federal agencies. Of note is that the Revocable License Agreement and Permanent Easement for two other pipeline projects that were presented to the GDNR at this meeting were denied.

The original route was co-located across more than 90 percent of its length with existing right of-way (ROW)—predominantly a Georgia Power high-voltage overhead powerline. Based on extensive coordination with the USFWS, USACE, GDNR-WRD,

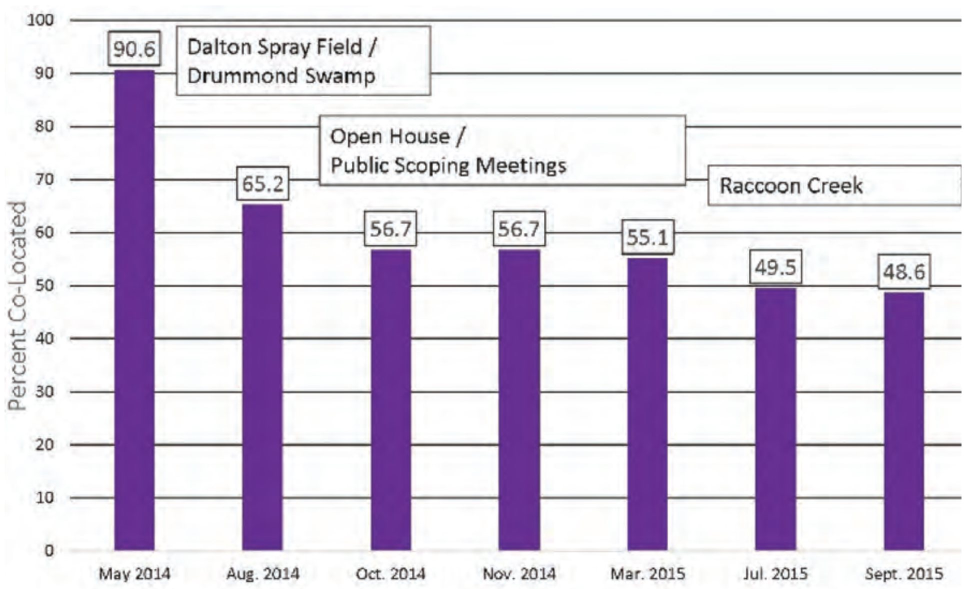

Figure 2. Chronology of the Project's Collocation Efforts

GDNR-Historic Preservation Division, The Nature Conservancy (TNC) and other stakeholders, the route was modified at many locations. Some of the major route revisions (reroutes) were designed to avoid Drummond Swamp, which hosts the world's only known population of Georgia Alder; Green Pond, a unique geological feature known as a sag pond; and Dalton Utilities Sprayfield, a 1,942-hectare (ha) (4,800-acre) land application system for wastewater. The most significant reroute was known as the Raccoon Creek reroute, a 16-kilometer (km) (10-mile [mi]) reroute that moved the route to the outer edge of the Raccoon Creek subwatershed, thereby avoiding direct impacts on the main stem of Raccoon Creek. The final Project route was slightly less than 50 percent co-located (see Figure 2).

Mitigation Goals

Transco's mitigation goals were simple. From an ecological and stewardship standpoint, Transco's goal was to identify a diverse portfolio of mitigation projects that offered the most ecological benefit. These goals were achieved by working closely with the USFWS, GDNR, and TNC. From a construction standpoint, maximizing the Project's construction timeframe by minimizing time-of-year restrictions related to clearing and in-stream work was a main focus. The Project was scheduled to start after migratory bird nesting season, which ends on August 1, but clearing restrictions associated with bats ends September 30. Knowing that in-lieu contributions were to be made, Transco made a significant effort to be more involved with the allotment of the mitigation dollars.

Resource Crossings

The final Project route crossed more than 130 roads, more than 300 waterbodies, including major rivers and sensitive waterbodies, and more than 100 wetlands. Major road crossings included Interstate Highway 75 and Interstate Highway 20, as well as three U.S. highways and six state highways. Major river crossings include the Chattahoochee River at the Coweta/Carroll county line, the Etowah River in Bartow County, the Coosawattee River in Gordon County, and the Conasauga River at the boundary of Whitfield and Murray counties. Sensitive waterbodies crossed include Etowah River, Conasauga River, Coosawattee River, Raccoon Creek, Holly Creek, Shed Creek, Pumpkinvine Creek, Little Pumpkinvine Creek, Two Run Creek, Marable Creek, Jackson Creek, Casey Springs Branch, and Bullpen Branch.

Ecological Setting

Northwest Georgia is one of the most biologically diverse areas in the world, particularly for aquatic species. In addition, a number of federally protected bat and plant species are known to occur in the Project area. The Project is located within three major river basins, each with a unique assemblage of aquatic species. The Middle Chattahoochee River, Etowah, Coosawattee, Oostanaula, and Conasauga River Basins each have different conservation priorities for aquatic species, as provided by the USFWS in a letter dated December 18, 2014 (USFWS 2014).

The southernmost portion of the Project is located in the Middle Chattahoochee River basin, which does not host any federally protected aquatic species, but does support a number of state-listed protected species.

Within the Etowah River basin are sub-watersheds that support a large diversity of aquatic species. These sub-watersheds, including Raccoon Creek and Little Pumpkinvine/Pumpkinvine Creek, have been identified by the USFWS as high-priority conservation areas. The Raccoon Creek system in particular has been identified by the USFWS, TNC, GDNR, and other partners as a high-priority tributary for aquatic and terrestrial habitat restoration, management, and protection. As of 2014, these agencies had invested more than $65 million in federal, state, and private dollars within the previous 10 years to protect 5,261 has (13,000 acres) of the Raccoon Creek watershed within state managed lands. Starting in 2009, the USFWS and TNC also spent considerable federal, state, and local funds, as well as hundreds of man-hours, restoring stream habitat along one reach of Raccoon Creek within and adjacent to the existing Georgia Power ROW. The goal of these efforts was to improve habitat for the federal endangered Etowah darter (*Etheostoma etowahae*) and the threatened Cherokee darter (*Etheostoma scotti*).

The Etowah River is known to support the federally endangered Etowah darter, at locations much farther upstream from the Project area. The greenbreast darter, a common species that is similar to the federal endangered Etowah darter, is known to occur within the Etowah River in the Project area. At the time of consultation in 2015, the USFWS could not confirm the presence of Etowah darter in the Etowah River and suggested that nuclear deoxyribonucleic acid (DNA) (i.e., mitochondrial DNA or MtDNA) analysis would be required to differentiate these species.

The Coosawattee River flows into the Conasauga River and together they form the Oostanaula River, near Rome, Georgia. The Conasauga River basin is one of the most biologically diverse river basins in the world for aquatic species, historically supporting about 90 species (10 percent of the North American fish fauna) of fish and at least 44 species (15 percent of the North American mussel fauna) of mussels. Fifteen of these fish and mussels are either state- or federal-protected species. Critical habitat for seven mussel species is also present in the Conasauga River.

In addition to aquatic species, three protected bat species and a handful of protected plant species are known to occur in the Project area. Gray bat hibernacula (*Myotis grisescens*) are known in the northwestern part of Georgia, particularly in areas underlain by limestone, which includes large sections of the northern half of the Project route. Northern long-eared bat (*Myotis septentrionalis*) roosting and foraging habitat is also present throughout the Project area. Because of declines caused by white-nose syndrome and continued spread of the disease, the northern long-eared bat was listed as threatened under the Endangered Species Act in April 2015. Five federally listed and 11 state-listed plant species have suitable habitat or are known to occur in the Project area.

Preconstruction Mitigation

Transco's mitigation efforts began early in the planning process. Avoidance efforts, like the major reroutes described above, in addition to dozens of smaller reroutes, were incorporated throughout the scoping and siting process. Transco used horizontal directional drill (HDD) technology to avoid impacts to sensitive waterbodies (two crossings of the Conasauga River, a crossing of the Coosawattee River, and a crossing of Holly Creek), several large wetlands, major roadways, and several sensitive cultural resources. Time-of-year restrictions were enforced at 29 waterbodies due to the potential presence of mussels or spawning fish. Standard minimization efforts typical of FERC-regulated projects, such as reduced construction ROW through sensitive areas and expedited construction through waterbodies, were also included in the construction plans. Wet, open-cut crossings of waterbodies were limited to a total of four waterbodies, only because dry crossings were not possible at these waterbodies.

In consultation with the USFWS and GDNR-WRD, Transco identified 76 waterbodies crossed by the Project to be field surveyed. These pre-construction field surveys were completed in 2015 and 2016 and provided a wealth of new information to the USFWS and GDNR-WRD. These agencies had some basic information about the known or suspected presence/absence of certain fish and mussel species in waterbodies crossed by the Project. The field survey report provided a robust data set that included population profile data, species occurrence, specimen counts, and other location and habitat data for waterbodies that were flowing at the time of survey. Field survey also identified the presence of the federally and state-threatened Cherokee darter at several waterbodies that were suspected, but not previously known to support this species. Even though Holly Creek was to be crossed using HDD technology, Transco agreed to survey this waterbody to provide additional data to the USFWS and GDNR-WRD. In addition, surveys were completed for burrowing crayfish in specific areas, and wintertime surveys were completed for the presence of spawning trispot darters (*Etheostoma trisella*) at a handful of sites.

Transco conducted pre-construction field surveys for five federally listed and 11 state-listed plant species, and summer roost surveys for bat species. For the plant species, the survey was completed in areas with suitable habitat that were identified by completing a habitat analysis. Transco was able to significantly reduce the survey area and increase the survey window for these species by using a renowned botanist to complete the habitat analysis. Occurrences of piedmont barren strawberry (*Waldsteinia lobata*), Georgia aster (*Symphyotrichum georgianum*), and large flowered skullcap (*Scutellaria montana*) were identified along the Project route. Bat surveys were completed in the summer of 2015 and captured one northern long-eared bat. The bat was a non-reproductive female that was fitted with a radio transmitter to track her movements. The radio transmitter was shed the first day.

Quantifying Species Impacts and In-Lieu Fee Mitigation Amounts

While the Project was designed to avoid and minimize impacts to sensitive areas that host protected species to the extent possible, not all impacts were avoidable. Impacts to protected aquatic and terrestrial species were discussed and quantified by the USFWS in two separate BOs issued by the USFWS. One BO was prepared for aquatic species and another was prepared for terrestrial species, including bats. The USFWS used existing data and field data that were provided by Transco to prepare the BOs and the incidental take statements.

Aquatic Species

For aquatic species, the USFWS anticipated incidental, non-lethal take of all Alabama moccasinshell (*Medionidus acutissimus*), Coosa moccasinshell (*Medionidus parvulus*), finelined pocketbook (*Hamiota altilis*), southern clubshell (*Pleurobema decisum*), southern pigtoe (*Pleurobema georgianum*), and rayed kidneyshell (*Ptychobranchus formanianus*) in the action area during the life of the Project via "harm of individuals, including glochidia, due to increases in turbidity associated with project construction and long-term, chronic erosion of disturbed stream banks and ROWs." For similar reasons and as a result of Project construction, restoration, and maintenance, the USFWS anticipated incidental take of all Etowah and Cherokee darters in the action area during construction (USFWS 2016a).

Incidental take of aquatic species was approved by the USFWS in the biological opinion (BO) subject to compliance with Transco Conservation Measures provided in the BO, and the Reasonable and Prudent Measures (RPMs), and Terms and Conditions of the BO. One of the Conservation Measures required Transco to compensate for impacts to listed aquatic species and their habitats by making an in-lieu fee contribution to TNC for priority actions to recover listed aquatic species in the Raccoon Creek and Conasauga River basins or elsewhere in the Upper Coosa watershed. In general, the USFWS requested mitigation for waterbodies in which Cherokee darter was known or suspected to present. To calculate costs, the USFWS used a proprietary algorithm that considered the ROW status (new or existing), stream length on ROW, mean channel width, and the waterbody's presence within Priority 1 or Priority 2 habitat. The algorithm calculated both direct and indirect credits and used a per-credit cost for both credit types to determine a total mitigation cost for impacts to aquatic species of approximately $930,000. Even though mitigation was provided for impacts to aquatic species, the USFWS and GDNR-WRD still disallowed water withdrawal from the Conasauga River during low flow conditions and required avoidance of specific waterbodies during spawning season for certain species. Because the USFWS has no mechanism to receive direct, in-lieu fee contributions, the money was contributed to TNC. Specific projects that were funded with this fee are described below.

Potentially Affected Species	Total Mitigation Amount
Aquatic Species	$930,000
Bats and Plants	$1,888,710
Total Species Mitigation	**$2,818,710**

Table 1. Total In-Lieu Fee Species Mitigation Provided by Transco for the Dalton Expansion Project through 2016

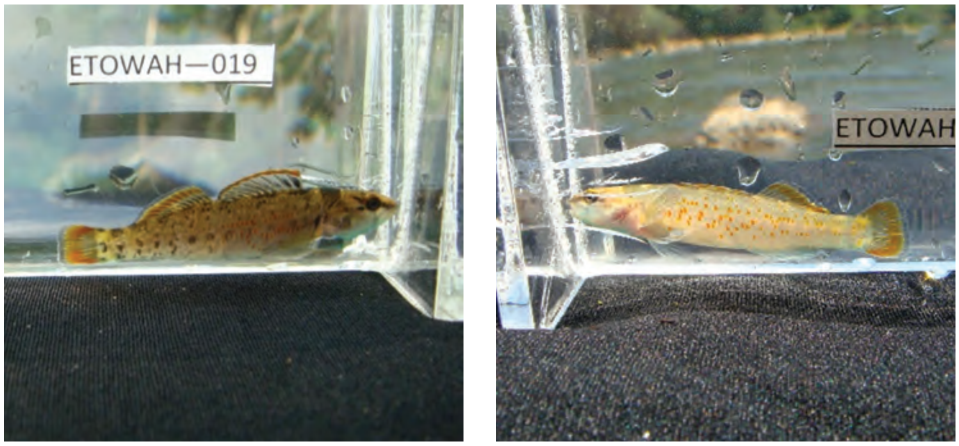

Figure 3. Etowah or Greenbreast Darter?

Terrestrial Species

In December 2015, prior to issuance of the terrestrial species BO, the USFWS entered into a Memorandum of Understanding (MOU) with Transco regarding terrestrial species (bats and plants). Based on the results of Transco's bat survey effort and existing bat occurrence data, the USFWS identified 59 has (146 acres) of occupied summer habitat and approximately 114 has (281 acres) of potential summer habitat within the Project footprint. Using the 2015 U.S. Department of Agriculture (USDA)-estimated value of Farm Real Estate/Acre fee of $3,270, and a 2× multiplier for occupied summer habitat, the USFWS calculated a total mitigation cost of $1,873,710 to offset potential losses to occupied summer bat habitat and potential summer bat habitat. The USFWS also requested $15,000 to fund a third-party salvage and relocation effort for large-flowered skullcap, piedmont barren strawberry, and Georgia aster. The largest benefit to Transco from the MOU was the removal of tree-clearing restrictions for bats. Other benefits included approval of construction in areas with protected plant species (USFWS 2015).

Within the BO for terrestrial species, the USFWS anticipated incidental take of all Indiana and northern long-eared myotis that:

> "…could occur within 664 acres (±60 acres) of forest that would be cleared along the Project corridor, especially in the 427 acres that occurs within the typical range of threatened or endangered bats. Based on the results of Transco's bat survey, direct harm or mortality is anticipated to be very low and, considering the low number of myotis calls and absence of maternity trees identified along the ROW, if harm were to occur, it would likely be realized by only few Indiana and/or northern long-eared myotis individuals" (USFWS 2016b).

Because the Endangered Species Act does not consider take of plants, large-flowered skullcap was not considered in the incidental take statement.

Transco incorporated all reasonable and prudent measures into the proposed action and provided $1,888,710 for the express purpose of providing conservation dollars for terrestrial species along the project, including Indiana myotis, northern long-eared myotis, and large-flowered skullcap. Therefore, the BO for terrestrial species contained no Terms and Conditions (USFWS 2016b). Table 1 shows the in lieu fee for total species mitigation provided by Transco.

Specific Mitigation Efforts: Aquatic Species

Etowah River Crossing

Historical data indicates the presence of the Etowah darter, a federally endangered species in the Etowah River. The Etowah darter is primarily known from the upper mainstem of the Etowah River upstream from Lake Allatoona, and the greenbreast darter, a similar species (see Figure 3) with no federal protection, has a much wider distribution. The Project crossing of the Etowah River is located more than 32 river km (20 river mi) downstream from Allatoona Dam. The main reason Etowah darters and a large number of mussel species are no longer present downstream from Allatoona Dam is related to the release schedule of this USACE structure. Since the dam was opened in 1950, and until the power house was damaged in 2015, daily or more frequent releases would result in

1.8- to 2.4-m (6- to 8-ft) increases in water level in the Etowah River, essentially removing many of the more sensitive species.

In December 2015, the USFWS provided a letter to Transco stating that previous genetic analysis of MtDNA identified haplotypes of both darters in specimens collected from the lower mainstem (i.e., in the Project area), but the data were insufficient to determine whether the two species currently occur together or if the two species overlapped and hybridized at some point in the past. In accordance with an agreement with the USFWS, and as a mitigation effort for the Project, Transco agreed to fund a study to analyze MtDNA from darter species collected proximal to the proposed crossing location. As part of an existing Scientific Collection permit, 20 *Nothonotus* species darters were collected from the Etowah River, five from the first shoal upstream, and five each from three shoals downstream from the proposed Project crossing location. Results indicated that none of the 20 darters collected were Etowah darters.

At the Project's crossing location, the Etowah River is approximately 46 m (500 ft) wide with water depths ranging from six inches to eight feet at normal flow levels. Natural fluctuations in the water level can be as much as 3.1 m (10 ft) during heavy rain events. According to the Geologic Map of Georgia (Lawton et al. 1976), and as verified during field investigations, the crossing is underlain by carbonate rocks that are very dense, but also prone to karst weathering. Transco completed numerous invasive and non-invasive geological and geotechnical investigations in this area to determine the feasibility of completing a trenchless crossing of this river, or another "dry-type" crossing, to avoid impacts on sensitive resources in the river. An HDD or other trenchless crossing was unlikely to be successful because of the rock density and the presence of numerous voids in the underlying carbonate rocks. Because of the presence of a strongly undulating river (bedrock) bed, large boulders, high water volume, and overall river width, a dry type crossing was also not feasible. The crossing location was further constrained by the presence of Native American fish weirs and other cultural resources that are common along the Etowah River. Therefore, a wet open-cut crossing of this river was proposed.

During discussion about a wet open-cut crossing of the Etowah River, the USFWS expressed concern about the effects of sedimentation on all aquatic species in the river. Both short-term spikes in sedimentation related to construction within waterbodies and chronic, long-term sedimentation from unstabilized ROWs and stream banks/channels at open-cut sites were cited by the USFWS as the most common threat to aquatic species in the Etowah River basin (USFWS 2014). In response, Transco prepared an Etowah River Turbidity Control and Monitoring Plan to identify the regulatory framework and the approach and measures that were implemented to control and monitor turbidity during construction.

As a result of the findings of the MtDNA analysis, the USFWS approved a wet open-cut crossing of the Etowah River. The crossing was completed in accordance with Transco's Etowah River Turbidity Control and Monitoring Plan in addition to minimal conditions provided by the USFWS.

Figure 4. Existing Raccoon Creek Bridge (facing upstream)

Raccoon Creek Bridge

The Raccoon Creek Road crosses over Raccoon Creek within the existing Georgia Power ROW and in an area that is intensively studied and monitored for the presence of Etowah and Cherokee darters. The current bridge presents a major impediment to fish passage for several reasons, but mainly because the downstream edge of the concrete foundation is perched (see Figure 4). The reaches of Raccoon Creek above and below this bridge have been the focus of conservation efforts for more than 10 years, and the USFWS and TNC identified replacement of this bridge as the number one conservation priority for aquatic species in northwest Georgia. Although the original Project route traversed this area, it was avoided by incorporation of the Raccoon Creek reroute.

Using a combination of funds from Transco, TNC, and the Paulding County

Department of Transportation, this bridge is scheduled for replacement with a clear span bridge or bottomless culvert, proposed to be completed in early 2019. Restoring fish passage in this area will connect two relatively disconnected stream reaches and greatly expand access for aquatic species to higher quality, upstream habitat. The photograph on Figure 4 illustrates the existing bridge.

Mussel Reintroduction Study

In the upper Coosa River basin, Transco funds will be used to initiate a mussel reintroduction study, proposed to begin as early as late-2018. Preliminary studies indicate that water quality in Raccoon Creek is adequate to support mussel survival. The study will involve placement of juvenile Alabama Rainbow (*Villosa nebulosa*) and Coosa Creekshell (*Villosa umbrans*) into mussel silos at three locations within Raccoon Creek (see Figure 5). Known host fish will also be collected at these three locations, infested with glochidia, and returned to the stream. A small sample of these fish will be retained alive for later examination of infestation intensity. Results from this study will be documented within a subsequent five year monitoring effort.

Constructed Riffles

One of the RPMs in the aquatic species BO required construction of artificial riffles at certain streams. The USFWS requested these structures to serve as additional habitat for aquatic species and to protect the stream channel from damage that might be caused by all-terrain vehicles or other vehicle traffic across these streams. In accordance with the RPMs, Transco will inspect and monitor these structures for 10 years.

Figure 5. Mussel Silos and GDNR placing a mussel silo in a Georgia stream

Specific Mitigation Efforts: Terrestrial Species

White-Nose Syndrome Research

Transco initiated discussions with the USFWS about mitigation efforts in early 2015 by requesting information about specific, high-priority conservation programs. In October 2015, USFWS Biologist Dr. Pete Pattavina provided information about a mitigation opportunity at a bat hibernaculum known as Black Diamond Tunnel in Rabun County, Georgia. This hibernaculum consists of an 1850s-era, 366-m (1,200 ft), dead-end railway tunnel that provides a stable, winter roost for northern long-eared myotis, tri-colored bats, and Rafinesque big-eared bats. Prior to white-nose syndrome, a syndrome caused by the presence of the psychrophilic fungus *Pseudogymnoascus destructans*, this tunnel was the largest tri-colored bat hibernaculum known, hosting approximately 5,300 tri-colored bats. In the winter of 2015, approximately 550 tri-colored bats remained. The roost is important because of the availability of high-quality bat foraging habitat in the Blue Ridge. It is also important due to the lack of stable, winter hibernacula in this area as a result of the state location over crystalline (rather than carbonate rocks). The USFWS has annual population data at this tunnel since 2010, including *Pseudogymnoascus destructans* swabbing data, as part of a national white-nose research study. Black Diamond Tunnel provides a perfect treatment area for white-nose syndrome because it lacks fauna typical of a cave ecosystem (and therefore does not run the risk of adversely affecting a natural ecosystem), but provides a hibernation area for hundreds or thousands of bats. The USFWS performed harp trapping at this site in the fall of 2015 and banded all swarming bats that were captured.

Using Transco dollars, the USFWS has funded an Integrated Disease Management Plan for white-nose syndrome in cooperation with Georgia State University. The USFWS also proposes to purchase the land surrounding the Black Diamond Tunnel for inclusion in the U.S. Forest Service (USFS) system for perpetual protection and long-term research. The multi-year Integrated Disease Management Plan for white-nose syndrome includes evaluation and development of a novel, prototypical treatment device (patent pending) as well as the evaluation and modification of effective anti-*Pseudogymnoascus destructans* volatile organic compound formulations to be used by the device for contact-independent management of white-nose syndrome. If this research is successful, it has large-scale ramifications. Further, because of the lack of other hibernacula in the region, and the availability of several years of census data, survival of bats in this hibernaculum can be directly tracked, and if the treatment is successful, effectiveness of the treatment can be gauged.

The USFWS is extremely excited about this research and its potential implications. Dr. Pattavina has shared this white-nose syndrome proposal with the USFWS's national white-nose syndrome coordinator in Hadley, Massachusetts, who, in-turn, is sharing it with the nation. On several occasions, Dr. Pattavina has stated that the Dalton Expansion Project has been the single most rewarding project of his professional career. The USFWS has offered to do stories on National Public Radio and other news outlets to promote this effort. This effort was the subject of a nationally syndicated cartoon strip (see Figure 6).

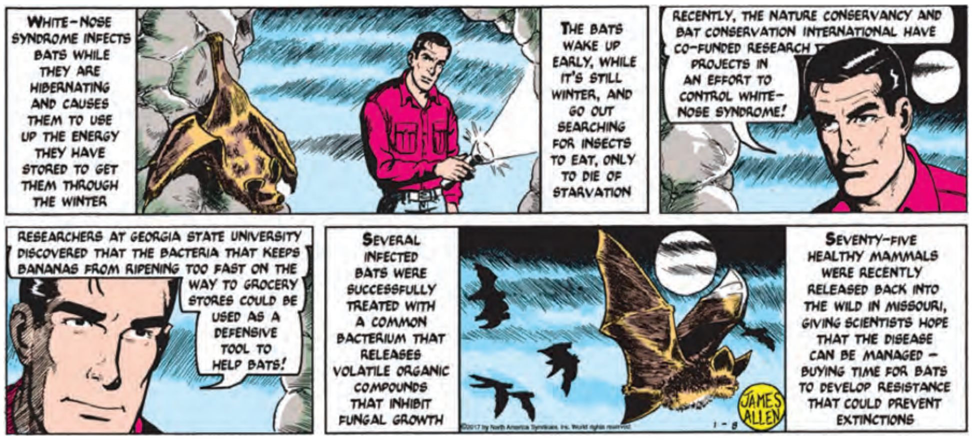

Figure 6. Mark Trail Strip from January 2017. *Copyright North American Syndicate, Inc.*

Cave Gate

Howard's Waterfall Cave, located in northwest Georgia, provides a hibernaculum for several species of bats and is also the site of a Cherokee syllabary in a small room near the front of the cave (see Figure 7). The Cherokee syllabary was created by Sequoyah in the late 1810s to early 1820s to write the Cherokee language. At Howard's Waterfall Cave, the syllables were drawn on the limestone walls using charcoal, and based on the age of the drawings, it is speculated that Sequoyah himself may have drawn them (Davis, Pers. Comm. 2018). Using money from the Cherokee Nation and Transco, a gate was erected inside the cave to limit access to the room that contains that syllabary and provide a quiet corridor for hibernating bats in the high-traffic cave.

Figure 7. Photograph of Cherokee Syllabary in Howard's Waterfall Cave. *Courtesy of Joe Thacker.*

Land Purchase

More than $1 million in Transco funds were combined with funds from the Forest Legacy program and a Recovery Land Acquisition Grant to purchase priority tracts within and adjacent to the GDNR's Paulding Forest Wildlife Management Area (WMA). The Paulding Forest WMA is in central Paulding County, in the Etowah River basin, and includes almost 13,000 has (32,000 acres) that encompass a large portion of the sensitive Raccoon Creek watershed and rare remnants of a "montane" longleaf pine forest. This forest type provides habitat for fox squirrels, Bachman's sparrows, bats, and other imperiled species. The approximately 88-ha (217-acre) Corley Tract was purchased and permanently protected via a deed restriction that was written expressly for bats. The 32-ha (80-acre) Tidwell Tract, 158-ha (391-acre) Forestar tract, and 178-ha (440-acre) Jones tract were also purchased and provide prime foraging and roosting habitat for bats. These lands are now owned and managed by GDNR as part of the Paulding Forest WMA. According to TNC, purchase of these priority tracts was expedited by several years using Transco mitigation funds. TNC also has plans to use remaining Transco mitigation funds to purchase an approximate 40.5-ha (100-acre) site in Paulding County on which an interpretive educational and research center will be developed.

Transco mitigation funds and other matching funds totaling almost $400,000 were used by TNC to purchase two priority conservation tracts in the Conasauga River basin. For these tracts, TNC has an unusual plan in that they will own and manage these lands in the short term, but will sell them to the USFS to become part of the Cohutta Wilderness area within the Chattahoochee National Forest. The money will then be "recycled" for other conservation projects.

Plant Relocation

Prior to construction, Transco worked with USFWS personnel and teams from the State Botanical Gardens to remove Georgia aster and large-flowered skullcap specimens from the construction footprint. In 2016, Georgia aster was removed from the Project ROW, which is adjacent to the Georgia Power ROW at this location and taken to the State Botanical Gardens for convalescing. These plant materials are proposed to be replanted on the Transco ROW in fall 2018. Transco is currently in discussion with Georgia Power because they currently maintain their adjacent ROW in compliance with a Candidate Conservation Agreement with the USFWS, GDNR, and others. Large-flowered skullcap were also removed from the Project ROW in 2016 and were relocated to a safeguarding site in a nearby National Forest.

Pollinator Plan

On June 20, 2014, President Barack Obama issued a Presidential Memorandum to create a federal strategy to promote the health of honey bees and other pollinators. This Memorandum created a task force whose goals were to develop a National Pollinator Health Strategy, which includes explicit goals, milestones, and metrics to measure progress. Using the guidelines within the National Pollinator Health Strategy, and under consultation with the USFWS and GDNR, Transco developed a Pollinator Plan for the Project. The purpose of the Pollinator Plan was to increase habitat for pollinators along the Project's permanent ROW. This procedure involves applying one of five self-propagating, maintenance free pollinator seed mixes on approximate one-acre plots at selected locations along the Project route. Locations were chosen at relatively regular intervals along the Project route to provide a north-south corridor, designed to facilitate migration of pollinating species. Transco is currently monitoring and managing these pollinator plots.

CONCLUSIONS

Williams worked with resource agencies to develop a unique mitigation portfolio for the Dalton Expansion Project that resulted in tangible ecological benefits. The mitigation portfolio included: funding of a white-nose syndrome research project: MtDNA analysis; land purchase; aquatic species population studies; protected plant species conservation; a mussel reintroduction study; installation of a cave gate to protect bat hibernacula and a Cherokee syllabary; and construction projects to improve fish passage and reduce stream turbidity. The critical first step in Williams' efforts to develop this portfolio was to foster a close working relationship with the USFWS and GDNR. Williams worked collaboratively with these agencies to identify protected plant and animal species potentially present along the Project route and to define survey areas and protocols. By getting agency input early in the Project's schedule, Williams was able to largely avoid ecologically sensitive areas. In addition, continuous agency coordination allowed Williams to identify high-priority conservation projects and goals in the Project area. As a result of several years of partnership with the USFWS, Williams completed formal USFWS consultation prior to issuance of the FERC's Certification of Public Convenience and Necessity.

In addition, Williams worked closely with the USACE to obtain authorization for Project impacts to wetlands and waterbodies. This authorization was received prior to issuance of the FERC's Certification of Public Convenience and Necessity.

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12th International Symposium

Environmental Concerns in Rights-of-Way Management

PART V

Technology

A Proactive Approach for ROW VM Using GIS and Remotely Sensed Data

Deborah Sheeler and
William Ayersman

The spatial visualization capabilities of geographic information systems (GIS) technology provide an efficient and cost-effective method to analyze and display remotely sensed data. By identifying predetermined and/or custom land cover classes and associated vegetation densities along right-of-way (ROW) corridors, resource managers are able to develop strategies for prioritizing planned maintenance, calculate accessibility to determine equipment needs and relevant safety protocols, map environmentally sensitive areas, assist in identifying a wide array of encroachment issues, and target only the specific locations that require a field inspection. Understanding how to utilize multispectral imagery, automated feature extraction processes, and GIS analysis techniques can lead to an advanced and proactive ROW vegetation management (VM) program.

Keywords: Aerial Imagery, Distribution, Geographic Information Systems (GIS), GIS Analysis, Image Analysis, Light Detection and Ranging (LiDAR), Photo Detection and Ranging (PhoDAR), Remote Sensing, Remotely Sensed Data, Rights-of-Way (ROW), Transmission, Utility Corridors, Vegetation Density, Vegetation Encroachment, Vegetation Management (VM).

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Remote sensing has a variety of applications for utility forestry and vegetation management (VM) (Pitt et al. 1997). The combination of remotely sensed data and geographic information systems (GIS) can provide a visual interpretation of large, complex datasets. Further, remote sensing and data analysis enables users to model environments, detect patterns, and identify trends that allow users to make informed decisions (Dixon et al. 1994; DeFries, et al. 1999; Verbesselt et al. 2009).

Remote sensing is defined as the acquisition of information about an object without making physical contact with the object (NOAA 2018). Various sensor devices can perform data capture, such as cameras, radars, and lasers mounted on multiple platforms based on the ground or on ships, aircrafts, unmanned aerial systems (UAS) (e.g. drones) or satellites. When processed, analyzed, and interpreted, remote sensing data allows for a wide range of applications in many fields of study (Lefsky et al. 2002).

The nature of the collection process dictates the structural characteristics of the data and its usefulness for specific applications. Aerial imagery, a common remote sensing product, uses cameras to capture digital images of the earth's surface and spectral characteristics (e.g., color, pattern, texture) of an object (Goetz et al. 1985). While camera sensors can capture aerial imagery and spectral data, other remotely sensed data products, such as LiDAR (light detection and ranging) and PhoDAR (photo detection and ranging), can generate 3D point cloud formats for enhanced visualization techniques. LiDAR uses laser light to measure distances by illuminating a target and analyzing the reflected light to produce mass point cloud datasets. PhoDAR uses overlapping high resolution images to measure distances between objects by analyzing similar features and patterns to produce point cloud data. All three products can be analyzed to generate land cover layers or determine the size of features and objects on the earth's surface. When combined, these products can be used to generate not only two-dimensional (2D) raster images, but also 3D models of the landscape.

As new VM applications are discovered, using a combination of these remote sensing methods and technology yields endless possibilities to assess potential issues and solve problems in and around rights-of-way (ROWs). These technological capabilities allow for a complete assessment of ROW corridors to determine potential risks to utility networks. In an industry where mitigating risks are a top priority, remote sensing technology not only provides an important analysis tool, but it also can help lead the way to solving challenging problems.

GIS Role in VM

GIS usage constitutes a multitude of entities that range from computer hardware, software, data, and personnel used to interactively capture, manage, analyze, and display geographic data. A GIS serves as a repository of location information and asset details. Location-based tracking allows users a way to visually identify exactly where assets and vegetation are spatially located and understand trends in the data as a result of current management practices (T&D World 2011). Innovative geoprocessing approaches in GIS enables decision-makers to locate issues and further analyze existing data to determine the most cost-effective approach and efficient work assignments. With a GIS, workers in the field can use mobile devices to access, view, and update information on a web map in real time or offline maps without a connection that will automatically sync updates when the connection returns.

Spatial data processing has additional capabilities, which can generate much needed summary statistics about circuits and substations up to management regions. This targeted analysis begins the conversation process of when, where, and how much focus should be given to particular areas of the network. Routine trimming cycles and line maintenance strategies can be developed using GIS analysis as a basis for strategic planning. By taking a priority-based approach to managing vegetation, cost savings can be optimized.

Approaches

For many utility companies, vegetation programs follow strict management guidelines that constitute trimming, pruning, or removing potential hazards, whether that be trees or other types of woody and non-woody vegetation (Fellers 2017). Transmission infrastructure is typically more focused than distribution since outages on those circuits would affect a much larger contingent of customers. To understand the extent of work to be completed in a given year, surveys are conducted either by walking, driving, or aerial mapping. These surveys can indicate the number of removals, linear feet of trimming or pruning, acres of mowing or the square footage of herbicide to be applied for herbaceous cover, and smaller woody vegetation.

Depending on the level of detail required, field inspections can add costs and introduce risks to employees through heat stress, insect and sun exposure, or tripping hazards. To reduce these costs and risks, aerial mapping surveys have become much more common in today's VM practices. Figure 1 compares the expected products and services that are receivable from Image Analysis, Field Survey, and LiDAR assessments.

LiDAR Data and Analysis

One of the most common remote sensing applications for VM involves the collection and analysis of LiDAR data. As a proactive approach, LiDAR data can be acquired to detect vegetation heights and assess potential grow-in and fall-in risks to conductors, thereby covering more ground while decreasing the safety hazards for field inspections. With LiDAR point cloud data, an object's height can be shown in a 3D model of vegetation, utility lines, and structures that are accurately mapped, manmade, and exhibit natural features (NOAA 2013). Given a set of clearance criteria, these assessments can analyze point cloud data to identify locations and distances of vegetation encroachment along utility corridors. Further analysis can quantify and prioritize clearance work needed along specific circuits. Using the dense point clouds, the number of trees can be estimated for trimming and removal by delineating individual crowns for dominant and co-dominant trees in the canopy. One downfall to this assessment is that understory trees tend to be underrepresented, where crowns cannot be identified accurately.

The main constraint to LiDAR analysis is the sheer cost to obtain, process, manage, and store the data. While the data is very useful for work planning and management, the bulk size of LiDAR data sets puts a strain on computer hardware and servers that other methods may not invoke. Although there are several configurations and forms that LiDAR data can be formatted when working with the point cloud data and derivatives, LiDAR is most commonly stored in LAS or LAZ files when acquired through a third-party vendor. Depending on the project size, these data can range from a few gigabytes to many terabytes. Conversion of these data formats to workable geospatial datasets creates additional storage requirements that can be hundreds of gigabytes in size, increasing the need for ample storage space.

Asset Management	Image Analysis	Field Survey	LiDAR
Powerlines		X	X
Substations	X	X	X
Towers	X	X	X
Poles		X	X
Vegetation Management	**Image Analysis**	**Field Survey**	**LiDAR**
Accessibility	X	X	X
Encroachment	X	X	X
Health	X	X	
Fall-in Risk	X(PhoDAR)^	X	X
Land Cover	X	X	X
Linear Trimming	X	X	X
Mechanical Pruning	X	X	X
Tree Density	X	X	X
Tree Height	X(PhoDAR)^	X	X
Tree Removal		X	
Tree Species	X(HSI)*	X	
Analytics	**Image Analysis**	**Field Survey**	**LiDAR**
Budgeting/Cost Analysis	X	X	X
Customer Outages	X	X	X
Hotspot Analysis	X	X	X
Work Planning	X	X	X
Deliverables	**Image Analysis**	**Field Survey**	**LiDAR**
Digital Data	X	X	X
KMZ	X	X	X
Mapping	X	X	X
Spreadsheets	X	X	X
Vegetation Segments	X	X	X
COST PER MILE	**$-$$**	**$-$$$**	**$$-$$$**

Figure 1. Comparison of Data Collection and Analysis Methods

^Tree heights can be estimated using photogrammetric processes that capture images and projects a 3D environment using a significant amount of overlap of adjacent images. Tree height estimation using images makes it possible to identify fall-in risk.
*Tree species can be mapped using hyperspectral imagery if available. Cost to acquire this data would greatly hinder the cost-effective approach to image analysis.

From point cloud data, elevations are transformed into raster grids through geoprocessing operations. Since LiDAR can penetrate foliage and similar obstructions, providing a complete 3D representation, bare earth digital elevation model (DEM), and digital surface model (DSM) can be generated to capture vegetation and other object heights. Through height thresholding, the separation of tall and short vegetation is possible, providing the ability to distinguish trees at risk of contacting the conductors. After vegetation has been processed into appropriate risk classifications, each vegetation class can be converted into polygons for additional analysis.

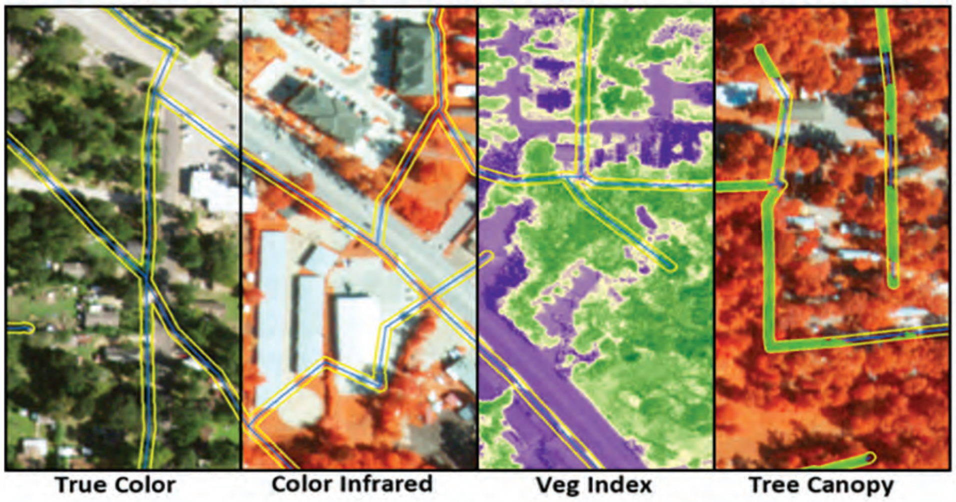

Figure 2. Processing steps to achieve tree canopy polygons for vegetation density analysis

Imagery Data and Analysis

Another method of vegetation assessment with remotely sensed data revolves around multi-spectral imagery collection and analysis. Depending on the imagery utilized, image interpretation can not only identify and classify land cover types across a large area of land, but also estimate object heights. The key word here is estimate.

Airborne LiDAR and photogrammetry are both viable methods for capturing point clouds for 3D modelling of manmade hard structures and vegetation. Although both methods produce point clouds, the manner of capturing data differs in many ways, resulting in point clouds with differing characteristics (Schwind 2018). Photogrammetric detection and ranging (PhoDAR) is a remote sensing 3D capture technology which uses photogrammetry to generate true-color point clouds by processing high-resolution imagery and interpolating known object locations within multiple overlapping photos. The potential value in this method is the powerful 3D visualization capabilities that are acquired at a lower cost and allow for faster processing turnaround time. Combined with previously acquired LiDAR data, imagery analysis can be ideal for evaluating potential vegetation encroachment locations.

In cases where photogrammetry is unable to generate accurate results, another imagery analysis method utilizes a 2D top-down, multi-spectral orthoimagery as a useful remotely sensed data source. While determining exact vegetation heights is not possible with this approach, you can complete a land cover classification and a health assessment of nearby vegetation to identify locations with higher densities of vegetation encroachment, in addition to locations of possible fall-in risks with nearby vegetation that shows signs of stress to help prioritize work along circuits. In order to provide the best extractions, the imagery would require a red and infrared band for distinguishing vegetation from other types of land cover. For VM, land cover data extracted from image interpretation can also be analyzed to identify locations of low-lying and tall vegetation types (e.g., grassland or tree canopy), which helps resource managers prioritize pruning cycles and chemical applications for effective VM.

With multiple high-resolution imagery sources attainable for little-to-no cost, this method has the ability to be replicated on a much quicker cycle at a drastically cheaper cost than LiDAR acquisition and processing. Some features of LiDAR cannot be duplicated with imagery analysis, but imagery assessment is still very much a viable option given the costs to complete a full system snapshot using the most current imagery available.

Common approaches for extracting vegetation with this method can be from machine learning training samples or vegetation indices (VI). Standard VIs include the Normalized Difference Vegetation Index (NDVI) (Tucker 1979; Running et al. 1995), Enhanced Vegetation Index (EVI) (Matsushita et al. 2007), and Soil-Adjusted Vegetation Index (SAVI) (Huete 1988; Epting et al. 2005), which are numerical indicators that use the visible and near-infrared bands of the electromagnetic spectrum and are adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not. The most frequently used index, NDVI, is a ratio (using red and near-infrared bands) ranging from -1 to 1 with vegetation being a positive value—normally greater than 0.3 (Julien et al. 2006).

For each multi-spectral image tile, a training data set or vegetation index can be calculated to determine the location of vegetation and non-vegetation cover types. After segmenting the vegetation data, tree canopy can be converted from individual pixels into grouped polygons to determine coverage within the distribution buffer (Figure 2). Polygon data are edited to correct any misclassifications that occur during the initial automated extractions. Depending on the quality of imagery sources, multiple rounds of quality control and assurance checks should be performed in order to make the data as accurate as possible.

Geospatial Processing

Regardless of the data extraction and collection process, geospatial post-processing is needed to define critical elements of any vegetation monitoring program. To determine quantifiable estimates of potential tree canopy encroachment, tree canopy density can be generated in two ways: 1) by full span or circuit using the percent of existing area of vegetation polygons within the utility corridor or 2) determining specific vegetation locations by converting the vegetation polygons into linear vegetation segments or points of interests through an automated transformation processes. In the case of linear trimming, converting polygons to a polyline format is a way to establish the length of the encroaching vegetation segments (Figure 3). Attributes can be transferred from the distribution line data to the vegetation segment data for additional queries and data summaries. This common metric, vegetation density, is represented by the percentage of the distribution line that has encroachment within the buffered distance. These density values make it possible to summarize data by feeder or circuit to help estimate and prioritize work by identifying locations along feeders with higher vegetation. By incorporating customer outage data, a proactive approach to analyzing and predicting circuits that could have a higher likelihood of multiple outages leading to increased customer minutes of interruption (CMI) and system average interruption duration index (SAIDI) metrics is a step in the right direction.

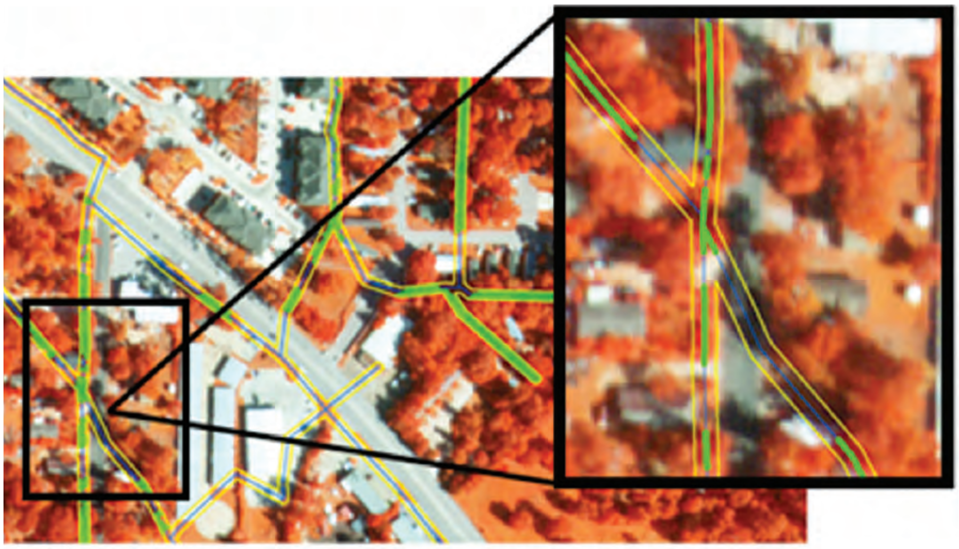

Figure 3. Transformation of Tree Canopy Polygons to Linear Trim Segments

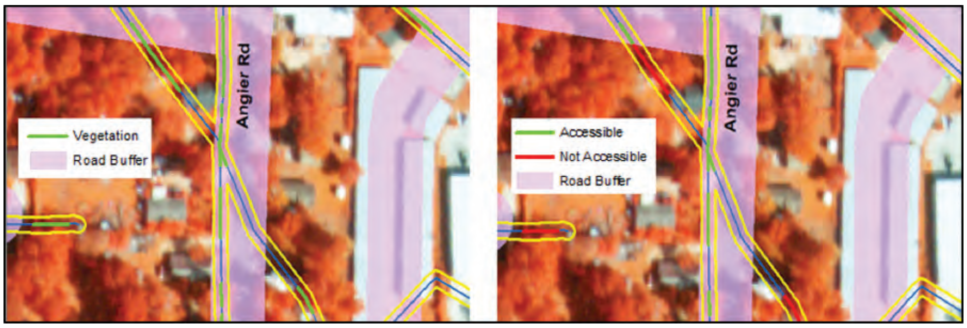

Figure 4. Accessible and inaccessible vegetation segments as defined by proximity to road networks

Vegetation Accessibility

Accessibility can be described as the ability to gain access to tree work by means of a bucket truck or other mechanical device. Using street centerline data, variable buffer distance for each road classification is implemented from the street (Figure 4). Any identified vegetation work that occurs inside this buffer can be considered accessible to a bucket truck or other type of mechanical equipment used for trimming, pruning, or removal. All other vegetation can be considered as not accessible. If a canopy trim segment is deemed non-accessible, any work associated with that section of tree canopy would need to be completed manually; for instance, by using a tree climber. In terms of budgeting and planning for tree work in a fiscal year, this metric can assist by estimating the linear footage of manual trimming vs. mechanical trimming, as well as determine safety requirement for the work to be completed. Metrics can be summarized for each feeder, substation, or management area.

Data Accuracy

Data accuracy is of the utmost importance in determining linear footage of tree encroachment and accessibility. Random check points are created along the utility lines to test for tree canopy encroachment accuracy. In order to provide a fully comprehensive accuracy result, testing of omission and commission errors needs to be conducted along the entire segment. Sampling only encroachment segments would not give an accuracy result that is fully comprehensive.

In general, LiDAR leads to more accurate mapping of vegetation heights for encroachment issues given the nature of how the data are mapped. The ability to use 3D rather than a 2D image creates an environment where it's possible to visually segment trees from other vegetation. Although this is the main limitation to using aerial or satellite imagery, referencing known spectral characteristics and relative spectral response (RSR) from different features will also provide better accuracy by determining which bands will work best for the application (Barsi et al. 2014).

Determining accuracy is twofold: spatial placement and length. Identifying the vegetation location is the first step, but to accurately assess and budget for future work, the appropriate amount of vegetation length needs to be accounted for. Testing for placement is more straightforward using imagery, but length precision requires some field testing. For past assessments, field measurements have been used to validate the methods of imagery extraction as a way to assess vegetation encroachment. Not only was spatial placement accuracy well above 90 percent, but the length was also within a distance of two meters for most vegetation encroachment data.

Common misclassifications include tree encroachment that occurred in heavily shaded areas on the aerial imagery and overextension of the LiDAR that shows tree canopy in non-vegetated areas on high resolution aerial imagery due to the span angle. Parallax in some images tends to be more pronounced, which can lead to misclassification due to "leaning" tree canopy into the encroachment area.

DISCUSSION

Management Implications

Improving Reliability Metrics

Energy companies face many risk factors for system disruptions ranging from equipment failures to vegetation, weather, and wildlife (Dokic et al. 2016). When these outages occur, utilities forgo revenues and have to bear the costs of fixing the outage quickly. This leads to commercial customers without a means to conduct business and residential customers to have complications at their residence. Within the past decade, blackouts caused by vegetation-induced outages have cost utilities billions of dollars (Campbell 2012; Dokic et al. 2016). While these outages can occur on any part of the system, the distribution network is considered to be more susceptible to outages due to the sheer exposure of the conductors to impending threats. To address this issue, the North American Electric Reliability Corporation (NERC) has begun regulating utilities to establish and enforce reliability standards. Failure to achieve reliability standards come with enforced penalties that can range from $1,000 to $1 million per incident, with some fines being assessed daily (NERC 2018).

Numerous utility companies openly acknowledge that one of the leading causes of power outages are the result of vegetation-related infractions (Doostan et al. 2018). By assessing vegetation density per circuit and prioritizing circuits by their amount of exposure to vegetation, energy companies have the ability to reduce future vegetation outages. Government-monitored and -regulated metrics, such as CMI, SAIDI, and SAIFI, are also potentially decreased as a result of this increased focus to vegetation-based failures (Combs 2017). For instance, SAIDI is measured in units of time in the course of a year, mostly in minutes. SAIDI can be reduced by removing vegetation from the worst performing circuits or by targeting circuits with high volumes of vegetation encroachment. In theory, this has the potential to reduce CMI, the numerator of SAIDI.

Work Planning

Spatial visualization capabilities of GIS technology provide an effective method of analyzing and displaying remotely sensed data to aid in developing work planning strategies. By determining the density of vegetation along distribution corridors, GIS analysis can help schedule and prioritize trimming cycles along circuits surrounded by the most vegetation, calculate vegetation distance from roads and circuit lines in order to determine equipment needs (e.g., bucket trucks), analyze required safety protocols, and provide field personnel the most efficient routes to locations identified for further inspection.

For example, when acquiring a new service territory, not much may be known about the current vegetation liabilities and maintenance needs. Using the methodology and approach described in this paper can open up management knowledge of whether or not to send field personnel for site visits. The time it would take for remote sensing to capture hundreds, if not thousands, of line miles could provide a return on investment (ROI) rather than having to pay for travel expenditures and labor costs to assess the current status of the entire system—not to mention less exposure to environmental and structural field hazards.

Safety and Equipment Needs

Safety within the utility industry is the top priority above all else. By honing the development of best management practices (BMPs) for prevention and education, utility groups have successfully reduced the numbers of incidents and deaths (OSHA).

As a proactive approach to assessing field conditions and potential safety hazards, analyzing remotely sensed data prior to traditional field inspections can preemptively reduce the number of accidents each year. Depending on the date of acquisition, remotely sensed data is essentially a snapshot in time. Although it may not represent existing ground conditions at the time of field inspections, it can—at the very least—reduce exposure to hazardous field conditions by identifying and preparing for potential hazards at specific locations. Whether for planning purposes or work requirements, field inspectors can precisely navigate to specific locations to determine equipment needs and relevant safety protocols.

CONCLUSIONS

The methods discussed in this paper are ways that utility companies can proactively plan and manage their vegetation work. LiDAR analysis is theoretically a more accurate method in terms of vegetation height identification, but the costs to repeatedly collect, process, and analyze the data can be expensive. The second method, imagery analysis, provides a cost-effective means to assess vegetation encroachment on a regular update cycle. Both methods have their benefits and drawbacks, but ultimately, it is up to the utility company to decide on the method that works for their organization and the return on investment. Ideally, LiDAR would be collected at some point to establish a baseline of current conditions of utility structures for engineering purposes with supplemental imagery analysis being used to update vegetation data as new imagery becomes available.

With a focus on improving reliability, products from these assessments will provide important information for prioritizing line inspections, as well as determining priority circuits for focused VM prescriptions, which greatly assist with cost projections and budgeting. In addition, knowing the density of encroachment along the distribution or transmission lines allows utility companies to prioritize circuits with higher density, while forecasting low-lying vegetation removal that may require potential herbicide applications. Reporting linear kilometers (or miles) of tree canopy and acreages of herbaceous cover will assist in making informed decisions when determining required equipment and budgets for ROW VM.

Making safety a top priority and reducing risks should always be at the forefront of any discussion. Ultimately, the use of remotely sensed data to prioritize field work can reduce exposure to risks as well as provide an effective approach to capturing a system-wide snapshot of potential vegetation issues.

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Data Management in a Dynamic Construction Environment

Jennifer Russell and Craig Neufeld

Keywords: Compliance Tracking, Data Collection, Data Management, Environment, Mitigation Measures, Mobile Technology, Pipeline.

Heightened regulatory and public scrutiny has increased the expectation of a proponent to effectively demonstrate compliance with project commitments and regulatory requirements, including environmental mitigation measures. The inability to demonstrate compliance can result in warnings, fines, and potentially the loss of regulator and public trust. Due to the wide variety of types of mitigation measures implemented on a single project, the data to demonstrate compliance is likewise varied in form, complexity, and quantity. Various tools are available for data collection, storage, and retrieval.

This paper discusses the types of data collected, the various tools available to be used (e.g., free online applications, Esri-based mobile mapping software, standard photographs via cameras, pen and paper, and custom-designed mobile forms), and the benefits of each in the context of construction of Enbridge's Line 3 Replacement Program. In addition to the typical data collection and management tools used, Enbridge implemented several novel technologies, including real-time mobile data collection that linked to online data storage, retrieval, and reporting capabilities. Collection of data electronically via form-based mobile applications was readily adopted by users due to the similarity to paper forms and ease of use.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

The Canadian portion of the Enbridge Pipelines Inc. (Enbridge) Line 3 pipeline was constructed in various stages in the 1960s and currently transports crude oil from the existing Enbridge Edmonton Terminal in Alberta to the Canada-U.S. border near Gretna, Manitoba. As part of the Enbridge Line 3 system-wide preventive maintenance program, the majority of Line 3 was identified for replacement (the Project).

The Project consists of replacing a 914.4-millimeter (mm) O.D. (NPS 36) pipeline approximately 1,073 kilometers (km) in length. The replacement pipeline has generally been constructed in a construction right-of-way (ROW) that parallels and overlaps the southern portion of the existing Enbridge pipeline system. The construction ROW was typically 45 meters (m) wide and was composed of a new permanent easement, temporary workspace on areas outside the Enbridge mainline corridor, and temporary workspace overlapping an existing Enbridge ROW. Associated with the replacement pipeline, Enbridge is also conducting work at several of its facilities to support the replacement and decommission the existing Line 3 pipeline.

An application to complete the Project was submitted to the National Energy Board (NEB) in November of 2014 and was the culmination of several years of environmental and engineering studies, landowner and aboriginal engagement, and regulatory consultation. Following a regulatory review process and approval, during which the previously mentioned studies, engagement, and consultation continued, construction of the Project commenced in the late summer of 2017. Construction is largely complete, with select areas of topsoil replacement, reclamation, and clean-up anticipated to continue into 2019/2020.

The Project is federally regulated by the NEB and subject to 89 approval conditions. Additionally, the Project crosses three provinces and multiple municipalities, each with their own permit requirements that have multiple conditions. In addition to the regulatory approval conditions, Enbridge made hundreds of commitments to protect the environment, satisfy landowner concerns, and engage with indigenous communities. Each of these conditions is routinely audited both in the field by the NEB as well as via information requests regarding project regulatory filings.

The expectation from the regulators and stakeholders (e.g., landowner groups and indigenous communities) is not only that Enbridge meet its conditions and commitments, but that Enbridge is able to rapidly and effectively demonstrate compliance with each. As one example, Enbridge made a commitment to a landowner group to clean equipment along the ROW for biosecurity purposes. The expectation is that not only does Enbridge maintain a record of each cleaning that occurred, but that Enbridge be able to rapidly produce records for each and every piece of equipment on the ROW to demonstrate compliance. This results in tens of thousands of cleaning records that must be readily available, searchable, and producible during an audit.

The current political and social climate in Canada regarding pipelines is one that emphasizes the need for transparency. As such, demonstrating that the intent or objective of a condition or commitment has been met is not a sufficient indication of compliance; actual demonstration of compliance fulfillment is paramount. Additionally, demonstration of the process is needed.

The types of information required by Project commitments and conditions also varies greatly, ranging from completion of environmental assessments (EA) for new land requests to geo-referenced topsoil replacement depths.

Problem

To demonstrate compliance and successfully execute the project, a large and varying array of data needed to be collected. The data used to demonstrate compliance is only as good as the data collected. Tools used to collect data that restrict the accurate collection of data inherently result in poor data used to demonstrate compliance.

Likewise, given the Project's size, complexity, varying types of data being collected, the amount of data being collected, the need for transparency, and the need to demonstrate compliance with multiple conditions and commitments, managing the data collection and storage became a significant constraint. Not only did the data need to be stored and managed such that it could be transparent and demonstrate compliance, but it also needed to be collected in a way that facilitated easy storage and rapid retrieval for reporting purposes.

And finally, while data is collected to track compliance, it is also meant to be useful to support the Project and the operation of the pipeline. Tools and management systems to collect and store data need to be useful for the day-to-day execution of the Project, as well as compatible with retrieving the data after construction is complete.

Solution

Due to the wide-ranging types of data being collected and managed, Enbridge employed multiple tools and techniques to collect, store, and manage environmental data during Project execution.

Objective

The objective of this paper is to assess how the various data collection and management tools used:

1) assisted with meeting expectations of stakeholders and regulators
2) simplified tasks of workers.

METHODS

To assess the various types of data collection and management tools used, we reviewed:

- The main types of data being collected during Project execution
- The options available for data collection
- The options available for data management

We then assessed how well each option available for data collection and management was suited for the various types of data being collected. We evaluated the suitability against two objectives:

- Meeting expectations of stakeholders and regulators
- Simplifying tasks of workers

To assist in the evaluation, we developed the following ranking system to evaluate suitability:

1. Unable to meet expectations or simplify work
2. Poorly suited to meet expectations or simplify work, but could still be employed
3. Suitably met expectations and simplified work
4. Well-suited to meet expectations and simplified work
5. Exceeded the expectations and greatly simplified work

RESULTS

Data Collected in the Field

Photographs

Photographs provide a visual record of a feature or activity that can both demonstrate compliance as well as assist in explaining an activity or feature. Photographs are trusted and relied on more so than field notes since they are more difficult to forge. Furthermore, a single photo captures more detail than can be transcribed to words. To increase the reliability of photographs for documentation, many workers use third-party applications that automatically imprint both the location and date directly on the photograph. This enables photographs to be identified later if they are saved with incorrect file names, as well as provides additional legitimacy to the photograph.

Photographs can exist in a variety of formats ranging from negatives developed on camera film, to hard copy photographs, to electronic versions. Film and hard copy photographs have essentially become non-existent as a means of collecting data given the prevalence of digital cameras. Digital photographs can exist as standalone files or imbedded within another document, such as a PDF.

GPS Locations of Point Features

The exact location of specific features is often recorded so that the locations of a feature or activity are appropriately described. Global positioning system (GPS) location data provides an exact (or nearly exact) location that can be re-located later. GPS data is independent of any local grid and requires no additional reference points, making it useful for future referencing. The exact format of GPS data does vary from latitude and longitudes to Universal Transverse Mercator (UTM) points, but in general, does provide an easy reference to a point feature.

A GPS location is simply a numerical reference to a previously established grid (e.g., Latitudes/Longitudes) and can take multiple forms. GPS locations are often simply written down during data collection. Alternatively, GPS data is often saved or downloaded from handheld GPS devices as waypoint files, which are simply an electronic files containing the numerical coordinates.

Georeferenced Polygon Features

In certain instances, a polygon feature was mapped from the field. This occurred primarily with wetland and heritage resource area delineation. Using a handheld device capable of tracking a location, the areas to be delineated and mapped were crossed while recording the specific locations.

Generally, the attributes associated with polygons mapped in the field were relatively simple and included a unique ID tag and potentially a few other key characteristics. This data was then used to assist in mapping of the features so that the location could be referenced at another date.

Environmental Characteristics

Part of work that was completed while constructing the Project was simply monitoring and recording different types of environmental characteristics during the different stages of the Project. This type of data ranged from water quality characteristics of trench water to the presence of certain habitat features on extra temporary workspace.

For example, Enbridge recorded topsoil depths at specific locations along the ROW following topsoil replacement. By measuring topsoil depths both at control locations as well as on the ROW, Enbridge was able ensure that topsoil was replaced to pre-construction depths following construction.

Another example of the type of data collected is the presence or absence of habitat features in areas of new footprint. Where new footprint was needed to support construction, Enbridge completed an assessment of the potential environmental impacts associated with construction on that new footprint. This included a site visit and documentation of habitat characteristics. The site visit, the location, and any observations were all collected and documented.

Deficiency Tracking

Throughout construction, there are inevitably areas or work completed by the contractor that did not immediately meet Enbridge standards, commitments, or conditions. These are referred to as deficiencies. To ensure that deficiencies are corrected and done so in an appropriate timeframe, specific actions are assigned to each deficiency. The status of each deficiency is tracked and monitored until it has been corrected. Data associated with tracking and monitoring deficiencies includes the status of each deficiency, observations, photographs, and action items.

Daily Activity Reporting

The monitoring and tracking of daily activities in the field is a large component of the work that the environment team completes during construction. Typically, this includes monitoring a specific type of construction activity (for example, a horizontal directional drill or the pumping of trench water) for a portion of the day, documenting the status of that activity, and identifying if any corrective actions are needed. This work is generally completed by the Environmental Inspectors (EIs) out in the field. Each EI would monitor multiple activities each day at multiple locations on the ROW.

Compliance Tracking

Certain activities, such as biosecurity cleaning, warranted the collection of data specifically to track compliance. In the case of biosecurity cleaning, the timing, location, type of cleaning, and photographic evidence of cleaning for each piece of equipment on the ROW was collected.

Types of Data Collection Tools Used

Paper/Notebook

When thinking about data collection in the field, whether it is the collection of topsoil depths or tracking conversations, inevitably a field notebook comes to mind. Writing on paper is something that people have been trained to do since grade school and so is second nature as a method used to record data. Paper and notebooks are both easy to acquire, require no training, and are dependable (they've been used for a long time successfully). The act of writing information down can also serve to reinforce the memory of that information and so may serve a secondary purpose.

However, paper can be easily lost, misfiled, or succumb to adverse environmental conditions (e.g., rain, mud, or snow). Likewise, when compiling information about multiple types of activities, often multiple forms are needed, resulting in the need to carry multiple blank pages around. While forms are one way of standardizing the type of data collected, there are limited means of validating and confirming the appropriate information has been collected in real time. To integrate data collected via paper-based forms or notes, it must be manually transcribed into a data management system, introducing the potential for error.

Projects such as Line 3 generate an extensive amount of data and information. For example, the environmental impact assessment completed for the Project application alone consisted of more than 4,000 pages of text and data. Cross-referencing data that is stored as text in pages of an application can be difficult or impossible. In addition, historical data is often used during incident investigations to demonstrate compliance or to support new project filings. The ability to leverage historical data if it is stored on paper or in text format can be quite limited.

- **Advantages:** Easy; low cost; dependable; easy access/readily available; universal; no limited learning time.
- **Disadvantages:** Temporary; difficult to organize; easy to lose pages; lack of standardization; storage post project completion; difficult to back- and cross-reference.

Handheld GPS Devices

GPS devices have become mainstream for recording geo-spatial information, and as such, are relatively easy to use by most users. Most GPS units, depending on the type and model, allow for data to be downloaded directly to a user's laptop for further processing, avoiding potential transcription errors. Geo-spatial data collected by GPS's allow for recording of accurate location data either for further integration or use, or simply for recording purposes.

However, slight changes between models and types of GPS devices can cause confusion with the less "technologically inclined" users. The quality of data collected via GPS units is dependent on multiple factors, including satellite geometry, signal blockage, atmospheric conditions, and receiver design features/quality (U.S. Government 2017). Depending on the type of GPS and the layers available for immediate viewing during data collection, there may be no way for immediate cross-checking of the quality of data collected (i.e., latitude and longitude or UTM coordinates are relatively meaningless to most people and most would not recognize an error).

Also, the ability to interact with GPS data may be limited. Not all companies have the capability or infrastructure to readily store, view, and use GPS data. As such, collection of GPS data may only be useful to some.

- **Advantages:** Accurately collects spatial data that can be immediately used and referenced (no post-processing is required)
- **Disadvantages:** No standardization of types of devices; new learning curve for each; may not transfer data well to current devices

Camera

The use of cameras to record and document activities in the field have progressed rapidly in the last 20 years. Film and limited number of photographs to be taken are no longer constraints. Digital cameras are capable of taking a large number of high-quality photographs with instant review to ensure quality. Photographs can be downloaded to a computer easily for further use or storage.

Digital cameras can produce high-quality images that can result in restrictions on file sharing due to the size of the photographs. It is possible to reduce the quality of the photographs taken; however, not everyone is familiar with that process. Once downloaded, photographs need to be named or somehow linked to activities observed throughout the day.

- **Advantages:** High-quality images; ease of use; intuitive, inherently descriptive.
- **Disadvantages:** Another device; requires daily downloading; requires daily renaming, cataloging, and associated notes.

Mapping Based Applications for Mobile Devices

The Project used a mobile web-mapping type application as a mobile map viewing tool with the ability to collect some polygon features in the field. This tool allowed for the visualization of features on a map in relation to the location of the device. Multiple features were loaded onto the map that could be searched for and found. Location data could also be collected, which could then be linked with a Project web map. This tool allowed for the use of project-specific areal imagery. Simple geo-spatial data including polygon features could be collected. When collecting multiple environmental data that needs to mapped, this tool provides the ability to quickly integrate onsite mapping with office mapping.

Like most applications, this tool required a specific account to be used. To make full use of the capability, users needed to plan their day out and download the specific imagery for that area. In the absence of collecting specific polygon features, use of this tool was limited to primarily a GPS-type device with unique maps included. While some information was able to be downloaded directly to the smartphone or tablet, the smartphone and tablet still required adequate cell coverage to fully use the spatial features.

- **Advantages:** Allowed for map viewing on smartphone; collection of polygon data; viewing of imagery.
- **Disadvantages:** Steep learning curve; used a lot of data; time consuming; lack of accuracy in remote areas; password required; inability to deviate if something didn't fit the form; requires familiarity with technology.

Form-Based Applications for Mobile Devices

Enbridge employed the use of a form-based application that could be used on smartphones and tablets. The application allowed for the collection of data and information electronically in the format of a form.

Form-based mobile applications provide similar benefits and drawbacks as paper-based forms. They prompt the user with direct information that needs to be entered in an organized way. Because the data is entered digitally, it can be easily extracted.

Similar to other applications for mobile devices, form-based applications require a base level of knowledge and familiarity with their own mobile devices as well as the applications.

- Advantages: Collects a lot of information; generally, intuitive (a form has a blank that needs to be filled in); can automatically link information from form to a database, server, or some type of data storage and management system.
- Disadvantages: Password required; inability to deviate if something didn't fit the form; requires familiarity with technology.

Data Management Tools Used

Spreadsheets

Spreadsheets are common, easily understood, and used by most users on the Project. They provide a visual way to store, track, and sort data that is intuitive and easily used. Many of the users on the Project have been working with spreadsheets for many years and are familiar with their use. Depending on the knowledge of the user, spreadsheets can be adapted to perform sophisticated functions. However, most of the use was restricted to tabulating and sorting data. Spreadsheets are commonly available via open sourced software, as well as purchased programs, and can be used to store both numerical data as well as text data.

While spreadsheets provide a way to store and tabulate most forms of data, their use can be limited once multiple types of more complicated data are being stored and accessed.

- **Advantages:** Simple; well-understood by most users; compatible on most devices; easily understood and no special training required; able to accommodate both small and large amounts of data.
- **Disadvantages:** Can lack sophistication when handling massive amounts of data; access of data by only one person at a time.

Scanned Documents/PDFs

Scanned documents are essentially electronic versions of paper documents. Storage, sharing, and transfer of these documents is therefore much easier since the transfer of storage of a physical item is not needed. Scanned documents can be more easily sorted and stored via standardization of file names.

The quality of scanned documents can often limit the ability to search for, read, and find data and information. Scanned documents provide the same benefits and drawbacks as paper, except that the document is on a screen.

PDF versions of documents are again much like paper documents, except that they are in electronic format. However, one of the benefits of a well-constructed PDF document is that it can be searchable to some extent, which can drastically reduce time when looking for specific information.

Scanned documents and PDFs are generally poor tools to store and manage data. They require a lot of effort to go through and transcribe applicable data that is needed. This can also lead to transcription errors. The static nature of the documents means that data stored is also static and can't be added to or manipulated in anyway.

- **Advantages:** Digital storage improves access; less space required to store; more accessible remotely; PDFs can be searchable.
- **Disadvantages:** Unable to add to or manipulate data; time-consuming to find and extract data; increased risk of transcription errors.

Project-Specific Websites

Enbridge developed a project-specific website that enabled viewing of data and the ability to add to select fields within a database. Data was collected in the field electronically in a format that automatically sent the data to a server for storage. The website was designed to allow viewing of the data and to generate custom reports based on that data. Each custom report was designed to meet Enbridge's specific project needs. The website was designed to be intuitive and tailored to meet the specific needs of the Project. The website was set up with certain permissions so that Enbridge could manage users' permission and ability to interact with the data. They offer custom reports as well as enabled storage and reporting on both large amounts of data during auditing, as well as daily reports for daily activities.

The website was set up exclusively for the Project and was developed to some extent, anticipating the needs of the Project. However, as the Project progressed, the anticipated needs did not always align with the actual needs, resulting in the need for revisions and adjustments. The initial roll-out was therefore somewhat rocky, as the functionality of the website was adjusted. Adjustments to one part of the website sometimes resulted in unintended and undesirable changes to another part. The level of effort to set up and maintain the website was much greater than other typical forms of data management.

- **Advantages:** Tailored to meet specific project needs; allows for custom reports; simplified daily reporting; ability to manage and track large volumes of data; ability to manage deficiencies.
- **Disadvantages:** Time-consuming to develop; required training to use; subject to technology glitches; updates potentially result in unexpected errors.

Project-Specific Web Maps

A Project-specific web map was developed for the project, which contained the environmental features that were also included on the environmental alignment sheets. It allowed the user to visualize each feature in proximity to the Project, as well as other features on the ROW. This aerial imagery provided context and setting for the user.

The web map allowed for the visualization of features and issues in relation to other features from a desktop or office setting. However, because most users were intimately familiar with the Project based on a constant presence on the Project site, the need for additional visualization tools was somewhat redundant. Access to the web map was restricted so that usernames and passwords were necessary.

- **Advantages:** Visual representation of data; easy to understand.
- **Disadvantages:** Not intuitive beyond simple viewing; repetition of environmental alignment sheets; required additional usernames and passwords.

Electronic Folders

Use of electronic folders to store and manage data requires that the data be first in an electronic file of some sort (e.g., PDF, Microsoft Word file, .jpeg, etc.). This means that the pros and cons of each of those files remain. Electronic folders have been used extensively for the Project, not just to manage and organize data and information, but to store and compile working documents. They are intuitive, easy to understand, and can be adapted for project needs.

Electronic folders are simply that—electronic folders used to organize electronic files that contain data. As such, while electronic folders can sort and organize files that contain data, they do manage raw data.

- **Advantages:** Can be easy to understand and intuitive.
- **Disadvantages:** Limited ability to manage data.

Binders/Hard Copies of Documents

Binders and hard copies of documents are used to store documents and files on site. Most of the time, these files are simply duplicates of electronic files that are on site because they can be more readily reviewed and accessed in a construction setting (e.g., environmental alignment sheets that can be scribbled on). When keeping records of items such as cleaning, binders and hardcopy forms may be kept on site for compliance tracking.

While data may be stored in binders and hardcopy files, management of that data is limited in this form. Due to the physical nature of the documents, management is limited to sorting the physical pages within each binder. Tracking and retrieving data can be time consuming.

- **Advantages:** Easy to understand and intuitive.
- **Disadvantages:** Limited ability to manage data.

Analysis of Data Collection and Management Tools to Meet Objectives

Tables 1 and 2 below summarize the ranking of the tools used on the Project according the various types of data being collected or managed.

Tools	Data Type							
	Photographs	GPS locations	Polygon Features	Environmental Characteristics	Deficiency Tracking	Daily Activity Reporting	Compliance Tracking	Average Score
Data Collection Tools								
Paper	1	1	1	3	3	2	3	2
GPS	1	5	4	1	1	1	1	2
Camera	5	1	1	1	1	1	1	1.6
Mapping applications	2	4	5	3	2	2	2	2.9
Form based applications	4	3	1	5	4	4	4	3.6
Data Management Tools								
Spreadsheet	1	3	2	3	4	2	4	2.7
Scanned Documents	2	2	1	3	1	2	1	1.7
Websites	4	4	3	4	4	4	4	3.9
Webmaps	3	2	4	2	2	1	2	2.3
E-folders	2	2	2	3	1	2	1	1.9
Binders	2	2	1	3	3	2	3	2.3

Notes: Ranking system to evaluate suitability of tools was as follows:
1. Unable to meet expectations or simplify work
2. Poorly suited to meet expectations or simplify work, but could still be employed
3. Suitably met expectations and simplified work
4. Well-suited to meet expectations and simplified work
5. Exceeded the expectations and greatly simplified work

Table 1. Ability to Meet Expectations of Stakeholders and Regulators

Tools	Data Type							
	Photographs	GPS locations	Polygon Features	Environmental Characteristics	Deficiency Tracking	Daily Activity Reporting	Compliance Tracking	Average Score
Data Collection Tools								
Paper	4	2	1	4	3	3	3	2.9
GPS	1	5	4	1	1	1	1	2
Camera	5	1	1	1	1	1	1	1.6
Mapping applications	2	3	4	2	2	2	2	2.4
Form based applications	4	4	1	4	4	5	4	3.7
Data Management Tools								
Spreadsheet	2	4	2	3	3	2	3	2.7
Scanned Documents	2	1	1	3	2	2	2	1.9
Websites	4	4	3	4	4	4	4	3.9
Webmaps	2	3	4	3	2	2	2	2.6
E-folders	3	3	2	3	3	3	2	2.7
Binders	2	1	1	2	2	2	2	1.7

Notes: Ranking system to evaluate suitability of tools was as follows:

1. Unable to meet expectations or simplify work
2. Poorly suited to meet expectations or simplify work, but could still be employed
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4. Well-suited to meet expectations and simplified work
5. Exceeded the expectations and greatly simplified work

Table 2. Ability to Simplify Worker Tasks

DISCUSSION

Ability to Meet Expectations

The ability of the different collection and management tools to meet expectations of the regulators and stakeholders differed by the type of data that was being collected. Not surprising, a mapping-based tool that was designed specifically to collect geo-referenced polygon features scored the highest for collecting polygon information. Similarly, the use of paper, GPS, and cameras, when used for their initially intended purposes, also scored high. However, when considering a single tool to collect the variety of data being collected on the Project, the form-based application scored the highest. Most of the data collected on the Project consisted of words, text, or feature information that was associated with a specific location. As such, the form-based application provided an efficient means to link that information with location data (i.e., GPS points) and photographs. The map-based application also had the ability to collect information and photographs associated with locations; however, it was unable to easily accommodate the large variety of information types. The regulators and stakeholders did not express a preference for the type of data collection tool to be used, except that data be collected and be able to be retrieved and stored. The ability of the mobile map and form-based data collection tools to feed automatically into other data management systems better met the expectations of regulators and stakeholders that data be retrieved and stored.

In terms of data management, only project-specific web maps were able to satisfactorily meet the expectations for all types of data (i.e., data was collected and could be rapidly and efficiently recalled). Spreadsheets were used to collect and manage information, particularly deficiency data, but their inability to handle photographs or link more complicated sets of information resulted in lower scores overall. The traditional means of storing information as scanned documents or in folders (or binders) did not meet the expectation that data be readily retrievable, with one exception. That exception being when there was relatively little data associated in a specific folder.

Ease of Use

In terms of ease of use, traditional tools again performed well when used for their intended purposes. For example, cameras were easy to use to take pictures and location information was readily collected by a GPS. The mobile application provided greater ease of use overall, mostly due to the ability to collect different data types within a single tool. When comparing the two mobile applications, the form-based application scored higher overall than the map-based application. This was due to several reasons:

- The data being collected was varied and often included various text fields specific to a particular activity.
- Forms built into the form-based application were structured like paper forms previously used.
- Each mobile application required a username and password, and the form-based application enabled simpler usernames and passwords.
- The form-based application was more intuitive to use than the web-based application.

Combining the ability to collect different types of information with a single tool allowed for fewer devices needed out in the field, which also simplified collection. In a similar way, because the information obtained via the mobile collection applications was automatically uploaded to a central database and server, the process and need to upload data each night was eliminated.

Regarding data management, storing data in binders, folders, and scanned document is relatively easy. However, sorting, organizing, and retrieving that data again was difficult, especially with larger amounts of data. The web map provided an easy way to visualize the location of features or data along the Project ROW, but didn't provide the ability to interact with data that was desired.

The Project-specific website was tailored to the user's work flow and therefore was somewhat more intuitive than other data management tools. Though the tool was designed and tailored to the Project, it did have several drawbacks. For example, it was still a new tool that needed to be learned.

General Traits That Encouraged Use

The expectations of the regulators and stakeholders focused more on the fact that data was being collected accurately and could be readily retrieved and reviewed, rather than the ease of use with which that data was being collected or managed. As such, expectations of were best met by tools that enabled the:

- Quick and accurate integration of data from the field to the office
- Ability to retrieve data readily for use and examination
- Ability to track and manage mitigation and compliance effectively with that data

The ability of each tool to simplify the workload of the user was dependent on traits of both the tool and the user. Because some of the tools did require learning a new system, users who embraced change tended to pick up use of the tools quicker. However, there were characteristics of some of the tools that did lend themselves to ease of use, while others did not. Key traits that simplified the user's daily workflow included:

- Reducing the number of passwords and log-ins needed
- Overall simplicity, or perceived simplicity, of the tools
- Prompts/directions embedded within the tools to help the user collect the correct data
- Familiarity of the tool with previously used tools (for example, an electronic form that mimics a previously completed paper form)
- Dependability of the tool in remote conditions
- Consistency of the tool

CONCLUSIONS

In general, the form-based application coupled with a project-specific website best met the expectations of regulators and stakeholders to collect and manage the data and also simplified the tasks of workers. Tools designed for specific purposes or a specific type of data, such as cameras, GPS, and excel spreadsheets all had valuable uses and met the expectations, but only when limited to the specific type of data they were designed for. The quantity of data collected, as well as the variety of types of data, favored tools that were more integrated and sophisticated. The success of those tools still depended on relatively intuitive familiarity and simplicity in use (i.e., did not require a lot of new learnings).

ACKNOWLEDGMENTS

We would like to thank Dan O'Neill (Enbridge) and the entire Line 3 Replacement team for their feedback, support, and persistence in developing and using these tools. It was the team that endured the challenges of tools that did not work as well as hoped and their patience that allowed for the development of tools that met the Project needs.

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GIS Mobile, Web, and Reporting Best Practices for Long-Term Re-Vegetation Monitoring: Ruby Pipeline Case Study

Michael Brown and
Rachel Newton

Long-term re-vegetation monitoring for pipelines and other linear assets can be a substantial exercise in planning, collecting, managing, tracking, and reporting field data. This paper covers how leveraging a geographic information system (GIS) as a centralized data management system for re-vegetation monitoring efforts can not only integrate mobile, web, and reporting functionality for a project, but also yield greater efficiency through reducing field data collection errors, aiding in task management, and automating deliverable production. The paper covers best practices for choosing the correct GIS technologies, establishing efficient field workflows, and designing automated data analysis and management systems by using the Python programming language within the GIS. The paper will use the Ruby Pipeline as a case study to explore these concepts and walk through how a GIS plays a critical role in the project lifecycle.

Keywords: Geographic Information Systems (GIS), Mobile Data Collection, Python, Pipelines, Rights-of-Way (ROW) Projects, Field Data Collection, Re-Vegetation Monitoring.

Environmental Concerns in Rights-of-Way Management
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INTRODUCTION

The Kinder Morgan Ruby pipeline is a 1,078-kilometer (km) (600-mile [mi]) pipeline, crossing four states, on which long-term re-vegetation monitoring has occurred for more than six years. More than 400 monitoring sites have been established along the pipeline right-of-way (ROW) to track the progress of vegetative restoration. The location of this pipeline and large scope of the project, in both size and timeline, offers many logistical and planning challenges that can be a substantial exercise in project design, field work, and the resulting reporting and analysis. While traditional methods to managing this process use a geographic information system (GIS) in smaller scope, limiting the focus of the technology to just the mapping of field data, the evolution of GIS technology, and solutions has made the system far more capable and able to be integrated in almost all aspects of the project lifecycle.

To realize more from GIS and extract its true value offering on a long-term re-vegetation project such as Ruby, the latest in GIS database, mobile, and web technologies must be leveraged. Ruby, a cloud-hosted GIS database, was utilized as the central data management system to which mobile forms, mobile maps, web maps, project management dashboards, and other systems connect. Esri's ArcGIS online cloud GIS system was used as the hosting platform for central data management and connected into the other project components by way of its Application Programming Interfaces (APIs). The ArcGIS online platform provided robust GIS database and application hosting, as well as an array of mobile data collection applications that could be used. Esri's Collector and Survey123 mobile applications were selected due to their abilities to work directly with the GIS database, operate in an offline capacity, and their pairing together to leverage both sophisticated mapping and smart form technologies in a single workflow. Finally, as field data was being collected directly into a centralized, authoritative database, off-the-shelf applications from Esri and custom Python code could be developed against the data to automate project tracking, data analysis, and reporting tasks.

This paper will discuss how a sophisticated, integrated GIS can be developed and tailored to the re-vegetation management (VM) workflows and deliverables, using the Kinder Morgan Ruby pipeline as an example, to drive greater project efficiencies and value.

METHODS

Requirements Analysis

GIS software and technology at its simplest is a toolset. While a powerful array of tools, subject matter expertise is needed to utilize those tools to build meaningful solutions to problems and challenges. The most important step to designing a full-lifecycle, integrated GIS for re-vegetation projects is to understand the workflows of the project planning, field data collection execution, quality checks of field data, analysis and summary statistics, and the reporting requirements. These are the key elements that need to be understood and the GIS architecture designed to support. In the following paragraphs, this paper will outline how the requirements analysis for the Ruby project were aligned to the cloud GIS platform and the integrated solutions built around it.

Mobile Data Collection Applications: Collector and Survey123

Requirements analysis on Ruby began by assessing the existing field workflows and developing GIS-based mobile data collection solutions, using the Collector (hereafter referred to as "Mobile Mapping Application") and Survey123 (hereafter referred to as "Smart Forms Application") mobile applications. Given that field work is where the bulk of the effort takes place on the Ruby pipeline project, this task was the most important and very detailed requirements were necessary.

Mobile Mapping Application

The Mobile Mapping Application was selected as it provides advanced mobile mapping and data collection in an offline capacity. Given the project's remoteness, the ability to work offline was a firm requirement for a mobile data collection application. The Mobile Mapping Application offered many benefits ranging from its ability to check data in and out from the cloud GIS database to its aerial base maps that could be downloaded to help field teams more easily navigate and identify their location in the field. The Mobile Mapping Application also allows for the collection of complex geometry (polygons) in the case that infestation areas need to be mapped. It can also be paired with high accuracy GPS devices to help achieve locational accuracies of sub-meter or better (Esri® 2018). The Mobile Mapping Application was used to capture data related to the following:

- Photos and Photo Locations
- Plant Species and Density
- Field Observations
- Infestation Modifications
- Access Routes

Smart Forms Application

While the Mobile Mapping Application was set up to handle the spatial data collection and navigation requirements of the project, the Smart Forms Application was selected to provide smart form functionality that made data collection workflows easier and more error proof. The Smart Forms Application has the ability to execute calculations and enforce other logical operations while filling out the forms. The Smart Forms Application and Mobile Mapping Application can also share data between the applications, allowing for spatially intelligent data collection workflows to be implemented (Chivite 2016). Examples of these functions include:

- Calculating the number of intercepts needed along a transect, using the length of the transect line, which is pulled from the Mobile Mapping Application, and passed to the Smart Forms Application.
- Pre-populate the most likely answer to a field in a form so that field teams need only fill in that answer if it is different than the default.
- Create relevancy in form questions so that certain answers expose or hide questions to help drive certain data collection workflows and streamline the data collection process.
- Required fields and appropriate form completion logic to enforce proper data collection and reduce errors.
- Spatially intelligent forms that inherit information from the Mobile Mapping Application into the Smart Forms Application, pre-populating form metadata and fields that relate to:
    - o Site ID
    - o A monitoring or control site
    - o Number of transects and quadrats at each site
    - o Number and location of photos.

GIS Database Design and Adaptation

Esri's ArcGIS Online platform (hereafter referred to as "Cloud GIS") provides a cloud-hosted GIS database that sits at the center of the mobile and web applications. The cloud database provides robust uptime and little-to-no maintenance. It also provides a simple user interface that does not require expertise in traditional GIS database technology and is packaged with powerful web application configuration tools to allow for querying, analysis, and visualization of the data. It is for these reasons that this platform was chosen over a traditional, self-hosted GIS database system.

An added benefit of working with this database system and the mobile applications is that the form design for the field data collection drives the design of the database tables, forcing a system in which mobile forms are always collecting into the database, not as individual files. This simple design enforces direct pushes from the forms to the centralized, cloud-hosted database and is what ultimately drives the value in all the other downstream solutions that will be reviewed in this paper.

Other key functionality requirements of the database include:

- Replication (or sync) to allow for offline data collection by mobile applications and registration back to the database.
- API for querying of the database tables by external systems and applications

Field Data Quality Control and Data Visualization

Given the large volume of data being collected in the field on a re-vegetation monitoring project like Ruby, efficient tools are needed to perform quality assurance (QA) on the incoming field data. QA tools need to be able to work directly with the received field data and function in an efficient workflow for the field team to find, access, and modify data requiring QA. Part of this workflow involves using summary views and infographs of the field data, which are critical to not only helping field teams spot trends or anomalies in their data, but also for remote project stakeholders to understand what is happening in the field to facilitate better project management.

To meet the quality assurance needs of the project team, web-based maps and dashboards were implemented and integrated with the GIS database. Because these tools were all web based, they could be used by staff and teams anywhere with an internet connection. This proved to be especially useful as it ensured both remote field and office teams were accessing the same authoritative view of the project data. To execute this on the Ruby project, a series of web mapping applications were designed to support the different

Figure 1. Representation of data passing between the Mobile Mapping Application and the Smart Forms Application

workflows and summary views required and a dashboard created to bring together these different applications into a single web page. The applications built are detailed below.

1. **Field Data QA Application…**A focused GIS data viewer and editor application that allows field team members to log in and validate their data within seconds of syncing it. Simple summary infographs are provided to help the team members spot potential trends or anomalies in their data and intelligent search tools prompt and guide the user to the new data requiring QA.
2. **Project Status Dashboard…** Combines summary infographs with a web map that tracks and color codes monitoring sites by their completion status. Completion status is determined through various business rules applied to the data coming in from the field by custom Python code that monitors the GIS database. This approach eliminates manual entry of status and tracks the project in an event-driven, automated way. The infographs help summarize Key Performance Indicators (KPIs) of the project so the various stakeholders see how the project is progressing and spot potential trends in the vegetation data being collected.
3. **Field Photo Viewer Application…** Pulls in all the photos from the field into a single, map-centric view, which allows the user to view photos, their location, and the data captured there. Applying a search functionality provides additional benefits to remote users and enables them to locate key sites of interest and see what the monitoring sites look like. This is especially beneficial when trying to communicate site conditions to others.

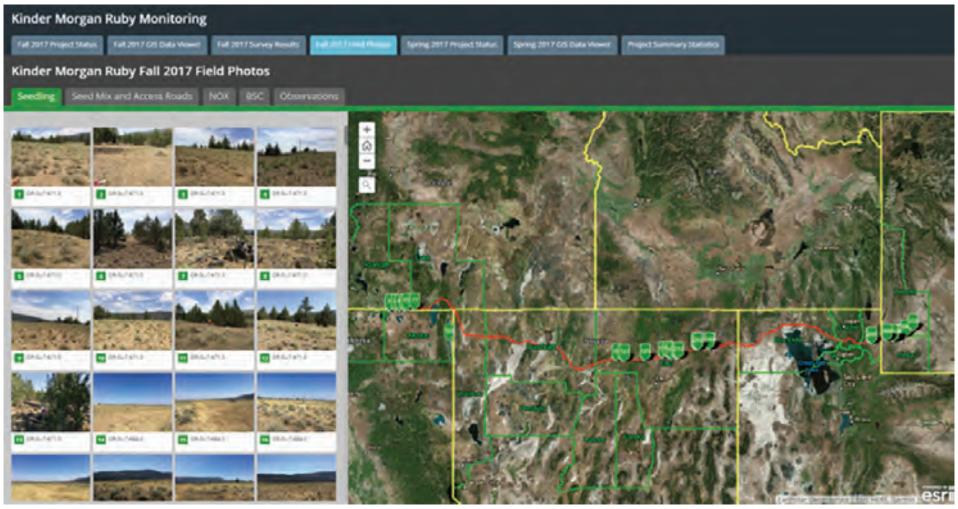

Figure 2. Field Photo Viewer Application within the project dashboard

Automated Analysis and Reporting

On the Ruby project, once field works ends, a new round of work begins with teams analyzing, summarizing, and generating reports from the field data to ultimately determine the success of the re-vegetation efforts. As the Ruby project leveraged a single, authoritative GIS database to house all this information, modern data science tools, and programming, such as Python, could be utilized to read the standardized data and execute automated data processing to generate these required summary statistics, graphs, and reports.

Python was chosen as the programming language for the Ruby project for the following reasons:

- Well-established modules for GIS software, spatial analysis, and map figure creation.
- Well-established data science modules for data handling, manipulation, statistical analysis, and plotting. On Ruby, the following modules were used:
  - Pandas
  - Plotly
  - ArcPy
  - Matplotlib
  - NumPy
- Modules for reading and writing directly from the cloud GIS database API

Python code was developed to read from the GIS database, extract, analyze, and export out the required summary statistics and graphs which included:

- Species Diversity Indexes
- Disturbance Classification
- Total Vegetative, Invasive Species, and Desirable Species Cover
- Basal, Foliar, and Canopy Cover
- Monitoring versus Control Plot Performance Criteria
- Timeseries Performance Criteria Trends

In addition to the summary statistics and plots that were generated with Python, the GIS mapping modules were utilized to automate the production of Photo Log reports. On the Ruby project, each site requires a Photo Log be generated that shows the photo location, photo direction, photo monitoring site boundaries, and other relevant project data. Performing this manually is a very time-consuming task, but with Python and the standardized GIS database, a GIS map template was created, and the Python code automated the process by reading the information from the database, loading in photos and information to the template, updating text and map extents, and exporting the PDFs.

RESULTS

This new, GIS-based approach to the Ruby project was only introduced in year six of the project and it was not clear how much benefit and efficiency the approach would create in past methods. When compared to prior years, the level of effort in the design and set-up of this system far exceeded the efforts spent previously. This high upfront investment is a natural part of developing more sophisticated and integrated systems, and a large part of why so much emphasis is put on the requirements analysis before any work is even performed. Once the project began, executing field work and ultimately, reporting the efficiencies, value added, and cost savings were recognized, and more than eclipsed the upfront expenditure.

Reduced Levels of Effort in the Field

As the project rolled out and field teams began using the mobile data collection applications and the Field Data QA Application, efficiencies and reduced levels of effort were instantly realized. Field teams were spending less time at each monitoring site collecting data as their workflow was streamlined and the intelligence built into the mobile forms made data collection more rapid and accurate. The Field Data QA Application allowed the field teams to QA their data immediately upon syncing, giving them the ability to evaluate and verify the data while it was fresh in their mind from that day's work as opposed to weeks later under the traditional approach when submitted and reviewed for report writing.

Additionally, the Mobile Mapping and Smart Forms Applications were run on small, lightweight tablets or smartphones, which reduced ergonomic strain and fatigue on the field teams compared to the previously used devices, which were bulkier and had smaller screens.

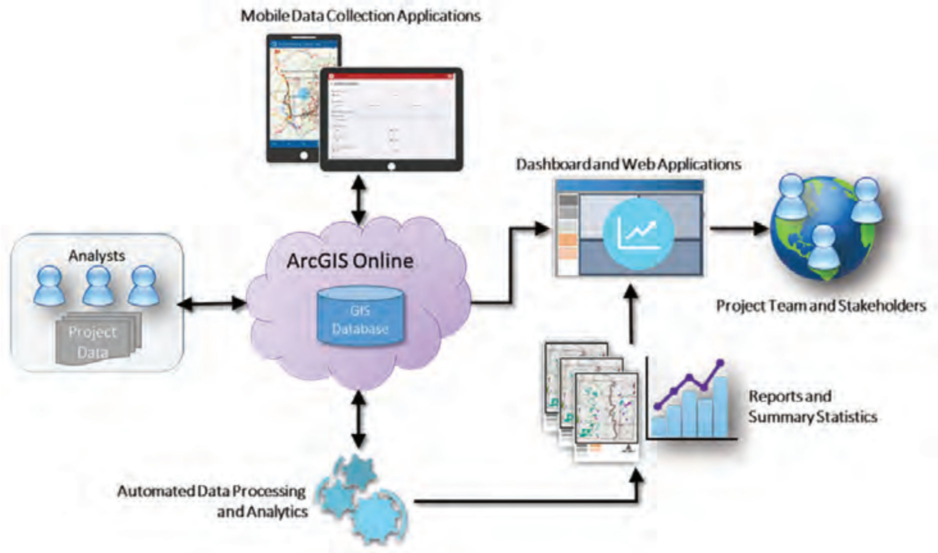

Figure 3. GIS architecture for the Kinder Morgan Ruby re-vegetation monitoring project.

Error Reduction

The smart forms standardized the way data can be entered and it enforced data collection rules, which ultimately meant the GIS database was receiving consistent, almost error-free data. Integrating the Mobile Mapping Application with the Smart Forms Application to pull in the user's location and monitoring site information from where they were standing dramatically simplified the workflow for the field team and guaranteed accurate metadata (site ID, monitoring or control site, etc.) and attribution for the vegetation data they were collecting.

Automated Data Processing and Summary Statistics

Building upon the normalized, quality data in the centralized database that resulted from the data collection workflows and techniques, Python scripts were developed to automate the data analysis and summary statistics. What was traditionally a manual task on the Ruby project was now managed by code and, in a single run of the code, would produce all the summary statistics, tables, plots, and more for the required reports. Using this approach, it took less than one week of a full-time employee's (FTE) hours to develop the Python code and generate the outputs where, traditionally, it would take one month of a FTE's time to accomplish this task.

Automated Photo Logs

Similar to the data processing and summary statistic savings from automation, the photo log reporting level of effort was reduced from two weeks of a FTE's time to less than a day of FTE time.

Ancillary Qualitative Results

The above results section notes specific metrics that were compared when establishing the cost savings to the project, but the project benefitted in many other ways as well that are more challenging to quantify in terms of true cost. Examples of this included:

- Dramatically reduced one-off map and status report requests from project stakeholders. The project dashboard and web maps allowed team members and stakeholders to log in at any time and view all their data.
- Reduced level of effort for report writers to be able to find and view site photos that needed to be referenced while writing the report.

- Simpler navigation in the field as the Mobile Mapping Application provided an aerial imagery and transportation base map that could be used to locate access roads and highways more easily.
- The Mobile Mapping Application put data at the fingertips of the field team, allowing them to look up information related to the State, County, Federal Agency, Milepost, Monitoring Site, and more.

Value Add of the Project Dashboard

Building the project dashboard in addition to the GIS database created a single, authoritative view for all team members and stakeholders to access, view, and ask questions of the data. It effectively brought transparency to the field and project data as the project team was now able to see all their data as they never could before. The resulting summary statistics and plots that were generated in the automation also generated web-based output that were integrated into the dashboard to further enhance the accessibility of the data and its results. Bringing all these key project components together in a single dashboard view helped the project team more effectively collaborate, execute, and create a value add that was not forecasted at the onset of the project.

Quantitative Overall Savings

- Between one and two hours saved per site by field team
- 90% savings on Photo Log reports
- 75% savings on field data QA-related efforts
- 80% savings on final report summary statistics, tables, and plots
  - o With the data processing system now built, the Spring 2018 efforts were reduced to two hours of FTE labor. These savings are expected for the Fall 2018 event as well, and will result in nearly 99% savings.

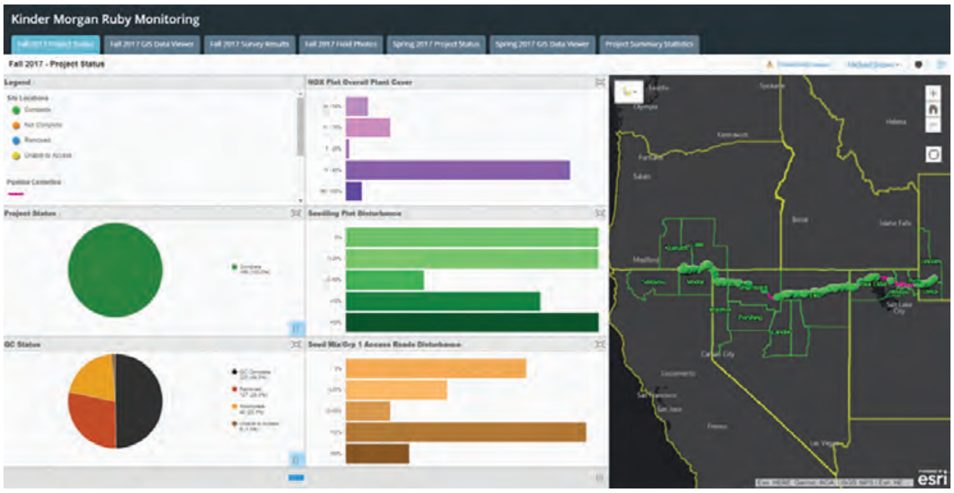

Figure 4. Kinder Morgan Ruby project dashboard showing project status, monitoring completion, field data QA completion, and field data summary statistics

CONCLUSIONS

The Kinder Morgan Ruby pipeline long-term re-vegetation monitoring project posed not only challenges in its remoteness, but also in the scope of the data collection and analytics efforts involved in the monitoring and reporting requirements. Traditional methods operated in a disconnected way with less efficient field workflows that involved many manual touch points to QA, normalize, process, understand, and report on the data. The build-out of the integrated GIS, while initially greater in level of effort at the onset of the project, ultimately provided considerable efficiencies, value added, and cost savings to the project due to the integrated way in which all elements of the project communicated and collaborated with the authoritative GIS database. By investing early in thorough requirements analysis with the subject matter experts, the individual components of the project were able to be digitized and integrated into a holistic, project lifecycle GIS that ultimately resulted in substantial cost savings and value adds to the project.

As the Ruby project continues into subsequent years, it is expected that this system will continue to increase in value as the automation and existing system infrastructure are repeatable into the foreseeable future of the project. Where applicable and of value, future enhancements to the GIS and other supporting technologies will be integrated into the solution stack to keep the system relevant and up-to-date in an ever-evolving technical landscape.

ACKNOWLEDGEMENTS

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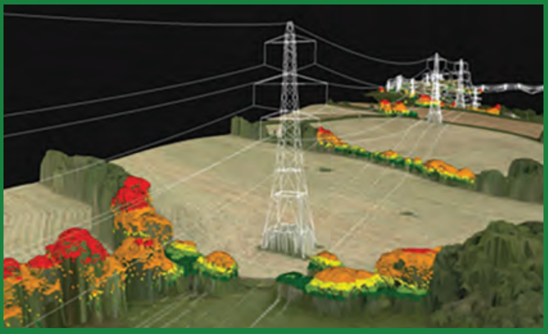
How Existing and Emerging Remote Sensing Technology Can Help ROW Planning and Management

David Campbell and
Steven Holroyd

Keywords: Aerial Survey, Classification, Habitat Mapping, LiDAR, Point Cloud, Satellite Imagery, Terrain Model.

Recent developments in airborne unmanned aerial vehicle (UAV) and satellite technology have enabled remote sensing technology for a variety of planning and management applications for rights-of-way (ROW). For planning new routes, a series of examples from the U.S. and Europe will be presented on how a mix of light detection and ranging (LiDAR), airborne, and satellite imagery has been used to accelerate the planning process and save the developer money. These examples include how the remote data have been used to create topographical models, map sensitive habitats, delineate wetlands, help archaeological investigation, and help risk assessment for ground-based works.

For ROW management, vegetation surveys are one of the key drivers for data collection. Airborne LIDAR data is already being used in vegetation management (VM) programs to help determine areas for cutting (Sohn et al. 2012), but this presentation will show how other technologies can also help. It will discuss how satellite-based imagery and synthetic aperture radar (SAR) could be used to help management of the ROW. It will look at how, by using a mix of remote-sensing technologies, ROW can be more efficiently managed both now and with emerging technology in future years.



Environmental Concerns in Rights-of-Way Management
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INTRODUCTION

Linear assets and their rights-of-way (ROWs) form an important part of the utility supply chain. As the demand for new routes and the management requirement of existing assets are constantly increasing, there has been an uptake in new survey techniques to reduce the burden on the industry. This includes remote sensing, which has the ability to provide efficient survey and monitoring techniques, helping to improve data quality and reduce survey cost.

Remote sensing involves the collection of data from satellite, aerial, drone, and ground-based platforms and now plays an important role within the industry for planning and management purposes. Techniques such as light detection and ranging (LiDAR), stereo image collection, and photogrammetry are regularly used to provide highly detailed datasets, which allow accurate measurements to be made over extended spatial areas (Lillesand et al. 2008). This paper will outline recent examples of this work and the advancements emerging technologies could offer.

METHODS

LiDAR

A LiDAR instrument can be deployed from a fixed-wing aircraft, helicopter, drone, or from a ground-based scanning system. LiDAR systems fire laser pulses and measure the time taken for the pulses to bounce back from a surface. As light moves at a constant speed, the LiDAR system is able to calculate the distance each pulse has travelled. A point cloud dataset is built by repeating this process at up to 150,000 pulses per second to create a detailed portrait of the ground or objects in the LiDAR field of view (Figure 1).

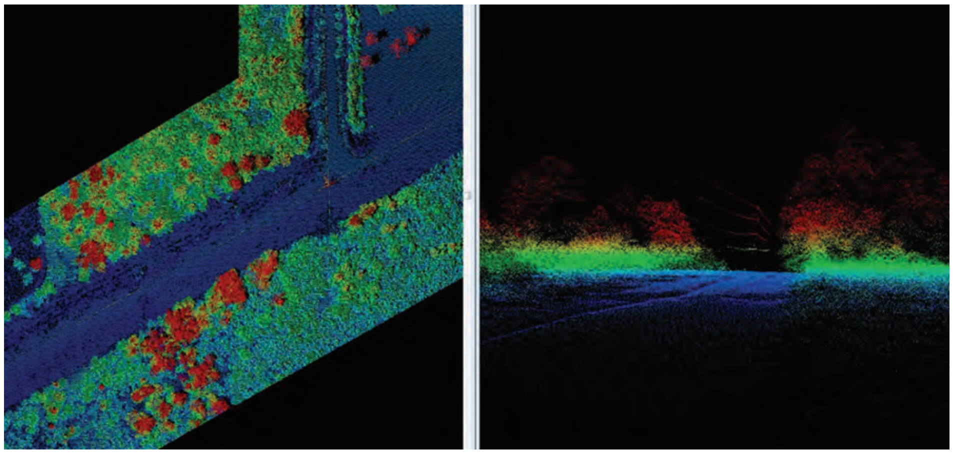

Figure 1. A high-density LiDAR derived point cloud in Florida.

In order to ensure accurate measurements are derived from the LiDAR system's global positioning system (GPS) and axis orientation, data are recorded alongside the ranging information. The data are then used to spatially reference the elevation map and correct measurements using the pitch, roll, and raw angles of the remote platform. The process creates highly detailed and accurate elevation data.

After collection and processing, points can be used to make accurate three-dimensional (3D) measurements. Common uses for ROW management include measuring vegetation proximity to powerlines and determining topography along proposed routes.

In order to aid analysis, points within the dataset can be classified based on the target they detail. Categories can be tailored to meet the needs of the survey, but common classifications include ground, trees, and buildings. A digital elevation model (DEM) is generated from the point cloud using interpolation to create a continuous elevation dataset based on the required point categories.

By categorizing and interpolating points in this way, two types of DEM can be generated from a single LiDAR point cloud. These are digital surface models (DSM) and digital terrain models (DTM), (Lillesand et al. 2008). DSM datasets contain all the objects within the survey area including trees and buildings. They are created by interpolating a continuous surface between all points collected by the LiDAR sensor. DTM datasets employ specialist algorithms to remove any objects other than the ground surface in order to show a bare earth model of the landscape. This ability can be of particular use to developers as DTM datasets show the potential ground topography if objects were to be removed or demolished. DTMs can also be used to model other considerations, such as local watersheds, which are not impeded by vegetation.

Photogrammetry

The process of photogrammetry uses stereo overlapping imagery collected from fixed-wing aircraft, helicopter, drone, or via a ground-based photographic strategy. The imagery collected will detail all sections of the survey area within several photographs. Specialist photogrammetry software can then be used to perform a pixel matching algorithm, combining the images into a point cloud dataset. The data is combined with GPS and platform orientation data to create highly detailed and accurate point cloud information.

The photogrammetry process is also able to incorporate images collected in an oblique manner. Oblique images can offer a different perspective for the analysis of ROWs when compared to more traditional vertical imagery, detailing elements such as tree undercut. The images are collected and processed in the same manner as vertical stereo imagery, but the incorporation of oblique perspectives allows the software to create point cloud data in areas otherwise obscured from view.

Using a process of point cloud classification photogrammetry can also be used to create both DSM and DTM datasets. In addition to the elevation datasets, the photogrammetry process can also generate a seamless ortho-mosaic of the survey area. Ortho-mosaic imagery shows a top-down perspective of the route, which can be used to generate a range of different outputs, including habitat and wetland maps. It can also be used to detail areas with archaeological interest. Datasets generated via the collection of LiDAR or via photogrammetric processing form a permanent record of the landscape, which can be used to guard against landowner litigation.

Satellite Imaging

Satellite imaging offers a valuable source of data for route planning purposes. There is a wide variety of satellite platforms available which carry a range of sensors. The suitability of the data collected is dependent on the image resolution, spectral information collected, and cost (Lillesand et al. 2008). Optical satellite image type ranges from high-cost, high resolution (up to 35 centimeters [cm] GSD) imagery to freely available (up to 10 meters [m] GSD).

Optical satellite data is often simple to use as the data is commonly available in an "off-the-shelf" format where the provider has undertaken key processing steps such as ortho-rectification. This allows the user to simply purchase data and proceed directly to the analysis phase of their work. There are, however, some datasets which can deliver additional information such as topography if additional processing phases are undertaken.

High-resolution optical satellite data has a similar capability to data collected via aerial survey. Scenes which are collected with a stereo strategy can be combined to create an ortho-imagery using specialist software. Data purchase costs for high-resolution data can be high and are often comparable to the cost of a dedicated aerial survey, given that most high-resolution satellite systems collect data via specially commissioned tasking.

Low-resolution satellite sensors have significantly reduced data purchasing costs (Gugerty et al. 2016). Some programs, such as Landsat and ESA Copernicus, make their data freely available and continuously collect imagery. This has created a large volume of data for high-level assessment of potential routes which can be used to control project costs and focus additional survey in areas where it is of most value. Both high- and low-resolution optical satellite systems are impeded by the presence of cloud, which restricts their ability to reliably provide data when required.

A key benefit of optical satellite systems is the continuity of data collection, which can provide historical data covering proposed ROWs. For example, NASA's Landsat program can offer a range of data types with a starting date of 1972. More recent developments have seen the introduction of the European Space Agency Sentinel 2 system (European Commission 2017). This has led to the availability of large volumes of 10 m GSD data, suitable for monitoring high-level land cover changes.

More detailed imagery is available through satellites such as the Worldview constellation, but they have a lower volume of archive data. This is due to the smaller image swath width covered by high-resolution sensors and the nature of their operation, which relies on commissioned tasking rather than continuous collection.

Synthetic Aperture Radar

Synthetic aperture radar (SAR) can be deployed from satellite, fixed-wing aircraft, helicopter, drone, or ground-based platforms. SAR systems emit and record the return of radar waves in different polarities. SAR systems measure the return time of the waves and their reflectance intensity to build an "image" dataset. A key benefit of SAR systems is their ability to penetrate cloud cover and collect data during the night due to the frequency of the radar waves they utilize. This has led to an increasing usage of SAR as they offer a more reliable source of data when compared to traditional optical sensors.

RESULTS

Proposed Routes

Remote data is commonly used during pre-works assessments to determine optimum routes for proposed ROWs. APEM have undertaken several projects for this purpose, utilizing a range of remote technologies to generate a number of differing outputs. The projects outlined below show examples of the usage of remote data to provide cost-effective investigations for route-planning purposes.

LiDAR

An example of the usage of LiDAR data for route-planning purposes was the West Cumbria Pipeline project. The purpose of the project was to provide a pre-construction survey record of land condition and topography along two potential pipeline routes. The longest survey route was 64 kilometer (km) long; the shortest was 38 km long. The average width of each area was approximately 50 m.

The two routes were both covered by a single helicopter flight. The LiDAR system deployed for this project acquired data with a mean point density of 12 points/m2. The vertical accuracy of the point cloud produced was +/- 0.10 m with a vertical accuracy of +/- 0.05 m. The data outlined the topography of each of the potential routes, allowing planners to assess the relative challenges each ROW would present during development. This included the presence of vegetation, pre-existing structures, or the requirement for landscape change.

After collection, points within the cloud were classified to allow for the generation of a DTM.

Airborne Photogrammetry

Photogrammetry was used to provide five cm GSD ortho-mosaic imagery covering a 200 m buffer along a 677-km ROW in Northwestern U.S. High-resolution multispectral ortho-mosaics were created from the imagery which were used to create a land cover classification maps.

Given the detail and multispectral nature of the ortho-mosaic data, a two-tier classification schema was developed to provide a comprehensive overview of the habitat types in the survey area. Tier 1 classes included broad habitat groups such as grassland and farmland, and Tier 2 classes provided more detailed descriptions of the specific land use (e.g., arable or pastoral farmland). A separate wetland classification was included to delineate areas of water.

Satellite Imaging

Data obtained by optical satellite imaging is widely used across land investigation projects. Outputs produced using satellite-derived datasets have included habitat and land cover change maps. Figure 2 shows an example of a satellite-derived land cover classification. Utilizing data captured by the ESA Sentinel 2 data, a process of supervised image classification was undertaken to generate a land cover map of an area of river catchment. High-level datasets can be used to target more detailed survey (for example, by highlighting forested areas along ROWs where a higher risk of tree ingress would exist).

Another example of the capability of satellite imagery to monitor land cover changes is shown in Figure 3. The Figure shows an area of moorland

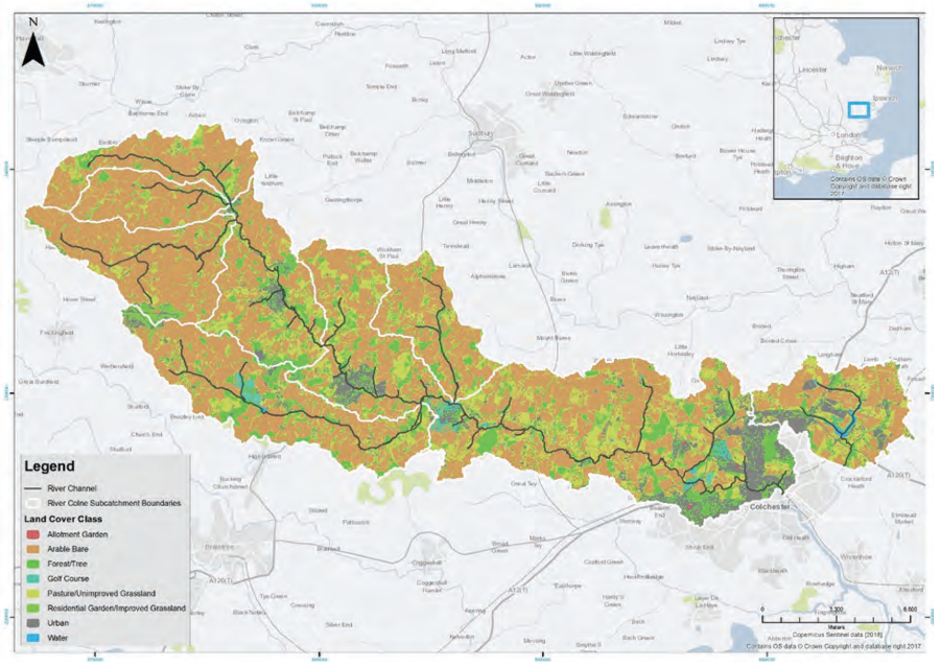

Figure 2. A high-level land cover classification map

Figure 3. An area of moorland prior to (left) and following (right) fire damage

directly prior to and following a fire. The dramatic changes within this landscape took place within several days, but the frequency in return time of the Sentinel 2 system was able to document the event in progress and provide archive imagery to show the moorland in its original state for comparative purposes.

VM

LiDAR is the most commonly used remote technology for VM purposes. As outlined above, LiDAR has the ability to provide highly detailed and accurate measurements across large areas at relatively low cost. However, there are several other remote technologies which can generate valuable data for VM purposes as outlined in the examples below.

Airborne Photogrammetry

In order to demonstrate the capability of photogrammetric aerial survey for ROW management, a survey of approximately 50 km of cable route was completed. The survey collected a total of 4,700 vertical images with a resolution of five cm per pixel.

With the inclusion of 93 ground validation points along the survey route, a point cloud dataset was generated with an overall accuracy of +/-0.14m. Automatic 3D proximity measurements were undertaken using the point cloud dataset.

This process determined the location of vegetation which fell within an acceptable threshold distance of the overhead lines (Figure 4). The closest point along the route was found to be 3.48 m with eight m^2 of vegetation coverage falling within four meters of a cable. This efficient survey method saved the management company time and money when compared to a manual walkover method, provided more accurate proximity measurements, and produced a permanent record of the findings along the survey route.

The project also used the creation of DSM and DTM elevation datasets to calculate the vegetation height along the ROW. The vegetation height information was used to highlight trees with a falling arc capable of interacting with the cables. A total of 184 m^2 of tree coverage was highlighted using this method.

In addition to exploring the capabilities of vertical stereo image processing, a project detailing an 11-km ROW near Newburg, New York was undertaken using an oblique aerial camera system. This system photographed the route with an offset from vertical of up to 45°, providing a view of tree undercut and trunk diameter. The survey was completed within an hour collecting a total of 12,447 images.

The project also included the use of satellite imagery to perform on-going, high-level monitoring of vegetation along the cable route. Using Sentinel 2 imagery, a process of automatic change detection was used to monitor the ROW for any large-scale changes such as tree removal or flooding.

SAR imagery collected by the Sentinel 1 system was also sourced to fill data gaps during periods of cloud cover. This demonstrated that change detection and land cover classification could still be undertaken regardless of cloud and lighting conditions, allowing regular monitoring to take place.

Figure 4. Points in violation of the accepted threshold distance highlighted

CONCLUSIONS

The work undertaken during the projects described in this paper has found that a mixture of remote sensing platforms and sensors can be used to provide valuable data for the planning and management of ROWs.

The survey of the West Cumbria Pipeline Project demonstrates that LiDAR point cloud data can provide horizontal accuracies of +/-0.10 m and a vertical accuracy of +/- 0.05 m, with the inclusion of ground-based validation points. The point cloud data generated was able to provide a detailed overview of potential ROW routes, allowing their relative merits to be assessed in a cost-effective manner.

The potential of photogrammetrically derived datasets for landscape and habitat assessment was also demonstrated in the Northwestern U.S. Producing ortho-mosaics with a spatial resolution of five cm GSD to provide an evidence base with sufficient detail to create two-tier habitat maps. The capability of photogrammetry to provide highly accurate three-dimensional measurements for VM purposes was also demonstrated, with an overall accuracy of +/-0.14 m.

Optical and SAR satellite systems were also shown to provide useful data for ROW planning and management purposes. The freely available data from the Sentinel 1 and 2 systems was used to provide regular monitoring of a cable route, providing habitat overviews, and assessing for any large-scale land cover changes.

ACKNOWLEDGEMENTS

The authors would like to thank the work undertaken by the remote sensing scientists and managers at APEM for the research and project work undertaken that allowed this paper to be written.

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Remote Sensing Technological Solutions to Protect ROWs in a Changing Environment

Jennifer Whitacre and
Eric Brown

Keywords: Catenaries, Hyperspectral Imagery, LiDAR, Remote Sensing, Right-of-Way (ROW), State Responsibility Area (SRA), Thermal Imaging, Visible Near-Infrared Hyperspectral Imagery (VNIR).

This paper will discuss threats posed to utility infrastructure and factors, such as evolving climate conditions and how to prepare a comprehensive plan to effectively respond to ongoing environmental and weather events. Today, remote sensing technology provides advanced capability to spatially assess vegetation and infrastructure health, allowing for a greater understanding between man-made infrastructure's relationships with the natural world. This relationship involves responding effectively to an ever-evolving ecosystem that is comprised of dynamic precipitation, temperature, and humidity patterns. These patterns contribute to a more volatile, imminent risk to transmission and distribution (T&D) right-of-ways (ROW). Thus, this should be taken into consideration when planning mitigation strategies to minimize the detrimental effect of winds, fires, floods, and landslides (Matikainen et al. 2016). New and improving technologies, such as light detection and ranging (LiDAR), thermal, ortho, and hyperspectral imagery contribute to establishing multifaceted, highly accurate models to assess risk based on identifiable and predictive conditions (Matikainen et al. 2016). These models, paired with cost and operational drivers from utilities, aid in predictive analytics for actionable efforts in the field. Sacramento Municipal Utility District (SMUD) and Quantum Spatial (QSI) will discuss how they have used these methodologies to understand unique threats to their systems with tailor-made deliverables. A couple of examples of these deliverables are the following: drought-intolerant danger trees within ROWs and aerial tree canopy threats that can originate outside of the ROW to threaten the electric high-voltage system.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

In 2017, the Sacramento Municipal Utility District (SMUD) and Quantum Spatial (QSI) partnered for a remote sensing project to provide light detection and ranging (LiDAR) and hyperspectral coverage of SMUD's 69-kiloVolt (kV) sub-transmission high-voltage system and the high-voltage distribution network throughout the State Responsibility Area (SRA) located inside of SMUD's territory. The goal of the collection was to utilize remote sensing data to reduce risk related to vegetation encroachments, improve public, employee, and contractor safety, electric regulatory compliance and reliability, improve patrol (inspection) efficiency, update SMUD's vegetation management (VM) workflow capabilities, spatially rectify the electric assets, and identify specific tree species and health of vegetation that exists within the SMUD territory (Delaney P and Walker B 2013). SMUD had worked with LiDAR imagery in the past, but had not utilized it to its full potential. Historically, SMUD only used LiDAR for the mandated North American Electric Reliability Corporation (NERC) alert and a subsequent flight on electric transmission circuits for vegetation clearance detections. Distribution is a relatively new market for LiDAR that comes with new challenges and benefits (F Bologna 2015). Distribution lines run close to homes and neighborhoods where trees and vegetation interfere. There are also many wires that are strung along the poles—primary, secondary, guy, communications, etc. This makes modeling the distribution lines more complex. Acquiring LiDAR for distribution provides a good insight into the system's risk profile, which can yield additional by-products for different business units and contribute important information that can be used for budgeting and planning work. QSI contracted with SMUD in 2017 for a five-year comprehensive remote sensing and

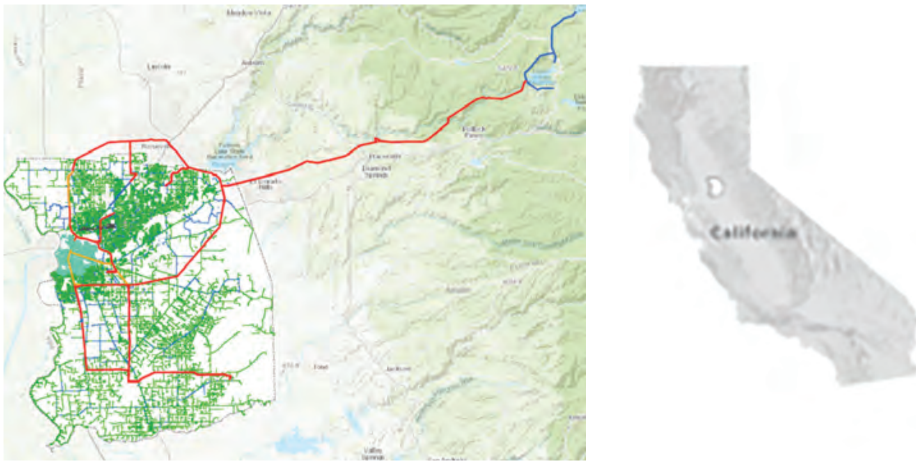
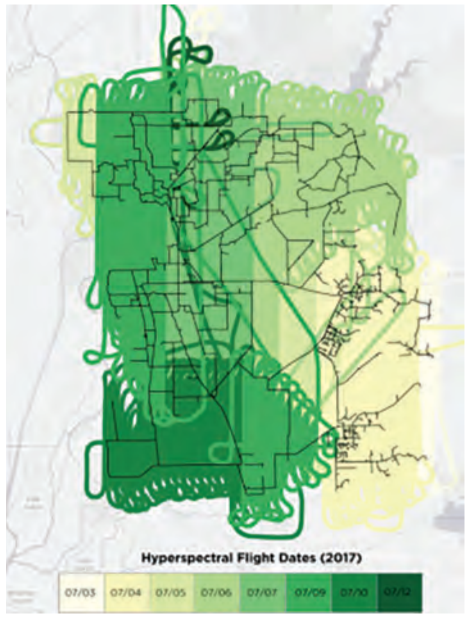


Figure 1. SMUD's transmission and distribution (T&D) system and SRA



LiDAR Survey Results	
Sensor	RIEGL VQ-1560i
Aircraft	Piper PA-31 Navajo
Altitude	1,200 Meters AGL
Aircraft Speed	140 Knots
Swath Width	1,386 Meters
Percent Overlap	60%
Laser Pulse Rate	2,000 kHz
Scan Rate	365 Hz
Field of View	60 degrees

HSI Survey Results	
Aircraft	Cessna 208 Caravan
Sensor Manufacturer	Headwall Photonics
Unit	Visible Near-Infrared
Sensor Array	Scientific CMOS
Wavelength Range (nm)	401-1011
Spectral Channels	114
Across-Track Pixels	1,860
FOV	29.35°
Targeted AGL	1,700 m
Resolution (VNIR/SWIR)	0.5m / 3m
Spectral Bands (VNIR/ SWIR)	111 / 130
Horizontal Accuracy (VNIR/ SIR)	< 1.5m / < 7.5m

Figure 2a–2d. Platform and Sensor's Parameters and Schedule

LiDAR program. During the first year, LiDAR and hyperspectral acquisition took place with the potential to move the program forward in the coming years.

The main objectives of this program were the following:

- Develop remote sensing analytics to pinpoint data where current VM conflicts exist and future opportunities to further improve public, employee, and contractor safety, as well as electric reliability system wide.
- Leverage technology to mitigate outages.
- Create new "species-based" targeted VM patrol programs.
- Provide quality control of both in-house vegetation inspections and contracted tree work.

METHODS

Acquisition

Remote sensing technologies that were utilized for this work included LiDAR and hyperspectral imagery. QSI also provided proprietary work management software, inSITE.

After receiving the targeted feeders (asset data) from SMUD, QSI began the flight planning process. Thorough mission plans were developed using optimized data acquisition techniques, modifying pulse rate, flight altitude, and aircraft speed to accommodate the terrain and location of the survey area. Mission planning was designed to optimize flight efficiency while meeting or exceeding project accuracy and resolution specifications. During this process, mission planners considered GPS constellations, terrain ruggedness, environmental constraints, and all available resources. In addition, a variety of logistical barriers were anticipated, which required permitting, coordinating to abide by airspace restrictions, and planning acquisition personnel logistics.

Ground control surveys were conducted, including acquisition of monuments and ground survey points to support the airborne acquisition. Ground control data were used to geospatially correct the aircrafts' positional coordinates and to perform quality assurance checks on the final LiDAR data. The spatial configuration of ground survey monuments provided control within 13 nautical miles of the mission areas for LiDAR flights. Monuments were also used for collection of ground survey points using real time kinematic (RTK), post-processed kinematic (PPK), and fast static (FS) survey techniques. Monument locations were selected with consideration of satellite visibility, field crew safety, and optimal location for ground survey point (GSP) coverage.

QSI utilized four monuments for this project. Any new monumentation was set using 15.875 millimeters (mm) by .762 762 mm (5/8 inches [in] by 30 in) rebar topped with stamped 63.5 mm (2-1/2 in) aluminum caps. QSI's Professional California Licensed Land Surveyor certified the establishment of all monuments. Ground survey was completed on June 11, 2017 prior to data acquisition. All static control points were observed for a minimum of one two-hour session and one four-hour session. At the beginning of every session, the tripod and antenna were reset, resulting in two independent instrument heights and data files. Fixed-height tripods were used when available. Data were collected at a recording frequency of one hertz using a 10-degree mask on the antenna.

The LiDAR survey was conducted with a RIEGL VQ-1560i LiDAR sensor using a Piper PA-31 Navajo aircraft. The LiDAR system settings and flight parameters were designed to yield high-resolution data of greater than 20 pulses per square meter (m) over terrestrial surfaces. The LiDAR coverage was completed with no data gaps or voids, barring surfaces that are non-reflective at the laser-emitted wavelength, such as water. Data collection began on July 6, 2017 and was completed by July 14, 2017. All QSI LiDAR systems were calibrated per the manufacturer and our own specifications, and then tested by QSI for internal consistency for every mission using proprietary methods.

Along the electromagnetic spectrum, QSI collected from visible to near-infrared (VNIR) hyperspectral imagery from a Cessna 208 Caravan. In order to ensure consistent illumination, QSI only acquired data when skies were clear over the area of interest and the solar elevation angle was greater than 30° above the horizon (~1000 to 1600 PDT). Compared to traditional broadband multispectral (3- or 4-band) imagery surveys, QSI utilized a narrow-band hyperspectral imaging spectrometer, which recorded reflected energy from 400 to 1000 nanometers (nm) across 114 narrow bands.

The average ground sample distance (GSD) for the imagery was 0.5 m (~1.6 feet [ft]). QSI ground crews placed a set of bright (45 percent reflectance) and dark (three percent reflectance) reference aerial targets to improve image calibration and consistency from one AOI to the next. Hyperspectral data collection began on July 3, 2017 and was completed on July 12, 2017. QSI analyzed approximately 810 line miles of 12 kV and 69 kV feeders of hyperspectral data to identify Palms, allowing for species-based targeted VM efforts.

All 900 square miles of hyperspectral and LiDAR data were collected within 10 working days.

ANALYSIS

QSI's LiDAR-derived products calculated conductor clearance distances along the 69 kV and 12 kV systems. The analysis identified trees/vegetation that had the potential to strike SMUD conductors and cause an outage. The basic work flow started with the LiDAR-rectified feeder shapes as the foundation for following analytics. The LiDAR data are used to adjust/correct positions of the poles and verify the current geospatial data for accuracy. Feature data is classified in the LiDAR data to model features, such as wires, poles, vegetation, and the ground. The insulator or pole attachment points are modeled, which provide the start and end of each catenary wire model. Distribution wire catenaries are generated to model the conductors and analyze adjacent vegetation for fall-in, grow-in, and overhanging tree limb detections. In some cases, the conductor material does not provide many LiDAR returns to the sensor. When this occurs, QSI uses regression modeling to estimate each wire's position using horizontal tension, insulator spacing, and span length. Catenary wires are strung using CADD modeling software. The modeling was completed for as-flown conditions and was not of engineering grade. The models represent a realistic, highly accurate conductor position that is based on the range of typical operating temperatures and variance. The catenary vectors are visually inspected to control for misidentified features, communication wires, and secondary wires.

Vegetation features were extracted from the point cloud for clearance detection analysis. Using point cloud geometry, spatial distribution patterns, and neighborhood analysis, datasets of identifiable vegetation crowns were delineated. Each tree was assigned a unique tree ID, and geospatial signature, which allows for year-to-year comparisons, growth measurements, and change detection analysis.

The clearance assessments detect vegetation infractions within a variable width right-of-way (ROW) based on trees ≥12 ft. Utilizing information derived from the LIDAR, analysis was run on all 69 kV and 12 kV conductors identified as primary wires in the data. SMUD and QSI worked together to develop specialized vegetation detection criteria to locate vegetation that could pose a risk to the network based on proximity to wires, tree height, and position in relation to wire (Table – Left). The assessment took into consideration three different categories of vegetation threats. Zone 1 identified vegetation within 1.5 ft of a primary wire; Zone 2 identified vegetation 1.5 to 4 ft from wire; and Zone 3 identified vegetation encroachments 4 to 12 ft from wire.

Vegetation Encroachment Categories:
At the time of flight, vegetation was encroaching on a primary wire:

ZONE	DESCRIPTION
1	Within 1.5 ft
2	1.5 - 4 ft
3	4 - 12 ft

Overhang*: A tree is found to have a branch overhanging up to 12 ft above a wire and within half a foot on either side of the wire

Fall In*: A tree is found to have the potential to fall across the line based on proximity to wire and tree height.

*Fall-in and Overhang included and attributed in addition to other vegetation parameters

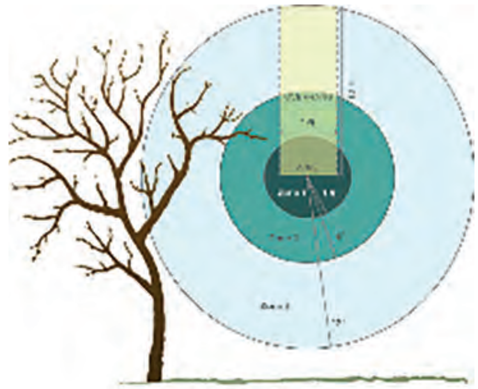


Figure 3a–3b.

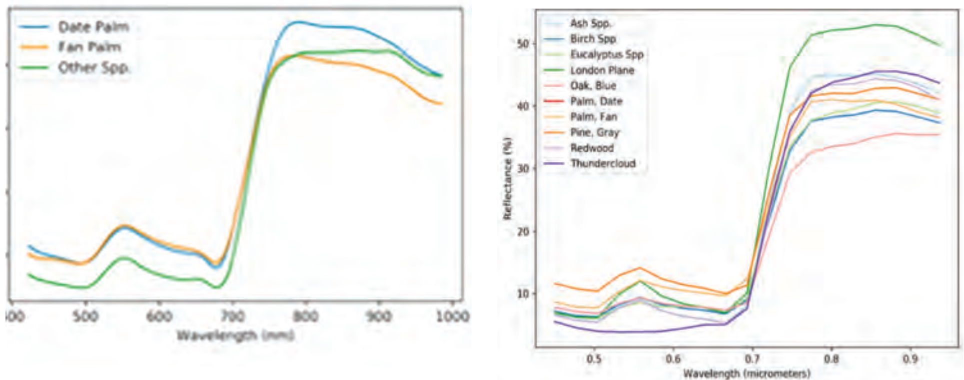


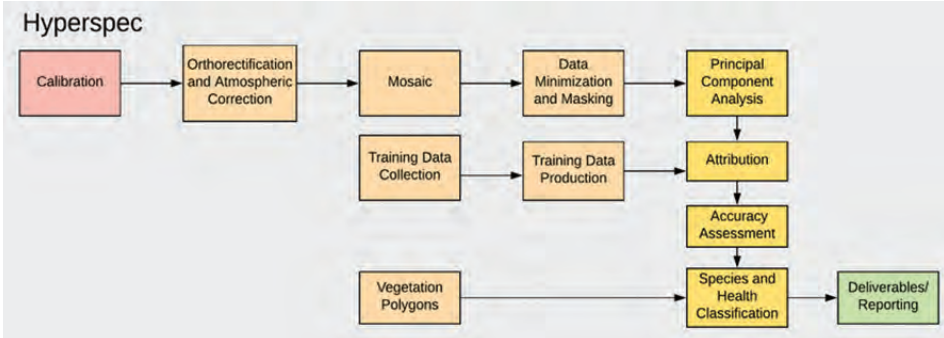
Figure 4a–4b.

The assessment used 3-D CADD models derived from the LiDAR to identify and calculate zone infractions. The detection parameters were calculated for the system conditions at the time of flight, so that each detection could be pinpointed to individual trees and attributed with codes for encroachment zones, fall-in potential, and over-hang. Due to the nature of algorithms used to rapidly process LiDAR data and the potential for noise points, the possibility of false positive clearance detections does exist.

The initial hyperspectral scope of work included review of 27 different tree species in two regions of the SMUD territory. The regions were the urban/north and the rural/south region. The 27 tree species were identified by SMUD as priority trees with high outage potential. Due to the high number of target species, it was extremely hard to manage the spectral signatures within each region. QSI and SMUD collaborated to refine the model to focus on one of top priority outage trees. This new model would allow for a species-based VM patrol effort.

Hyperspectral data processing requires a robust training dataset. These data sets contain field-verified locations that are used as examples to influence a machine learning model. For this training data set, QSI incorporated SMUD's field feedback, which enhanced the training dataset for Date and Fan palm species.

A simplified, trifurcated model placed date palm, fan palm, and all other species into three categories for classification. After palm attribution, detection analysis was run on all of the affected feeders. If a tree was not a palm, it retained original species and detection results. In the case of a tree triggering detections on multiple feeders, the most severe detection code took priority.



Palm Tree Encroachment Categories:
At the time of flight, a palm tree was encroaching on a primary wire:

PRIORITY	DESCRIPTION
1	Under/Over/Side Growth Less than 1.5 feet
2	Side-Growth Within 50 feet and above wire
3	Side-Growth Within 50 feet and below wire
4	Under-Growth Within 12 feet of wire

ZONE	DISTANCE TO WIRE	12 kV TOTAL	69 kV TOTAL
1	Within 1.5 feet	9	---
2	1.5 - 4 feet	114	76
3	4 - 12 feet	4,234	6,789
Fall-ins	Within 100 feet	2,786	2,836
Palms	Within 50 feet	65	1,299

Figure 5a–5c.

RESULTS

SMUD's contract specification for the project's absolute vertical accuracy at 2 sigma was 0.15 m. Utilizing the 103 ground survey points collected in the AOI, the data's vertical accuracy at 2 sigma was 0.047 m. QSI's targeted 20 points per m2 collection specification was accomplished with acquisition of a LIDAR dataset with an average point density of 31.8 points per m2.

All data was delivered to SMUD utilizing

QSI's proprietary software tool, inSITE. This tool was provided to SMUD's VM team to deliver secure, enterprise-wide access to LiDAR and hyperspectral imagery analytics in addition to tracking the progress of field validation and tree work for LiDAR-guided patrols.

By the time the deliverables were provided (nine weeks later), SMUD had

already completed their ground patrol, which is where SMUD's VM inspectors perform a ground inspection of the lines to ensure encroachments are, at a minimum, greater than four feet from the wire to ensure compliance with mandated state regulatory requirements and electric reliability. The clearance analysis from the LiDAR was used to QC the work already performed by both the SMUD VM Planner and the contracted tree crew.

The LiDAR did find nine trees that were potential public safety threats. Of these nine trees, eight were listed by the SMUD Planner, but not yet worked by the contract tree crews and one that was not listed (missed) by the SMUD VM Planner. All nine tree detections were Zone 1 grow ins on 12 kV lines. There were approximately 190 Zone 2 tree grow ins. This is where vegetation is as close as four feet from the wire.

For the Internal Grid Asset (GIS) program, spatial conflation, and pole location, approximately 16,135 poles were found. The results of this process are located in Figure 6b. This product is a good way to internally leverage the LiDAR data across different business units inside the utility. The pole data are assigned original SMUD IDs to be consistent with GIS databases. The span data was spatially rectified to more accurately reflect their location based on the newly collected LiDAR data (Matikainen et al. 2016).

Due to the high number of priority species, it was extremely hard to manage the spectral signatures by each ecoregion. QSI and SMUD decided to refine the hyperspectral model to focus on an individual priority species. Date and Fan Palms have an extremely high number of historical outages associated with them. The individual-species palm identification yielded more than 1,300 trees instead of 46 when looking at 25+ individual species. QSI and SMUD worked together to help field-verify the palm locations. QSI provided palm locations to SMUD through the inSITE software platform. The SMUD patrol inspector visited the location of palms to verify results. Out of 519 palms reviewed, 32 trees were missed as obvious (out in open) and by co-mingling (canopy crown co-mingling with other species). This gave a verified palm identification accuracy of 94 percent.

DISCUSSION

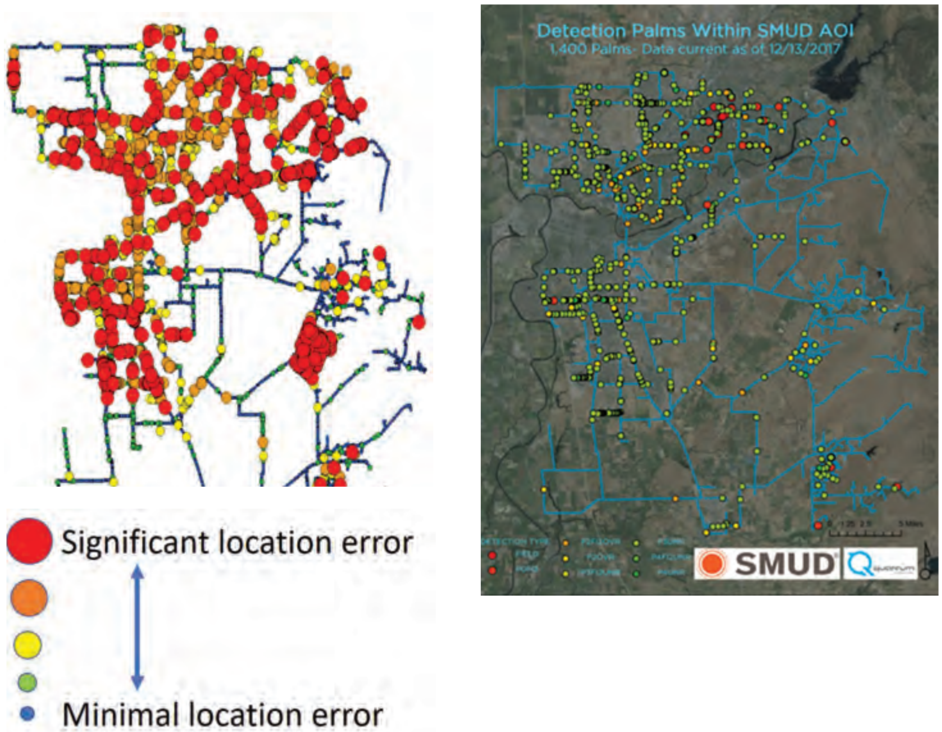
It is important to consider how the climate and weather are affecting the system and how this has long-term effects in the way the system is being patrolled/managed. Using technology such as LiDAR, digital imagery, and hyperspectral imagery provides unbiased and accurate analytics of the system (Li A et al. 2017). Targeting the most outage-prone trees for the species-based tree patrol helps mitigate risks, such as outages and potential fire risk.

The results from the LiDAR vegetation analysis can also be used to help with budget planning for the next fiscal year. Being able to visualize the location and forecast number of trees that need work in the system enables companies to calculate the prune and removal (work) spending for the year. This same information can be used for work planning.

CONCLUSIONS

SMUD intends to continue with the annual remote sensing data collections. Change detection will allow SMUD to follow growth patterns to help define tree work cadence. They will be able to start quantifying the total number of trees worked, which will provide accurate answers to tree inventory reduction and important information on reduced system risk.

Remote sensing provides actionable data for quick, accurate, and unbiased results. SMUD received all 810 distribution line miles within nine weeks, with initial urgent critical detections delivered within five weeks of data collection.



	Total Palms Delivered to SMUD	Subset Patrolled as of 12/6/2017	HSI Missed Palms	Accuracy
Palm Delivery	1362	519	32	94%

Figure 6a–6d. Palm Detection Accuracy

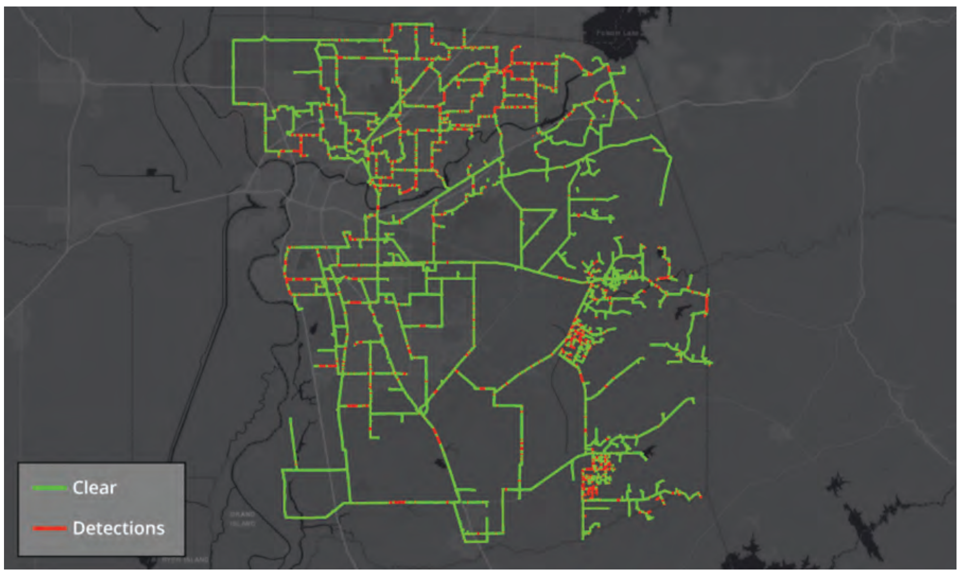


Figure 7. System Overview of Spans with Vegetative Risk

Due to the amount of data being processed, focusing on three to five specific species for hyperspectral analysis provides better identification of trees. Focusing on Palms (date, fan, other) provided accuracies of 90+ percent.

Remote sensing provides unbiased tools that allow utilities to visualize, forecast, plan, and budget work effectively for pending environmental and weather events to name a few.

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Eric Brown, Program Manager for SMUD Electric T&D, is responsible for program management and supervision of the VM staff. This includes budget, operations, and program-wide accountability for public, employee, and contractor safety along with electric reliability in SMUD's Grid Assets Department. Brown has more than 20 years of VM experience in Industrial timberland and range management, with a primary emphasis in utility VM (UVM) in both investor-owned and municipal utilities. Brown is the current President-Elect for the Utility Arborist Association (UAA) 2020, Western Regional Representative for the UAA, and current Director for the El Dorado County Fire Safe Council. Brown is also a member of the North American Transmission Forum (NATF) on the VM Core-Team and VM Practices Group.

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The Role of Field Technology in the Effective Response to Extreme Weather Events

How Florida Power & Light Excelled in the Aftermath of Hurricane Irma

Dan Marsh and
B. Christopher Kelly

Keywords: Aerial Assessment, Crew Dispatch, Damage Assessment, Emergency Response, Field Technology, Natural Disaster Response, Storm Response, Storm Restoration, Technology Deployment, Transmission Vegetation Management (TVM), Vegetation Work Management.

Extreme weather events are becoming an increasing threat to utilities nationwide and Florida Power & Light (FPL) is no exception. In the past decade, FPL has proactively invested more than $3 billion in storm hardening with the objectives of improving grid resilience, reducing weather-related outages, and minimizing long-term costs to FPL rate payers.

The examination was to quantify the impact of the storm hardening investments and better inform FPL as they prepare for a future where the frequency and intensity of severe storms is expected to escalate.

Using data from Hurricane Wilma (2005) as a baseline, FPL drew a comparison with Hurricane Irma (2017), which highlights that the strength and damage potential of Irma was more than 50 percent greater than Wilma. Yet, FPL achieved a 60 percent improvement in the average number of outage days per customer, an 80 percent reduction in the number of poles lost, and 80 percent reduction in the number of days to energize all substations.

FPL achieved these remarkable outcomes by executing on their preparedness strategy (e.g., developing and adhering to pre-storm checklists and requesting the right number of crews and equipment prior to landfall) and through the effective use of field technology in response to an extreme weather event.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

For more than 35 hours in September 2017, Hurricane Irma brought tropical storm-force winds to a wide swath of the southeastern U.S., with gusts registering 297 kilometers (km) (185 miles [mi]) per hour. In Florida alone, 15 million people evacuated their homes. Trees were uprooted and vegetation was destroyed.

Hurricane Irma was one of the most powerful Atlantic hurricanes ever recorded—leaving a deadly path of devastation throughout the Southeast. The massive storm made two landfalls: originally hitting the Florida Keys at 2:06 a.m. on Sunday, September 10 as a category 4 storm and again, less than two hours later, hitting Marco Island as a category 3 storm. With maximum sustained winds of 209 km (130 mi) per hour, the impact of Irma to FPL was catastrophic, affecting customers in all 35 counties across 43,452 km (27,000 sq. mi). In total, 90 percent of the FPL customer base lost power.

In the aftermath of this widespread storm event, the FPL transmission vegetation management (TVM) team faced the challenge of rapid damage assessment and dispatching crews to mitigate vegetation conditions along thousands of kilometers of transmission rights-of-way (ROW). The FPL team mounted an effective and efficient response by leveraging the vegetation work management system they use every day in normal operating conditions. By turning to technology that was familiar and proven, the FPL team avoided the pitfalls commonly encountered with dedicated damage assessment tools that are used only in rare, large-scale events. The result was a seamless transition into "storm mode" that enabled rapid aerial assessment and near real-time dispatching of critical work locations to field crews.

OVERVIEW OF FPL TVM

FPL is the third-largest electric utility in the U.S., serving nearly five million customer accounts, or an estimated 10 million individuals across almost half of the state of Florida. A leading Florida employer with approximately 8,700 employees, FPL is a subsidiary of Juno Beach, Florida-based NextEra Energy, Inc. (NYSE: NEE). With 49,000 overhead transmission and distribution lines, 11,265 transmission line km (7,000 mi), 6,920 NERC line km (4,300 mi), and 25 megawatts (MW) of generating capacity, FPL boasts service reliability better than 99.98 percent.

The FPL VM team is centrally organized and supervised and includes 12 ISA-certified arborists with forestry (or equivalent) degrees, FPL transmission training certification, and continuing education credits.

FPL TVM manages to Vegetation Action Thresholds (VAT), which are calculated based on the minimum vegetation clearance distance (MVCD), plus additional distance required for cable swag and sway potential, and a buffer of two feet. A minimum of two full ROW inspections are conducted per year to oversee and manage to agreed-upon standards (i.e., keep vegetation outside of VAT).

FPL/NextEra Energy's practices are to use an integrated VM (IVM) approach to achieve program objectives through identification of compatible and incompatible vegetation through inspection, implementation of appropriate control methods to discourage incompatible vegetation, and promotion of compatible vegetation.

FPL employs geospatial information systems (GIS)-based, VM technology that inventories vegetation allowable in VAT and enables the team to assign variable work types and trim cycles based on vegetation-specific growth rates as well as observation of changing environmental factors.

STORM HARDENING

Since 2006, FPL has invested more than $3 billion, in addition to ongoing system maintenance and improvement work, to make the energy grid stronger and smarter. This includes strengthening more than 600 main powerlines (including those that serve critical facilities such as hospitals, police, and fire stations and emergency communication systems) to withstand wind gusts of 130 mi per hour (mph) or more; replacing 18,000 wood transmission structures with those made of concrete or steel; clearing vegetation from more than 217,261 km (135,000 mi) of powerlines; inspecting more than 1.4 million power poles using the latest infrared technology, and upgrading/replacing those that no longer meet standards for strength; and installing more than 4.8 million smart meters and 36,000 intelligent devices along the energy grid using advanced technology that helps detect problems and restore service faster when outages occur.

HURRICANE IRMA STORM PREPAREDNESS

Facing millions without power, widespread flooding throughout its service territory, and significant vegetation debris, the FPL recovery effort was unprecedented. The Energy Company mobilized an army of more than 28,000 responders in one of the largest and most successful power restoration efforts in U.S. history.

Developing and Adhering to Pre-Storm Checklists

Thanks to significant storm-related planning efforts during recent years, the FPL VM program uses vegetation checklists that outline the steps to be taken within 72, 48, and 24 hours of an impending storm and what to do when the storm makes landfall.

Crew mobilization: With a 72-hour notice of an impending storm, personnel needs are evaluated, crews identified (and verified), and personal storm plans developed.

Equipment mobilization: As the 48-hour mark approaches, equipment readiness takes place. This includes placing equipment in safe locations during the storm and checking all equipment to ensure it will meet operating performance requirements (e.g., check freshness of fuel for chainsaws, all-terrain vehicles [ATVs], and argos; change truck oil; test radios and batteries; secure property). In addition, team members acquire any needed personal items.

Personal Preparation: As the storm nears within a 24-hour timeframe, the team's personal storm plans are executed. This includes securing personal property as well as packing food, clothes, and water in preparation for the possibility of sleeping in a tent or truck for an extended period of time.

Personal Safety: At landfall, all personnel are required to stay in a secured facility and ensure the safety of themselves and their families. After the storm passes, each personal situation is assessed and those who can report to work.

Managing Pre-Storm Logistics

Requesting the right number of crews and equipment—prior to landfall

While storm logistics can be exceptionally complex, FPL has implemented a process that provides extreme storm response resiliency and flexibility. Based on the storm assessment and associated needs analysis, the FPL VM team works hand-in-hand with in-house logistics specialists to secure heavy equipment storm contracts, specialized equipment, tree crews, vegetation specialists, hurricane-rated hotels, and staging sites. This includes capturing and maintaining an ever-changing roster of mutual aid crew members along with their phone numbers, equipment capabilities, and locations.

This allows for the restoration teams to be strategically poised to respond the minute they're actively deployed.

STORM RESTORATION EFFORTS & TECHNOLOGY DEPLOYMENT

Gaining Efficiencies Through the Use of Technology

One of FPL's TVM team advantages in its recovery effort was a fully functioning "blue sky" GIS-based software platform used for its TVM program. This platform had all current transmission corridors and assets pre-loaded and immediately accessible on the computers or smart devices of field inspectors and crews. Since the field inspectors used the same software for the maintenance program, there was no training or orientation required to use the software and respond immediately. The solution is designed that whether the user has internet connection or not, operations are not impacted, because all the information, including utility infrastructure and maintenance prescriptions, were pre-loaded and cached on each inspector's computer.

Using existing Clearion mobile patrolling software called the Transmission VM System (TVMS), the FPL team conducted aerial assessments of the damage from three coordinated helicopters that were patrolling simultaneously and identifying blow-ins, leaners, vines, close conditions, and lines on the ground. These locations were placed directly into the digital map with global positioning system (GPS) coordinates, and then issued to a field crew to efficiently route them and reduce the estimated time of arrival. A GPS point combined with land base maps help reduce the time it takes a crew to find the exact work location, and it can reduce the crew's reliance on other personnel, such as planners or contract arborists. The GPS location is superior to the old process of providing crews with a street address for the work locations. Often, the address may not exist or be easily accessible, or the parcel may be large or challenging to find due to damage to street signs and mailboxes

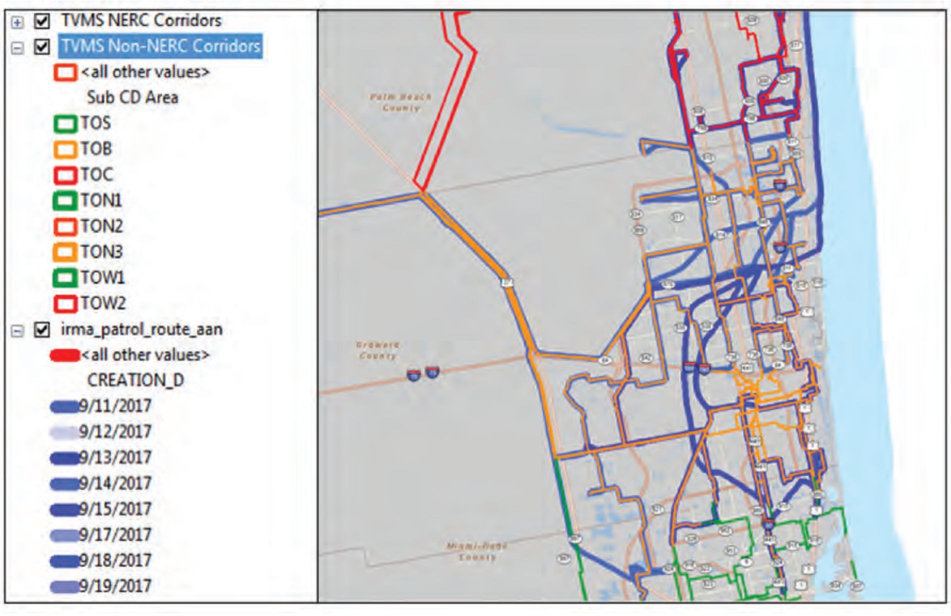

Figure 1. Example of a map image of South Florida (right), including the pre-loaded existing utility corridors for Palm Beach (red), Broward (orange), Miami-Dade (green) counties, and the helicopter patrol tracks (blue). There is also the legend (left) including information on the corridors and an example of the dates that they were patrolled in Broward County.

during a natural disaster. Another benefit of the patroller software is that the digital map automatically moves along as employees patrol the corridor, so there is no manual panning required. If paper maps are used, the patroller is required to organize the map series and ensure they are recording the work at the correct location on the paper map.

The data captured was synchronized from the helicopters to the server using in-flight Wi-Fi. The FPL office staff then created real-time work batches and assigned them to crews. This allowed crews to execute on urgent job tickets before the helicopters landed. Importantly, FPL's TVMS provided a real-time, high-level dashboard for executive progress updates, along with granular status updates and maps that could be shared for immediate VM decision-making.

The results from initial transmission system flights and subsequent follow-up flights highlighted the extent of the damage at differing intervals along with the progress being made in identifying, correcting, and reducing the number of outstanding issues (e.g., number of dead, damaged, and leaning trees for removal or trimming).

OUTCOMES

Prior to Irma, one of the largest storms to ravage the southeast was Hurricane Wilma in 2005. Wilma crossed the Florida peninsula from the Gulf coast to the Atlantic in approximately four and a half hours, with the strongest winds centered over south Florida. Irma followed a northerly path from the Florida Keys to Georgia and beyond, with the strongest winds blanketing much of the state, especially the west coast.

Using data from Hurricane Wilma (2005) as a baseline, FPL drew a comparison with Hurricane Irma (2017) which highlights that the strength and damage potential of Irma was more than 50 percent greater than that of Wilma

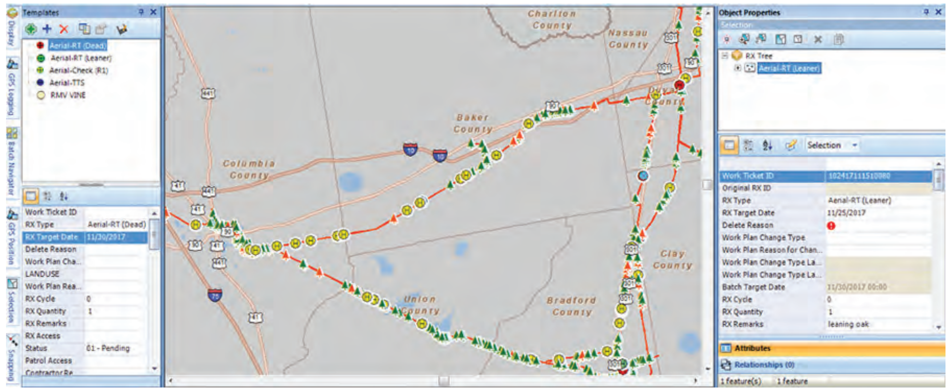

Figure 2. Mobile image, including pre-created vegetation classification templates and work type specifications below (left), the map showing the inserted features (middle), and the Object Properties of the feature that is selected on the map (right).

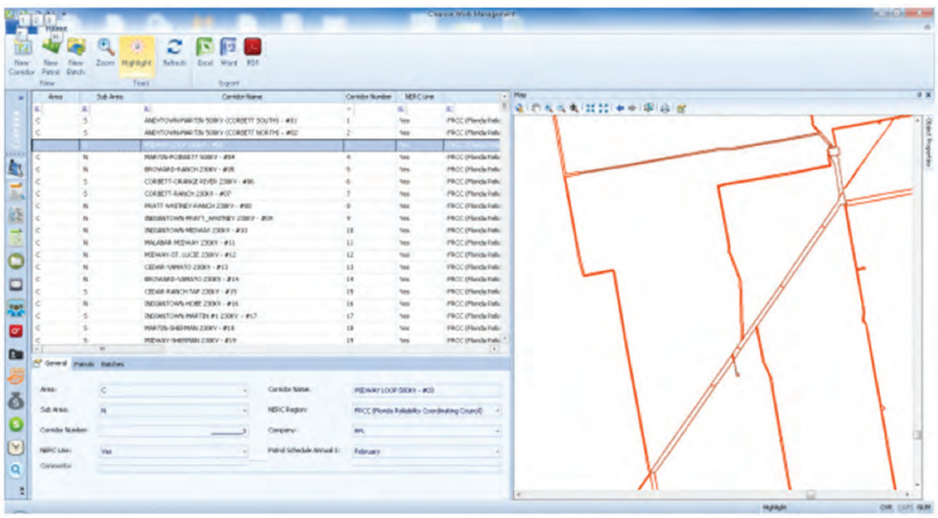

Figure 3. Work Manager image showing the new and current patrols (left) and when a patrol is selected, the specifics of the patrol are shown underneath and are highlighted on the digital map (right). The results from initial transmission system flights and subsequent follow-up flights highlighted the extent of the damage at differing intervals along with the progress being made in identifying, correcting, and reducing the number of outstanding issues (e.g., number of dead, damaged, and leaning trees for removal or trimming).

Count of Work Ticket ID	Column Labels						
Row Labels	Check Storm Damage	Remove Dead Trees	Remove Leaning Trees	Remove Storm Damage	Trim Storm Damage	Grand Total	Total Sum o
North Florida	4	65	23			92	$
Ortiz	102	44	27		8	181	$
Venice	18	18	25	2	21	84	$
Grand Total	**124**	**127**	**75**	**2**	**29**	**357**	**$**

Area	Inspections Completed
North Florida	20%
Ortiz	100%
Venice	100%

Figure 4. Inspector report excel data sheet image, including real-time data exported from the TVMS. The report allows visibility to tree removal and damage assessment, as well as the progress on inspections completed per area. This is an example of a simple way to communicate the daily restoration efforts during inclement weather.

(Table 1). Yet, FPL achieved a 60 percent improvement in the average number of outage days per customer, a 40 percent reduction in the number of poles lost, and an 80 percent reduction in the number of days to energize all substations (Table 2).

	Irma	Wilma
Category Storm	4	3
FL Landfall Maximum Sustained Winds	130–156 mph	120–150 mph
FPL Counties Impacted	35	21
Cyclone Damage Potential Index	4.3	2.8
Customers Impacted	4.4 million	3.2 million
% of Customers	90%	75%

Table 1. Damage Potential Comparison

	Irma	Wilma	Improvement
Average Days Without Power Per Customer	2.13	5.37	60%
Days to Restore	10	18	44%
50% of Customers Restored	1 day	5 days	80%
75% of Customers Restored	3 days	8 days	63%
95% of Customers Restored	7 days	15 days	53%
Poles Lost	4,600	12,400	40%
Days to Energize All Substations	1 day	5 days	80%

Table 2. Recovery Comparison

CONCLUSIONS

FPL's investments in storm hardening and planning are making a significant difference for its customers.

While weathering a storm of such magnitude is always challenging, FPL's TVM department has proven that having the right systems and processes in place makes operating in difficult conditions significantly more effective and efficient—and leads to much better outcomes.

FPL leadership and VM teams understand that every storm is different, along with the damage that comes with it. With a culture of continuous improvement, FPL continues to learn from past storms and make adjustments to its storm-response capabilities.

Coming into the 2018 storm season, FPL took many actions as results of lessons learned during Hurricane Irma including, but not limited to, making further enhancements to the grid to ensure it is stronger, smarter, and more storm-resilient, as well as stressing the importance of VM with government partners and community leaders.

In May 2018, FPL tested the response of more than 3,000 employees to a hypothetical storm. This weeklong drill, which included Florida Governor Rick Scott, leaders in the energy field, and local first responders, was a critical component of FPL's extensive year-round training to ensure employees are ready to respond when their customers need them the most. As part of the exercise, the company worked with other emergency operations centers and played a role in the statewide exercise called HurrEX.

As part of the exercise, the hypothetical Hurricane Cobalt, which mimicked 1964's Hurricane Isbell and had similarities to Hurricane Wilma, made landfall late on May 2 as a Category 2 storm in Florida's southwest coast and exited the state around West Palm Beach. During the simulated exercise, FPL employees were evaluated on their response and restoration efforts in regards to operations, logistics, communications, and customer service, among other areas.

The company showcased the technology that was used during last year's storms during the drill, including the mobile applications that put damage information and restoration activity directly in the hands of FPL restoration specialists. Combined with more storm-resilient infrastructure and a rapid restoration effort, this technology helped prevent outages and aided crews in restoring power to customers faster.

As FPL prepares for the next hurricane season, storm drills will remain a critical part of preparation. These exercises, in addition to the substantial investments made in energy grid hardening, have helped restore power more quickly following major storms.

This puts FPL in the best possible position to quickly respond to outages and restore power to our customers.

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AUTHOR PROFILES

Dan Marsh

Marsh is the supervisor of TVM at FPL, and has been in the utility VM (UVM) industry for more than 25 years. Current responsibilities include VM of 13,840 km (8,600 mi) of transmission and distribution lines in 23 states and two provinces of Canada. Marsh graduated with a Bachelor's in science in Agriculture Science, with a specialization in Forestry from Pennsylvania State University. He is a past president of the Florida Vegetation Management Association, past chair of the North American Transmission Forum, and serves as an advisor to both organizations. He maintains his International Society of Arboriculture (ISA) Certified-Arborist credential and is active with both the ISA and UAA organizations.

B. Christopher Kelly

Kelly is the chief executive officer for Clearion. Kelly has been in GIS and mobile technology development and deployment for more than 20 years, working with leading utility, telecom, gas, and transportation companies across the globe to solve complex operational challenges. He co-founded Clearion in 2006, focusing on the VM challenges facing transmission and distribution electric utilities. Today, Kelly and his team provide end-to-end technology solutions designed to help companies radically transform their work environments, strengthen communication among work groups, and serve their customers more effectively. Kelly graduated with a Bachelor's and Master's in science from Georgia Institute of Technology and lives in Atlanta, Georgia.

PART VI

Vegetation Management

Integrated vegetation management (IVM) has been identified as a best management practice (BMP) for maintaining areas such as utility rights-of-way (ROW) and other sites where the establishment and management of early successional plant communities is an objective. Revisions to ANSI A300 Part 7 (2018)—IVM are based in part on a review of and harmonization with the principles of integrated pest management (IPM). One of the most significant revisions in the new Standard includes adaptions of the core principles of Economic Injury Level (EIL) and Economic Threshold (ET) found in IPM. The corollary for each in the context of IVM is "Tolerance Level" and "Action Threshold," respectively. This paper describes important similarities and differences between IPM and IVM and focuses on the practical application of important concepts.

Adapting the Principles of Integrated Pest Management to IVM on Electric Utility ROW

John W. Goodfellow

Keywords: Action Threshold, Economic Injury Level, Economic Threshold, Tolerance Level.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Integrated pest management (IPM) at its core is a system intended to optimize management of the interaction between the pest and host using an integrated array of cultural, biological, physical, and chemical control methods. Similarly, integrated vegetation management (IVM) is a system intended to manage the interaction between tall-growing, incompatible trees (pests) and overhead conductors, and includes the use of cultural, biological, physical, and chemical control methods. Both IPM and IVM focus on preserving the value and function of an asset. In the case of IPM, the asset may be a crop or landscape planting, and with IVM, the asset is the transmission line. In the context of IPM, the threat (pest) to the asset may come in the form of an insect or disease, whereas in the context of IVM, the threat is posed by trees.

Both IPM and IVM provide a means of structured decision-making intended to facilitate an efficient response to threats that may have an adverse effect on management objectives. They share a strategy of active management of the threats posed by pests rather than simply focusing on short-term control of a problem.

ANSI A300 presents performance standards for the care and management of trees, shrubs, and other woody plants. These standards include several that address a variety of activities, two of which are relevant to this evaluation. ANSI A300 Part 7 established standard practices for IVM, and Part 10 standard practices for IPM. The reasons for IVM and IPM are stated explicitly in ANSI A300 Parts 7 and 10, respectively:

- 70.2. The reason for IVM is to create, promote, and conserve sustainable plant communities that are compatible with the intended use of the site, and manage incompatible plants that may conflict with the intended use of the site.
- 10.2. The reason for IPM is to provide a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes health, environmental, and economic risks.

Two factors led to the practical application of IVM: the recognition that competition between plant forms can suppress the establishment and growth of trees, and the development of effective methods of eliminating vegetation incompatible with management objectives for a site. The commercial introduction of the growth-regulating class of herbicides (e.g., 2,4-D) soon after WWII provided an effective means of selective removal of trees. Early recognition that relative stability in low-growing plant communities could suppress the growth of trees, and that they could be created by selective chemical control methods, first appeared in the 1950s (Eglar 1953). Recognition that selective applications of herbicides could reduce cost and create “high conservation value” followed (Neirring 1958). The watershed environmental book *Silent Spring* (Carson 1962) recognized that the purpose of selective application of herbicides on a right-of-way (ROW) was to “eliminate tall woody plants and to preserve all other vegetation.”

In the 1970s, the economic benefits of managing for a stable, low-growing shrub community was recognized (Eglar 1975; ESEERCo 1975). Subsequent adoption of these concepts by the utility industry occurred as they were introduced. The first direct reference to application of IPM as a construct useful for managing transmission line ROW by the industry followed (EEANY 2002). ANSI A300 Part 7 and the best management practices (BMPs) (Miller 2007), both published in 2007, clearly establishes the intended relationship between IPM and IVM. A comprehensive summary of the evolution of IVM was presented at the 11th International Symposium on Environmental Concerns in Rights-of-Way Management (McLoughlin 2015).

ANALYSIS

A general comparison of IPM and IVM reveals several core management principles that are common to both systems:

- An emphasis on a biological and ecological understanding of the target species (pest).
- Establishment of management objectives, tolerances, and treatment thresholds.
- Assessing and monitoring target species populations.
- Reliance on a variety of biological, cultural, physical, and chemical methods.
- Emphasis on proactive preventive responses to target species (pests).
- Inclusion of post-treatment evaluation of control methods and treatments to determine the need to adjust and improve the program.

These same principles are found in both ANSI A300 Standard Part 7 (IVM) and Part 10 (IPM).

DISCUSSION

An updated and revised edition of ANSI A300 Part 7 (IVM) is expected to be published in late 2018. One of the objectives of the drafting team for this Standard was to review and harmonize requirements of the new IVM Standard with the over-arching principles of IPM, and with the current version of ANSI A300 Part 10 (IPM). While both systems share similar constructs, there are differences.

Both systems focus on managing pests, but IPM generally focuses on insects, fungi, and other diseases of desirable host plants. IVM, in contrast, focuses on establishing and maintaining populations of compatible plants by controlling incompatible plant species.

In this context, species of plants that are incompatible with site objectives are pests. This is the classical definition of a weed: a plant out of place. This difference is more than a distinction between life forms. Pest pressure managed by IPM tends to vary widely within a season. In contrast, the pest pressure that is the focus of IVM may develop during multiple growing seasons. This affects the intensity and frequency of monitoring necessary to adequately assess conditions.

While both systems rely on biological, cultural, physical, and chemical methods, the actual treatments vary, most notably in regard to biological controls. IPM makes use of introduction of predatory insects and release of pest pathogens, but IVM does not. A variety of pests and diseases theoretically could control incompatible tree species. However, they are only pests in the context of their incompatibility with the specific objectives of a site. In other locations, these same species clearly have value. Introduction of organisms that would have an adverse effect on all trees would be irresponsible. Biological controls in the form of direct seeding to compatible plants has had limited success. However, biological control is one of the cornerstones of IVM. This is accomplished by creating compatible cover types, which can resist invasion and suppress the growth of trees through competition. This is referred to as "chemically facilitated biological control."

IPM and IVM on transmission ROW also differ in terms of acceptable tolerance. While there may be some level of pest pressure and subsequent damage to host plants tolerated in an IPM system, there may be zero tolerance for any risk of a tree-initiated fault on a high voltage transmission circuit.

One of the most significant revisions made to ANSI A300 Part 7 is the inclusion of Tolerance Levels and Action Thresholds. This change was made to better align with the concepts of "Economic Injury Level" (EIL) and "Economic Threshold" (ET), which are core to classical IPM systems:

- EIL is the point in which loss of crop yield or value equals the cost of management. When (if) this happens, management shall occur.
- ET is the point in which management action should be taken in order to prevent conditions reaching the EIL.

The corollary to the EIL in the context of IVM is the Tolerance Level, defined as the maximum allowable incompatible plant pressure (e.g., species, density, height, location, or condition) without unacceptable consequences. In essence, this is the level of incompatible plant pressure (e.g., species, density, height, location, or condition) that can be reasonably expected and tolerated without creating unacceptable consequences (economic or otherwise) that conflict with the stated management objectives for the site and require the implementation of a control method(s). Similarly, the corollary to the ET is the Action Threshold, defined as a level of incompatible plant pressure (e.g., species, density, height, location, or condition) where vegetation maintenance treatments should occur to prevent conditions reaching the tolerance levels. If conditions reach the tolerance level, control methods shall be implemented. An example of a tolerance level for a transmission circuit compliant with a North American Electric Reliability Corporation (NERC) FAC-003.4 line would be when vegetation conditions (incompatible trees) encroach on the minimum vegetation clearance distances (MVCD). This would be a regulatory violation. The Action Threshold would be determined by the vegetation manager and used to determine when treatment is to occur to prevent incompatible tree populations from breaching the MVCD. Examples of other potential Tolerance Levels and Action Thresholds could be based on considerations such as economic optimization of treatments, access, aesthetics, safety, or other matters of concern to the vegetation manager.

Both these concepts appear in the forthcoming revision to ANSI A300 Part 7. It is worth noting that ANSI A300 Part 10 does not explicitly include any reference to tolerance levels, but the concept is reflected in the definition of action threshold (Part 10, 104.1): "The point at which the pest threatens the stated IPM objectives and requires the implementation of a management tactic."

It is important to acknowledge another difference between IPM and IVM in regard to the concepts of injury levels and thresholds. These values in IPM, particularly in the context of modern agriculture, are empirically established, precisely determined, and widely recognized by practitioners. In contrast, IVM may rely on more general values determined by individual practitioners.

CONCLUSIONS

The forthcoming revisions to ANSI A300 Part 7 increase alignment of IVM with IPM. While there are differences noted, both systems make use of a set of common principles. Both systems provide similar structure with flexibility that supports the development of a comprehensive approach to achieving site objectives by managing pest pressure.

While IPM typically focuses on insects and disease, IVM is based on a deliberate strategy to encourage the development of sustainable compatible vegetative cover types, which suppresses the establishment and growth of incompatible vegetation. These compatible ecological communities protect and preserve environmental and cultural resources at the same time achieve operational objectives such as reliability, access, safety, and regulatory compliance in a cost-effective manner.

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AUTHOR PROFILE

John W. Goodfellow

John Goodfellow has 40 years of experience in the utility industry; having held positions of responsibility for VM, transmission and distribution (T&D) operations, maintenance, engineering, and construction at three electric & gas utilities. He is recognized as a leading authority on UVM and reliability, and currently manages an active portfolio of VM-related research projects focusing on electrical characteristics of tree-conductor contacts, tree biomechanics, and IVM practices. He is chair of the ROW Stewardship Council’s Technical Advisory Committee responsible for IVM accreditation requirements for “ROW Steward” recognition.

Goodfellow received a Bachelor of Science degree in Environmental Resources Management from SUNY College of Environmental Science & Forestry, and a Bachelor of Science in Forestry from Syracuse University.

Adapting to Challenges for Transmission Land Assets in Australia

Stephen Martin

Energy prices in Australia are one of the key areas of concern for households and businesses. Economic regulators, politicians, and energy users are subsequently placing increasing pressure on network businesses to realize efficiencies and reduce costs passed onto consumers, while shareholders expect reasonable returns on their investments. Transmission network businesses are adapting to these and various other challenges associated with managing land assets. Some unique Australian case studies associated with vegetation management (VM), fire risk management, arboreal marsupials, biosecurity threats, and ancient erosive soils will outline some of these challenges, and how Australian transmission network businesses are responding to a rapidly changing external environment.

Keywords: Land Assets, Easements, Corridors, Challenges, External Environment.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

The electricity system supporting Australia's modern economy and lifestyle is experiencing change on an unprecedented scale. The transformation is driven by customers as they embrace new technologies, take control of their energy use, and support action on climate change (CSIRO and Energy Networks Australia 2017).

Regulators and politicians are expecting transmission network entities to keep downward pressure on prices and, where possible, reduce their portion of the electricity bill for consumers. This places pressure on budgets allocated for land maintenance.

Almost in complete contrast with these expectations, landowners directly affected by transmission network assets have increasing expectations of linear infrastructure providers to mitigate and compensate them for associated impacts. Safety and environmental regulations are also driving utilities and associated service providers to consider the implications of land maintenance work in more detail than ever before. Utilities subsequently want risks quantified and services valued, including those associated with the maintenance of land assets.

Land maintenance includes the following aspects:

- Vegetation management (VM)
- Fire risk management
- Access maintenance
- Biosecurity control measures, including cleaning down facilities
- Landowner and stakeholder liaison
- Co-use management of easement

METHODS

The analysis of various case studies experienced by Powerlink Queensland has been used as an example of the challenges facing transmission network utilities in Australia and how they are responding. They provide examples and may not be representative of broader issues experienced across Australia.

Land assets facilitate transmission networks across Australia with differing standards and requirements. The industry association Energy Networks Australia (ENA) has focused considerable resources on providing member organizations with guidance on the management of land assets, with a focus on VM in recent years. General comments at a national level are drawn from the body of work performed by the ENA.

RESULTS

ENA Land Management Guidelines (ENA 2008) were developed to assist in providing performance criteria for electricity networks. These guidelines were particularly useful for distribution networks that did not have performance criteria imposed through planning instruments, but needed guidance for staff, contractors, and regulators.

As a transmission network business, Powerlink has performance criteria set through various planning instruments. However, land management guidelines have assisted with providing a common language nationally and negotiating updates for state codes of practices. Harmonization of requirements for maintenance practices associated with land assets remains an objective of ENA with a focus on VM.

Vegetation Management

Vegetation communities across Australia have adapted to extremes in weather conditions and ancient soils. In many instances, their very survival relies on fire being present in the landscape, which poses challenges for transmission assets.

In most Australian vegetation communities, increasing levels of disturbance will result in an increased response from pioneer species to regenerate. As a result, Powerlink aims to manage vegetation by selectively removing incompatible species by applying registered herbicides where landowners permit their use. This method is adaptive across changes in landscapes and land use, provided herbicide usage does not conflict with the land use.

Selective removal of undesirable species also provides environmental benefits from improved habitat for wildlife movement across easements (Goosem 2000), while also providing cost-effective and safe management of vegetation. Pohlman and Goosem (2007) also confirmed that the edge effects on vegetation close to transmission lines were less than those associated with roads following Tropical Cyclone (TC) Larry in 2006. This was primarily attributed to the retention of compatible species that effectively closed the edge of the forest to wind bursts.

Over-canopy spanning portions through the Wet Tropics Management Area has been largely successful, though designing for the mature height of vegetation has not always been precise. The result has meant high cost and risk. VM has been needed in remote locations to prune or remove vegetation that breached exclusion zones. It highlights the difficulties in over-canopy transmission line design, which is often exacerbated by elevated fire risks.

Fire Risk Management

While fire is a natural part of the Australian landscape, this poses additional risks for land assets near transmission lines. When combined with urban expansion onto the fringe of bushlands, the risk of fire causing catastrophic outcomes would be increasing without a coordinated approach with landowners and emergency services. Powerlink's long-standing involvement in the State Interdepartmental Committee on Bushfires and the Southeast Queensland Fire and Biodiversity Consortium are seen to be vital in collaborating to improve management of fire risks in conjunction with joint land maintenance.

Fire weather conditions in

Queensland have historically been favorable in lower fire risks than southern parts of Australia with high rainfall and humidity during summer. Proactive VM and fire risk management further lowers the risk profile for Powerlink's transmission network. As a result, Powerlink has never received an insurance claim associated with fire starts.

Fires can also impact transmission networks, particularly in causing network outages. Coordinated efforts with stakeholders are also assisting with improving asset protection and considering biodiversity outcomes from prescribed burns.

Fuel load assessments are also performed as part of land inspections, which are performed, on average, every two-and-a-half years. Bushfire prone areas are identified through State Government planning data sets, which are primarily used for informing town planning decisions (i.e., implementing control measures where developments are planned next to bushlands). Fuel load reductions are sometimes undertaken when fire weather conditions and fuel loads warrant the investment. Follow-up selective herbicide treatments are needed for this to be an effective treatment that modifies species composition.

Arboreal Marsupials

Removal of incompatible species and managing fuel loads results in modified ecosystems that impacts arboreal species, creating breaks in the canopy creates islands for arboreal species movement, which can result in increased predation. The extent of these impacts has been supplemented by research and the introduction of mitigation measures.

Brady and Baxter (2013) and Taylor and Goldingay (2013) confirmed selective use of installed poles and nesting boxes by different arboreal species, including Mahogany gliders (*Petaurus gracilis*) and Squirrel gliders (*Petaurus norfolcensis*). Powerlink has installed and trialed different mitigation measures, which have then been supported by research and monitoring. This included support following TC Yasi to understand the impacts on local communities of Mahogany gliders (*Petaurus gracilis*).

Figures 1 and 2 demonstrate monitoring results and methods for mahogany gliders as reported by Brady and Baxter (2013).

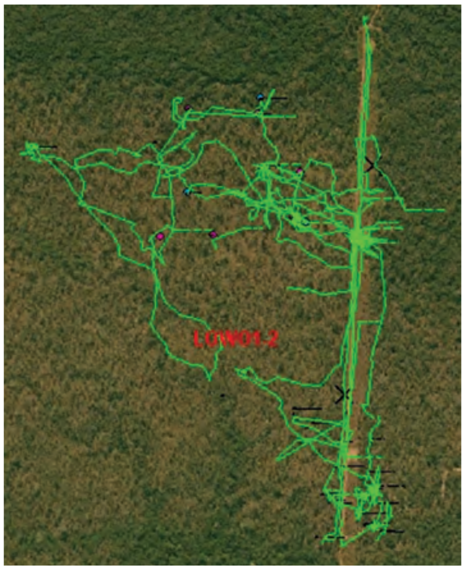

Figure 2. Mahogany gliders (*Petaurus gracilis*) movements near transmission lines

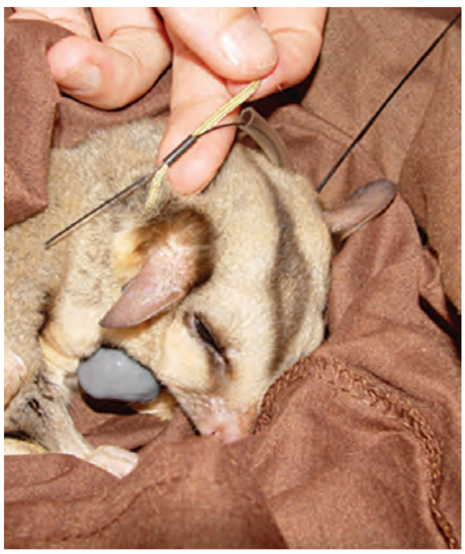

Figure 2. Mahogany glider (*Petaurus gracilis*) fitted with a transmitter

Biosecurity Threats

As linear assets that traverse the landscape, transmission lines cross catchment, electoral, property, and vegetation community boundaries. While not responsible for introducing biosecurity threats into the country, transmission network businesses face the challenge of not contributing to the further spread of threats to ecological, agricultural, and economic systems.

Low (2001) states:

> "Exotic invasions, because they are irreversible and cumulative, deserve to be taken more seriously. More than 2,700 weeds have become established in Australia so far, at a cost to the economy of more than $3 billion… What makes our pest problems unique is the way in which so many of them were deliberately created… Of our 18 worst environmental weeds, 17 were intentionally imported."

Powerlink has a long-established network of vehicle clean-down facilities that supplement public and private facilities. Martin et. al. (2005) shared Powerlink's design parameters with stakeholders across the state and has made investments into public clean-down facilities for broader public benefit.

As part of Powerlink's expansion into the Surat Basin to meet customer demand for energy as part of coal seam gas extraction, biosecurity concerns from the community rose to the surface as one of their key issues. While few weeds existed in the area, the concern was that construction activities and ongoing maintenance would increase the risk of new threats being introduced. Powerlink addressed community concerns by grouping zones with common biosecurity threats to consolidate control measures and facilitate timely construction of transmissions assets.

A review of biosecurity risks at a landscape level and associated control measures are underway following legislative changes in 2014. Current control measures have evolved based on landowner concerns that continue to become more complex with time. A landscape approach is needed to consolidate control measures based on science and risk, while engaging with landowners and the broader community.

Ancient Erosive Soils

Kanowski and McKenzie (2011) summarize our ancient erosive soils as part of the Australian State of the Environment Report:

> "Most of Australia's soils are ancient, strongly weathered, and infertile. Surface layers have low levels of organic matter, and are often poorly structured…These constraints and their interactions with climate have made it difficult to develop sustainable systems of land use."

Linear corridors transecting these soils are typically in steeper terrain to avoid impacts on urban communities and to reduce construction costs. Access tracks are typically designed for dry weather 4WD standard, minimizing ground disturbance wherever possible. However, weather conditions mean that access in wet weather conditions are sometimes necessary, which leads to damage to access and erosion. Repair work is necessary, which is grouped into refurbishment work if it is beyond maintenance programs.

Water crossings are typically bed level crossings to limit impacts on native fish movements, but pose safety risks for staff and contractors using access immediately after rain. The combined risks of traversing access tracks in wet weather conditions has resulted in increased use of helicopters to assess asset conditions immediately after extreme weather events. Utilization of remote sensing technologies is being assessed to further reduce the need for accessing assets on the ground and contribute to reductions in erosion.

Other Challenges

Field Delivery teams are presented with many challenges in maintaining land assets. From an asset management perspective, Powerlink is demanding more asset condition data than ever before to better understand and manage risks. Improved asset condition data is essential for prioritizing land maintenance with constrained budgets; however, increasingly we are exploring automated digital solutions to assist inform investment decisions.

Land use can help or hinder the maintenance of land assets associated with transmission networks. This includes co-use issues that need to be identified and managed based on risk. Preventing an activity that could be incompatible with transmission land assets is our objective, but this relies on landowners notifying Powerlink of their intentions. In some instances, easements have become so encumbered with issues that securing a new easement is the only viable option. Support from local government in managing potential co-use issues through planning approvals is essential, but varies across the state.

Landowners are increasingly placing conditions on entry onto their properties, regardless of easement terms and conditions. In 2014, Powerlink developed a Land Access Protocol in response to growing concerns from landowners in the Surat Basin. Stakeholders more broadly need to be identified, prioritized, and managed. By consciously and proactively doing so, Powerlink is aiming to improve its social license to operate. Traditional Owners are considered in a similar way to landowners and are managed by the same team within Powerlink.

Baseline data for monitoring ecological performance has been established for a selection of sites within protected areas (Goosem and Pohlman 2014). These monitoring sites provide reference for how much land maintenance practices have changed the species composition with time. A review of these sites has not been a priority since initial baseline data capture, but their true benefits will be in monitoring changes for longer periods of time.

Powerlink has invested directly and indirectly into research associated with land assets. This has resulted in a greater depth of understanding by Powerlink and the research community on potential impacts from transmission networks. This understanding has, in many instances, enabled smoother project approvals, agreements on codes of practice, and improved relationships with protected area management.

Martin (2016) outlined a review against the ENA and the Australian Fire and Emergency Service Authorities Council (AFAC) national guidelines, considering strategic, program, operational, execution, and monitoring elements of land maintenance. The review identified opportunities for improvements, which have formed part of Powerlink's continual improvement of land maintenance.

DISCUSSION

The case studies presented in the results demonstrates an indication of the diversity of issues that need to be managed in association with transmission network land assets. The review performed against national guidelines (Martin 2016) highlighted the need for issues to be considered and managed from a strategic, program, operational, execution, and monitoring perspective to be successful. While issues in Australia have some unique aspects, the need for a holistic approach to be effective is a universal learning for all those managing transmission network land assets.

CONCLUSIONS

Powerlink balances the requirements of stakeholders to manage land assets based on risks and priorities. Economic regulators and energy consumers expect cost reductions to be realized, while landowners and other regulators expect increasing levels of diligence. Powerlink is well positioned and is responding to the challenges that managing transmission network land assets present.

ACKNOWLEDGEMENTS

Powerlink has provided me with many opportunities to gain knowledge and experience across a broad range of disciplines relating to land assets. My ability to contribute this paper is the result of their investment in me and land assets across an extended period of time.

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AUTHOR PROFILE

Stephen Martin

Martin is actively involved in knowledge-sharing, which is demonstrated through his involvement in various industry bodies, such as the ENA VM Working Group. Presenting at the Right-of-Way (ROW) Symposium will fulfill a lifetime goal and ambition.

In addition to his lengthy experience within the electricity industry, Martin has worked for state government in advising on land care and soil conservation practices and has also been a director of a small consultancy business.

Martin is currently Land Strategist for Powerlink Queensland, which includes setting policy, monitoring performance, liaising with stakeholders, and identifying efficiencies during a period of significant change.

Martin looks forward to providing some insights into the challenges for adapting transmission land assets in Australia with you.

Climate Change Adaptation Strategies in VM

Josiane Bonneau and
Sydney Mucha

Keywords: Adaptation Strategies, Climate Change, Preserving Biodiversity, Vegetation Management (VM), Rights-of-Way (ROW).

Climate change is affecting a number of ecological parameters, including but not limited to species ranges, migration timelines, spread of invasive species, length of growing season, and increased fire and flooding risks. These shifts in the environment are accelerating, predicted to persist into the future, and present across all types of lands, including rights-of-way (ROWs). These impacts of climate change are a threat to overall biodiversity; however, ROWs can play a critical role in ecological community resilience by adapting their vegetation management (VM) practices.

Making changes to the way ROW vegetation is managed for climate change adaptation without relevant guidance is challenging. This paper presents a number of guidance documents, scientific literature, case studies, and recommendations that can help ROW managers make these changes. Many of these recommendations are already occurring on ROWs, while others will require minimal changes to VM practices, resulting in concrete wins for both managers and biodiversity. The changes that ROW managers have made can be capitalized upon and for those interested in acting proactively and demonstrating a commitment to innovation, the integration of climate change adaptation strategies in ROW VM can offer a practical, tangible opportunity to contribute to large-scale objectives.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

The modern wave of scientific research on the subject of climate change adaptation strategies only became mainstream in the 1990s with the Intergovernmental Panel on Climate Change (IPCC) First Assessment Report, despite the identification of climate change impacts as early as the 1950s (Hansen and Hoffman 2011). Today, it is widely accepted in the scientific community that climate change is occurring around the globe with observable effects—warming atmospheric and ocean temperatures, shrinking ice sheets, sea level rise, changes in precipitation patterns, and seasonal shifts in bloom and migration times—becoming more noticeable at regional and local levels (Hansen and Hoffman 2011). This shift toward observable effects at a finer scale has elevated the need for managing lands in respect to climate change into the private sector, including rights-of-ways (ROWs). These local impacts will be present in the future; therefore, the need for landowner and land manager actions is projected to become more important on a local and global scale (Hodgson et al. 2011).

The majority of current climate change strategies in the private and public sector target resilience of the built environment. The pipeline, railroad, and utility industry sectors, as well as departments of transportation, have made progress in evaluating the impacts of climate change on their operations and adopting adaptation strategies for infrastructure resiliency (ODOT 2012; Pacific Gas and Electric Company 2016; U.S. Department of Energy 2016). Few of these sectors' climate change strategies appear to integrate ecosystem resilience, despite the decision-making abilities of the groups regarding the respective lands managed.

The landscape-scale conservation literature in North America first identified ROWs as remaining connected lands for the conservation of species more than a decade ago (Clarke et al. 2006; Huijser and Clevenger 2006; Lensu et al. 2011; Haddad 2015; Lembrechts et al. 2017; Gardiner et al. 2018). Linearity in connected lands are thought to allow for the movement of species and habitats as the climate warms and species seek northern refuges. As ROWs are thought to contain the most connected landscapes in the U.S. and many other countries, there is an opportunity for ROW managers to become stewards by:

- Building awareness around land management practices that may positively contribute to climate resiliency and their potential compatibility with ROW management
- Identifying current vegetation management (VM) practices that already contribute to or that are already in place on managed lands/systems/area
- Adapting ROW VM practices for climate change to help create resilient natural communities

This paper presents research conducted to determine if adaptation strategies for managing vegetation on ROWs in the face of climate change are readily available. It also presents the outcomes of the evaluation of general climate change adaptation strategies for their compatibility with ROW management. The research and evaluation seek to inspire modifications in VM practices on ROWs to include actions to preserve biodiversity and create resilient ecological communities.

METHODS

To evaluate the current state of knowledge on climate change adaptation strategies in land management, specifically for linear features, literature reviews and peer-reviewed journal articles on climate change, VM, ROW management, land management adaptation strategies, and resilient ecological communities were compiled using several databases (Penn State Libraries, American University Libraries, Wiley Online Library, and Conservation Corridor). The information collected from these literature searches helped form the VM adaptation strategies recommended for ROW managers.

In addition to peer-reviewed research, governmental and intergovernmental reports were consulted from the following sources: United Nations (UN), Canada, U.S. (including a closer examination of the state-issued reports), the European Union (EU), and Australia. The government publications were reviewed, including State Wildlife Action Plans (SWAP), the EU Climate Adaptation Platform, the UN Strategic Plan for Biodiversity 2011-2020, the Australian Biodiversity Conservation Strategy, and the Canadian Biodiversity Strategy. These resources were selected for review based on credibility, accessibility, likelihood of addressing climate change adaptation recommendations, and depth of involvement in climate change. The information collected from these guidance documents helped form the VM adaptation strategies recommended for ROW managers.

The deeper examination of the state of knowledge and practices in the U.S. stems from the federally mandated State Wildlife Action Plans, which require the states to consider the effects of climate change when managing their habitats and species. One plan from each Environmental Protection Agency (EPA) region was examined, as a sampling approach. Within each state plan, the land-based and education-oriented recommendations were extracted. Distinction was made between general recommendations with limited implementation cues and those more specific recommendations with some details to guide actions.

With the list of generic and specific recommendations generated by the review of guidance documents and literature, those most compatible with ROW management and operations were identified. Those recommended adaptation strategies were then discussed with ROW managers to determine if the adaptation strategies could be adopted by ROWs. These adaptation strategies were then liked to scientific literature supporting the actions to the desired outcome—ecologically resilient communities. These clear linkages could then be utilized as a means of communicating the support of climate change adaptation strategies into ROW management.

RESULTS & DISCUSSION

Impacts of Climate Change on VM

Climate change is expected to be an all-encompassing problem, touching on all aspects of resource and land use management in the immediate future (Hansen and Hoffman 2011). The main changes expected to impact vegetation managers are: fluctuations in temperature and precipitation patterns, increases in the frequency of pest, disease, and invasive species outbreaks, and variations to species ranges and migration patterns, all of which will impact VM.

Research has shown that certain areas of the American west will become drier and hotter, which is predicted to lead to an increased risk of drought and fire (Hansen and Hoffman 2011). The exact opposite is thought to be occurring in the eastern part of North America, with a projected increase of rain events. These increased rain events could easily lead to flooding, landslides, and increased plant growth. Both the increase and decrease in precipitation events present potential complications in ROW management and an increase risk in impact to the infrastructure due to the increased risks associated with fires and flooding.

In the last decade, an increase in the frequency and occurrence of tree pests and diseases have been observed (Hansen and Hoffman 2011). While these diseases and pest outbreaks would occur despite the changing climate, warm temperatures are thought to aid the spread the disease and the pests' ranges (Hansen and Hoffman 2011). These infestations and outbreaks can lead to an increase in tree death, the loss of soil stabilization, landslides, and potentially fires. In addition to pest outbreaks, invasive species encroachment is expected with the sudden and wide spread tree deaths projected to occur. Invasive species can colonize an area, forcing out the native vegetation, and often times have different propagation rates than the natives they replaced (Hansen and Hoffman 2011). The outcomes are likely to impact ROW maintenance costs due to increased monitoring and control efforts.

In recent years, scientists have documented range changes, shifting migration periods, and variations in expected versus observed bloom times for various species due to climate change (Chen et al. 2011; Hansen and Hoffman 2011). These changes in animal and plant behavior are predicted to increase as previously cooler areas stay warmer longer and atmospheric carbon dioxide increases. These changes may lead to adjustments in ROW maintenance schedules to accommodate longer growing seasons, changes in breeding seasons, and shifts in species ranges.

Current State of Knowledge on Climate Change Adaption Strategies

The availability of actionable strategies for non-government lands is extremely limited and hard to access, with most resources available being vague or general in nature. The most consistent and useful resources available found have been from governmental, intergovernmental, and peer-reviewed scientific research (see citations).

In the resources available, trends emerged, such as the stated need for more research and monitoring to better understand how flora and fauna will be impacted by climate change. This finding is not surprising due to the complexity of the climate change challenge and is also reflected in the lack of specificity in species adaptation recommendations. The majority of literature also calls for broad protection of existing habitats and provision of linkages and connections between those habitats. In addition to common and broad strategies, each guidance document consulted provides supplemental suggestions to adapt VM to protect biodiversity and foster ecosystem resilience.

Table 1 compiles the information collected from various guidance documents on the implementation of climate change adaptation strategies by landowners.

The inter-governmental guidance documents (European Climate Change Adaptation Platform and the UN Strategic Plan for Biodiversity) contain a number of tangible and replicable adaptation strategies, as well as some more general statements. The EU guidance contained twice as many adaptation strategies than the UN's strategic plan, which is focused more on targets and metrics than implementation. The UN guidance contained only three adaptation strategies with two being concrete. The only recommendation to be found in both focuses on wildlife corridors and habitat linkages.

The national guidance documents reviewed included the Canadian Biodiversity Strategy and the Australian Biodiversity Conservation Strategy (2010–2030). The national guidance documents listed two common strategies: the creation of wildlife corridors & habitat linkages and protection & preservation of habitat. Only the Canadian guidance had a concrete and replicable strategy, while the Australian guidance contained seven vague strategies.

The U.S. government has not recently published a climate change strategy and therefore was not included in the national evaluation. Instead, relying on the mandate given to various agencies to integrate climate change in

Adaptation Strategies / Guidance Documents	European Climate Adaptation Platform	Canadian Biodiversity Strategy	Australia Biodiversity Conservation Strategy 2010-2030	U.S. State Wildlife Action Plans	UN Strategic Plan for Biodiversity 2011-2020
Adaptive management of existing habitats in response to climate change impacts - general	●			○	
Adaptive management of existing habitats in response to climate change impacts - forests	●			●	
Adaptive management of existing habitats in response to climate change impacts - grasslands				○	
Adaptive management of existing habitats in response to climate change impacts - wetlands			○	●	
Creation and enhancement of riparian buffers	●			●	
Creation/restoration of quality habitats			○	●	●
Creation of wildlife corridors/habitat linkages	○	○	○	●	○
Education for building capacity in deployment of climate change adaptation tactics				●	
Education for raising awareness about climate change			○	○	
Management of fire risk	●		○	○	
Management of invasive species			○	●	
Prevention of natural disasters using integrated land use planning	●				
Protection and preservation of habitat		○	○	●	●
Research/monitoring of the impacts of climate change on ecosystems and species		●		○	
Use of decision support tools				○	

● Concrete and replicable adaptation strategies

○ Broad (not concrete or replicable) adaptation strategies

Table 1 indicates what level of detail and replicability for climate change adaptation strategies have been recommended by selected national-level and intergovernmental biodiversity/climate change guidance documents. Most guidance documents reviewed either had all concrete or vague adaptation strategies across their recommendations and it is important to note that all acknowledged the need for more information on the subject of climate change adaptation in ecosystems. Overall, all guidance documents made some attempt to better guide land managers for the impacts of climate change.

Table 1. Level of detail and replicability for climate change adaptation strategies in selected national-level and intergovernmental biodiversity/climate change guidance documents

SWAP / Adaptation Strategies	NH	NY	MD	GA	MI	AR	IA	UT	CA	WA
Adaptive management of existing habitats in response to climate change impacts - general		○							○	
Adaptive management of existing habitats in response to climate change impacts - forests	○		●							
Adaptive management of existing habitats in response to climate change impacts - grasslands	○		●							
Adaptive management of existing habitats in response to climate change impacts - wetlands			●	○	○			●		
Creation and enhancement of riparian buffers								●		
Creation/restoration of quality habitats	○		●		○			●		○
Creation of wildlife corridors/habitat linkages	○			○		○		●		○
Education for building capacity in deployment of climate change adaptation tactics			●						○	
Education for raising awareness about climate change	○									
Management of fire risk	○					○			○	
Management of invasive species			●	○						○
Prevention of natural disasters using integrated land use planning	○		●					●		○
Protection and preservation of habitat			●	○		○				○
Research/monitoring of the impacts of climate change on ecosystems	○			○	○	○	○		○	○
Use of decision support tools			○							

● Concrete and replicable adaptation strategies

○ Broad (not concrete or replicable) adaptation strategies

Table 2 demonstrates that the most common adaption strategy for the U.S. was research and monitoring of existing habitats. Maryland had the most adaptation strategies present, with most being replicable and detailed. Utah's plan was the only other one that had some level of detail. Other SWAPs did contain vague adaptation strategies.

Table 2. Level of detail and replicability for climate change adaptation strategies in selected SWAPs

their efforts where and when relevant, a sampling of SWAPs were consulted as a proxy to a national strategy for the U.S. When the combined state-level recommended strategies are compared to the national strategies, the U.S. appears to similarly promote research and monitoring of existing habitats as well as encouraging wildlife corridors and habitat enhancement. Individually, the states provide a varying degree of relevant information, from none to highly applicable.

Individual SWAPs were examined to indicate the U.S. strategy as a whole and were examined more closely. When the SWAPs were taken as a whole guidance document, all adaptation strategies were touched upon but one: integrated land use planning to prevent natural disasters. However, upon examining the individual SWAPs, great discrepancies between the individual plans were seen. The randomly chosen SWAPs (one from each EPA district) were New Hampshire (NH), New York (NY), Maryland (MD), Georgia (GA), Michigan (MI), Arkansas (AR), Iowa (IA), Utah (UT), California (CA), and Washington (WA) (Table 2). For each recommended action, if one of the SWAPs examined indicated a concrete and replicable adaptation plan, this was reflected in the overall U.S. rating by indicating a full circle for that recommendation. This method was also followed for broad, undetailed plans that would be difficult to replicate, resulting in a hollow circle.

The plans for the states of Maryland and Utah proved to be innovative in their inclusion of tangible climate change adaptation strategies specifically targeting land managers and the states' perceived interest in moving away from additional research and data collection. The Maryland SWAP mentions the use of a decision support tool, a practical recommendation only found in one other national plan. This level of specificity was expected to be part of the California plan—a more environmentally progressive state, which, surprisingly, only included very broad recommendations with limited replicability in other regions. Restoring habitats and pursuing wetland management were the most cited methods to adapt to climate change that were supported with a concrete action plan. Less common recommendations included grassland management and educational awareness.

Adaptation strategies presented in Tables 1 and 2 indicate that increased connectivity and reduced fragmentation are meaningful tactics to maintain biodiversity as the climate continues to change. Protection, restoration, and preservation of habitats, while general, is equally promoted as a versatile approach. A focus on fire management emerges as a locally relevant recommendation to prioritize in target regions. The overall absence of education and awareness as a key strategy remains an unforeseen finding.

Recommendations

Research confirms that climate change adaptation strategies recommendations for VM on ROW are non-existent, despite the connection between linear features and the strategies in Tables 1 and 2. The majority of recommendations provided by authors and government remains at this time very general and not reissued for various context. The recommendations for climate change adaptation for land owners and managers, however, are familiar and can be translated into tangible adaptation strategies that are compatible with the ROW context (Table 3).

When first consulting with VM professionals on the topic of climate change adaptations, the consensus among the group was that integration of climate change adaptation considerations in VM planning and execution would be complicated, outside the technical comfort of the on-the-ground teams, expensive, and likely incompatible with traditional operations. However, the research highlights simple and accessible strategies that do not rely heavily on new technologies, expensive materials, or highly specialized labor. These recommendations can be easily translated into actions for VM teams or contractors and implemented within varied scopes and scaled to fit with available resources and objectives.

By implementing these recommendations, clear, definitive links can be drawn to climate change adaptation and ecosystem resilience (Table 4). These links are shown through current research on climate change adaptation strategies and have been tested on managed lands throughout the globe. While no one recommendation can be utilized on all ROWs nor will one lead to the most benefit to biodiversity, it is important that ROW managers understand the link to ecosystem resilience before implementing these strategies. By having a clear vision for their desired outcomes, strategies are more likely to be implemented and followed by employees.

Many of the adaptation strategies recommended in the ROW context are likely already in place across many ROW systems, whether pipeline, transmission, railroad, or roadside. Yet very few efforts are accurately portrayed as supporting resilient ecosystems or being linked to climate change adaptation. Opportunities to communicate existing actions and progress to support climate change efforts internally and externally is within reach. The communication relies to the tie between the recommendations and their support of adapting to the ever-changing environment under the effects of climate change.

Case Studies

Case Study 1: Superior Streets

Exelon's subsidiary, Commonwealth Edison (ComEd), manages their Superior Street Prairie in a way that provides connected habitat linkages to surrounding protected prairies and forest preserves. ComEd's 5.66-hectare (ha) (14-acre) transmission ROW is located 16 kilometers (km) (10 miles

Recommended adaptation strategies	Implementation adaptation strategies for ROWs
Establishment of native plant communities on ROWs	New ROWs can be seeded with native seed mixes, existing corridors can be enhanced by controlling for incompatible invasive species, and specific spans of the ROW can be targeted for restoration.
Creation of wildlife corridors/habitat linkages	Segments of the ROW can be managed to mimic the objectives and management techniques of high quality adjacent off-ROW patches, creating continuous habitat. Linkages can also be created on ROW by minimizing obstacles and drastic changes in vegetation communities.
Creation/restoration of quality habitats	New ROWs can be seeded using native seed mixes, existing ROWs can be enhanced with overseeding with natives or planting natives.
Translocation of species	ROW managers can assist in the movement of species (plants and animals) by partnering with their local wildlife agency to relocate the species on their land.
Creation/management of buffer zones	ROWs can be narrowed in length and by working with neighboring properties, ROWs can be managed in a way consistent with neighboring partners.
Management of invasive species	ROWs can be monitor for invasive species and pests; ROW managers can also track the movement of invasive pests and diseases in an area to prevent the spread into their lands. By working with neighboring land owners, ROW managers can make coordinated efforts to prevent the spread of invasive species and pest.
Utilize seed mixes that are more adaptive to climatic extremes	ROW managers can select fire and drought tolerant plants to lower the risk of fire damage to assets and species on the ROW.
Manage for shifting northern boundary of species ranges	ROWs can be seeded with mixes that include grasses and forbs that are found in the lower range of the ROW for the whole area that falls within that range, assisting in the movement of species as the climate forces species to shift their ranges northward.
Recategorize invasive species selected for management control (fugitive species)	ROW managers should monitor invasive species that have moved into a new area; however, if the species is providing an unmet need in the habitat, caution should be exercised before outright removal.
Reduce non-climate stressors	ROW managers can reduce non-climate stressors by managing invasive species, increasing soil health by use of lime or fertilizers and preventing habitat fragmenation by managing lands close together in a similar way.
Increase biodiversity on ROWs	ROWs can be seeded with a variety of native species with different blooming times and varieties that meet different and changing habitat/species needs.
Education for raising awareness about climate change	Joining committees and regional groups, leading or creating opportunities to increase employees' and community members' awareness of climate change and adaptation tactics being used can help build public support for these activities on ROWs. who work to manage climate change
Education for building capacity in deployment of adaptation tactics	Contractors can be trained to recognize native communities and invasive species to implement adaptation techniques. Working with employees and contractors on proper seed mix selection can lead to more effective management of ROWs and reduce costs associated with fixing ineffectively-deployed techniques.
Research/monitoring of the impacts of climate change on ecosystems	ROWs can be managed using the techniques mentioned above and actively publish research on test plots associated with climate change adaptation strategies.

Table 3 shows the ways in which the implementation actions of climate change adaptation strategies are diverse for ROW managers. The wide variety of adaptation strategies indicates that almost any can be adopted on ROWs to foster biodiversity and ecologically resilient communities.

Table 3. Recommended implementation of climate change adaptation strategies for ROW management

Recommended adaptation strategies	Link to Climate Change Adaptation & Ecosystem Resilience
Establishment of native plant communities on ROWs	Native plants provide habitat and sources of food to the native species in an area. As the climate continues to warm, ensuring native food sources supply can enable species to inhabit the area for a longer period of time (Lambrecht et al 2017).
Creation of wildlife corridors and habitat linkages	Wildlife corridors and habitat linkages facilitate the movement of species as their ranges shift with climate change impacts, which is critical for enabling access to areas with more suitable conditions in fragmented landscapes (Fowler 2015, McGuire et al. 2016). Corridors may also facilitate the spread of genotypes that can tolerate warmer temperatures (Krosby et al. 2010).
Creation and restoration of quality habitats	Creating new and restoring existing habitats increases the available habitat refugia for species to move to permanently as their ranges change or temporarily when fleeing from disturbance and therefore increases resiliency to drastic ecosystem changes (Timpane-Padgham et al. 2017).
Translocation of species	Translocation involves moving species to new areas outside of their historical range. It can reduce extinction risk for species with limited/no ability for movement (e.g., lack of corridors), or can be used to move species from populations adapted to warmer conditions to cooler areas to increase the probability of subsequent adaptation as the climate warms in these newer areas (Hoegh-Guldberg et al. 2008).
Creation and management of buffer zones	Buffer zones can be used to protect important/high-quality natural areas against climate change impacts and non-climate stressors exacerbated by climate change, such as reducing edge effects and moderating impacts (e.g., urban heat island, excess stormwater runoff) that may be stronger in more developed areas (U.S. Forest Service Climate Change Resource Center 2018).
Monitoring and management of invasive species	Increasing temperatures may allow invasive species to expand their ranges northward and further outcompete native species in ecosystems weakened by rising temperatures and other impacts of climate change (Georgia Department of Natural Resources 2015). Monitoring for new infestations and responding quickly to control them can help prevent the northward spread of invasive species and prevent them from impacting native species and habitats that are already stressed by climate impacts (U.S. Forest Service Climate Change Resource Center 2018).
Utilization of seed mixes adaptive to climatic extremes	Selecting native species that are better adapted to a range of climatic conditions in seed mixes can increase the resilience of native plant communities along ROWs by reducing the communities' sensitivity to climatic changes (Washington Department of Fish and Wildlife 2015).
Management of ROW for shifting northern boundary of species ranges	Potential refugia (species having to move from the effects of climate change) can be protected and managed in the historical northern reaches of species' ranges, and potentially more northerly areas they may move to in the future, to ensure species continue to have adequate habitat as their ranges shift northward (Heller & Zavaleta 2009)
Recategorization of invasive species selected for management control (fugitive species)	As the climate warms, species ranges for both native and non-native species will shift northward and the distinction between invasive and non-invasive species may become blurred. Reclassifying invasive species as "fugitive species" and selecting which ones to manage for may provide greater clarity for future discussions about habitat management (Heller and Zavaleta 2009, Hodgson et al. 2011).
Reduction of non-climate stressors	Reducing the impacts of non-climate stressors (e.g., poor soil health, low biodiversity, fragmentation) on ecosystems can reduce the likelihood of rapid, acute reactions to climate change and maintain a greater ability for resilience against climate stressors like extreme weather events and increasing temperatures (Maryland Department of Natural Resources 2016; Staut et al. 2013).
Increase of biodiversity on ROWs	Managing ROWs for a greater diversity of species can increase resilience to climate change impacts, helping ensure that ecosystem processes continue to function and that habitat resources are available to a broader range of wildlife species and supporting a greater overall number of plants and animals in the habitat, both now and in the future as the climate and species ranges change (Timpane-Padgham et al. 2017).
Climate change education and awareness	Educational activities designed to raise awareness about climate change can build support for climate change adaptation tactics by enhancing understanding of why they are being implemented (Maryland Department of Natural Resources 2016).
Capacity-building for adaptation tactics deployment	Engaging in activities to increase knowledge about implementation of climate change adaptation tactics enhances capacity for effective adaptive management of habitats and species, both on-site and in the surrounding community (Anderson 2010).
Research and monitoring of the impacts of climate change on ecosystems	Research can generate data to track the effects of climate change on the distribution and abundance of plant and animal species, track changes in habitat conditions, create models to predict changes in habitats and species populations, inform landowners' management decisions as conditions change, provide insight for risk management, and assess the effects of adaptation activities on species and ecosystems (Fowler 2015, New Hampshire Fish and Game Department 2015).

Table 4: Recommended adaptation strategies are presented here with explanations provided by literature sources. Many of these strategies may be already in place currently on ROWs. Leveraging these actions and expanding upon them with additional strategies can lead to more resilient communities and foster biodiversity.

Table 3. Correlation between recommended adaptation strategies for ROW management and support of resilient ecosystems as cited by scholarly articles and governmental strategies

[mi]) south of Chicago and is contiguous with Calument City's Superior Street Prairie, the Forest Preserve of Cook County's Sand Ridge Nature Preserve, and Green Lake Savanna. The combined linkage with these sites enables wildlife to move within a complex ecosystem of 101.7 ha (250 acres) in an otherwise urban area. ComEd continues to maintain the habitat linkage by controlling invasive species, participating in prescribed burns, and practicing annual site inspections. The Superior Street Prairie is an example of how utilities can maintain reliable electricity while working with local and regional groups to provide quality habitat linkages to allow for climate change adaptation.

Case Study 2: Salamander Stepping Stones

In 2014, Atlantic City Electric became one of the first companies to actively implement climate change adaptation strategies on its ROW in Middle Township, New Jersey to benefit the rare eastern tiger salamander. As sea levels are projected to rise due to climate change, many state and federal agencies are concerned the salamanders' breeding habitat will be restricted to levels that will place the species near extinction. The state's Department of Environmental Protection contacted Atlantic City Electric with a proposal to create vernal pools on the company's ROW that would allow for the ease of movement along the corridor for the protected salamander. These stepping stones are maintained by adaptive management and will allow for the species to continue to breed in its known range in a quality habitat.

CONCLUSIONS

Including climate change adaptation strategies in VM is possible. It is also essential to help address the likely growing risk to biodiversity from climate change. By relying on research outside of the ROW world and applying existing practices, direct and meaningful actions can be made to protect biodiversity and create resilient communities on ROWs. While this approach will not be the same as integrated VM (IVM) with industry leading the way for the past 50 years, there is a chance for the industry sector to play a vital role in rolling out a suite of actions on transmission lines, pipelines, railroads, and roadsides to test the methods suggested by researchers.

The findings of this research truly encourage ROW managers to show leadership and innovation by taking specific steps:

1. Identifying actions that have already been adopted and can be communicated differently to show support for resilient ecological communities.
2. Selecting compatible new climate change adaptation actions from the options presented here to adopt.
3. Implementing voluntary actions in the immediate future for reclamation, restoration, community engagement, and capital projects to show a commitment to the environment.
4. Factoring in long-term planning and maintenance cycles in bids to include climate change adaptation strategies.
5. Measuring, monitoring, and communicating efforts, which can be used to contribute to the key objectives of corporate sustainability.
6. Communicating efforts and outcomes related to climate change adaptation internally and externally.

ACKNOWLEDGEMENTS

We would like to thank the community at Exelon and their subsidiary companies, ComEd and Atlantic City Electric, for allowing us to share their success stories, and the researchers of climate change adaptation strategies for taking on a seemingly impossible task daily in the name of preserving the environment.

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Since joining the Wildlife Habitat Council in 2005, Bonneau has occupied various positions within the organization, as Biologist, Director of Field Programs, and, currently, Senior Director, Conservation Strategy & Planning. Bonneau focuses on the development of mechanisms and launch of industry strategies for corporations to embrace conservation as a tried-and-tested business value. With her team, she maintains a technical support system to translate this value into tailored contemporary conservation actions across the globe.

Bonneau specializes in natural resources management in the mining industry, linear infrastructure planning, and remediation projects. She balances her passion for biodiversity with participation in industry committees and focus groups, including the Board of Director of the ROW Stewardship Council (ROWSC). While attending Université du Québec à Montréal, Bonneau received a Bachelor of Science in Ecology. Prior to joining WHC, she dedicated close to a decade to the field of emergency management before joining the timber industry as a scientific consultant.

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As Manager of Conservation Planning, Mucha focuses on corporate conservation in regulated industries such as Utilities and Remediation. She also works collaboratively with other members of the department, the entire WHC staff, and partners to ensure member organizations are receiving current guidance on conservation methods.

Prior to joining the Wildlife Habitat Council, Mucha worked as an Environmental Scientist at a consulting firm ensuring government clients' compliance with environmental regulations and sustainability goals. Mucha has also worked as a research and teaching assistant at American University where she also earned her Master's in Environmental Science with a focus in Green Infrastructure and Sustainability. Before coming to the nation's capital, Mucha earned her Bachelor's in Environmental Science and a minor in Sustainability Studies from Davis & Elkins College in Elkins, West Virginia. Complementing her love of sustainability, Mucha also actively maintains her LEED Green Associate Certification and volunteers at the National Zoo.

CNUC Transmission Pipeline VM Survey 2017

Randall H. Miller

Keywords: Maintenance, Pipeline, Energy.

Pacific Gas and Electric (PG&E) commissioned CNUC to survey pipeline vegetation management (VM) programs in 2017. The survey was sent to 140 transmission pipeline operators with 21 respondents. Results indicated that transmission pipeline vegetation management (TPVM) programs are not highly organized operations. However, in general, responding utilities had the foundation of good VM programs. The most common programmatic justification given for pipeline VM was public and worker safety, followed by regulatory compliance, reliability, and cost—in that order. Many responding pipeline operators utilize the same VM tools that are used for high-voltage transmission corridors. Inspections, work plans, and work tracking is electronically captured and communicated. Responding utilities would benefit from greater centralization and more emphasis on ANSI A300 and International Society of Arboriculture (ISA) best management practices (BMPs).

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

There are more than 1.5 million miles of natural gas and oil pipeline reticulating North America. Vegetation can conceal flaws that could result in potentially explosive leaks in gas pipelines causing environmental and property damage. In addition to concealing defects, unmanaged vegetation on pipeline rights-of-way (ROWs) can block access, potentially damage above ground pipeline segments, and tree roots can compromise the integrity of underground pipelines (Nidd 2014).

The current pipeline survey follows procedures applied in previous investigations of electric utility vegetation management (UVM) programs (Cieslewicz and Porter 2010). The intent has been to assist utility arborists in identifying trends, BMPs, and opportunities for improvement. The pipeline survey was designed to identify the same trends, BMPs, and opportunities among participating pipeline operators.

MATERIAL & METHODS

A VM survey of North American natural gas and hazardous liquids transmission pipeline operators and owners was undertaken in 2017 (Porter and Cohen 2017). The survey was completed both in a fillable PDF form and online. The instrument consisted of 71 questions targeted at capturing attributes of pipeline VM programs.

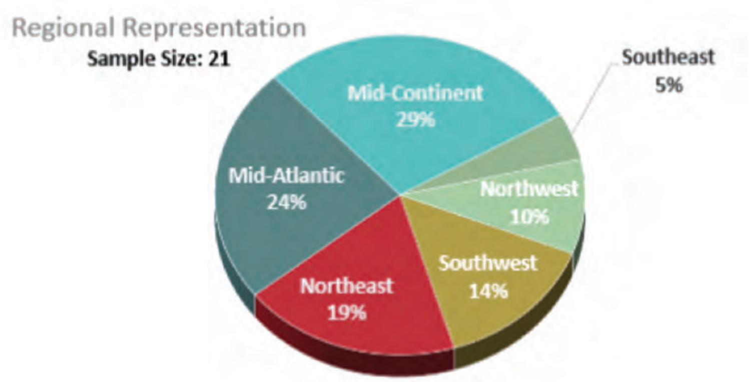

Figure 1. Regions Represented By Responding North American Pipeline Utilities

Questions targeted five characteristics:

1. General program attributes
2. Finances and VM budgets
3. Transmission pipeline vegetation management (TPVM) personnel.
4. TPVM program priorities, regulations, and landowner relations.
5. Safety

Surveys were emailed to 140 pipeline company representatives. A list of contacts was provided by the Utility Arborist Association (UAA), and a working group from the Rights-of-Way (ROW) Symposium aided in identifying potential pipeline vegetation managers. Additional surveys were sent to pipeline personnel who were identified by the initial contacts. Follow-up calls were made to encourage participation of companies who did not respond. The American Gas Association promoted survey participation among their member utilities as well.

Responding companies were assigned discreet identifiers to maintain anonymity in reporting. Data analysis employed basic statistical descriptors—percentage, average, mean, and median. Subjective comments were also compiled.

RESULTS

General Program Attributes

Twenty-one pipeline utilities (15 percent) representing 23 states and four Canadian provinces returned completed surveys. Only 20 percent of companies reported their ROWs are usually free of trees to the point that maintenance is focused on trees at the edge or off-ROW, 60 percent of companies said this is sometimes true, and the remaining 20 percent reported this is not true (Figure 1).

The most frequently used VM strategies among responding utilities were electronically-tracked inspections and work plans; integrated VM (IVM); routine removal of all trees in the ROW; and specified ROW edges measured for management. Herbicide applications applied through the IVM process are utilized by most of the respondents, although only 11 percent agreed this was always true and 37 percent said it was never true. None of the responders agreed that most of their ROWs have stable plant communities and are nearly free of inappropriate trees, 10 percent said they usually have stable ROWs, 60 percent said they sometimes have stable plant communities, and 30 percent would not claim this for any of their ROWs (Figure 2).

Of the companies that use herbicides to control and convert ROW vegetation, 75 percent do not employ closed chain of custody, a BMP for herbicide applications (Figure 3).

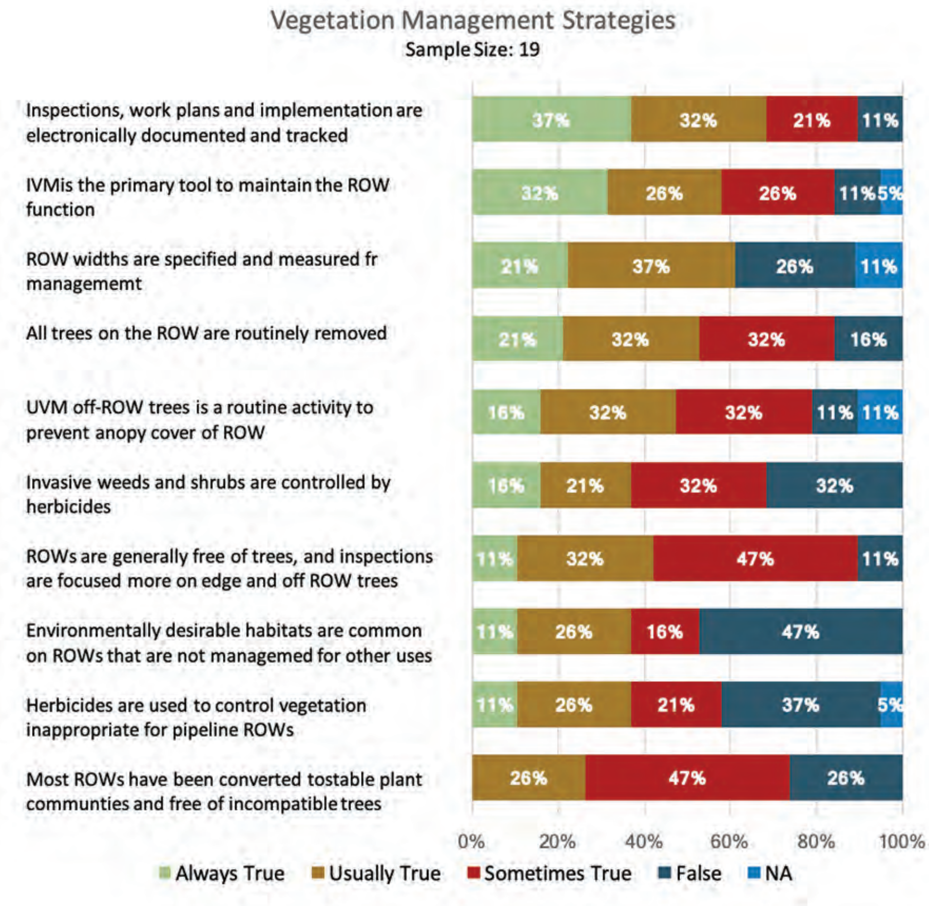

Figure 2. Most Frequently Used VM Strategies

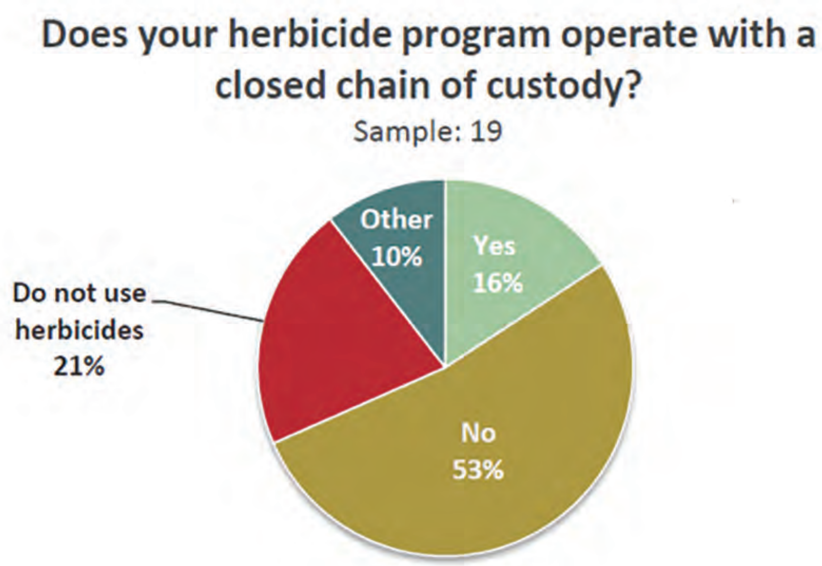

Figure 3. Closed Chain of Custody

Eighty percent of respondents expect VM workers to report non-vegetation conditions (Figure 4).

Roughly 72 percent of participating utilities performed regular routine maintenance or mostly performed routine maintenance. However, a significant number focus on reclamation (Figure 5).

More than 50 percent of survey responders perform annual ground inspections. The majority conducted annual aerial inspections on transmission pipeline miles and 20 percent reported that VM personnel always perform the inspections. A few utilities used LiDAR, remote sensing, and drones. Surprisingly, the overwhelming majority are not using laser rangefinders to measure conditions (Figure 6).

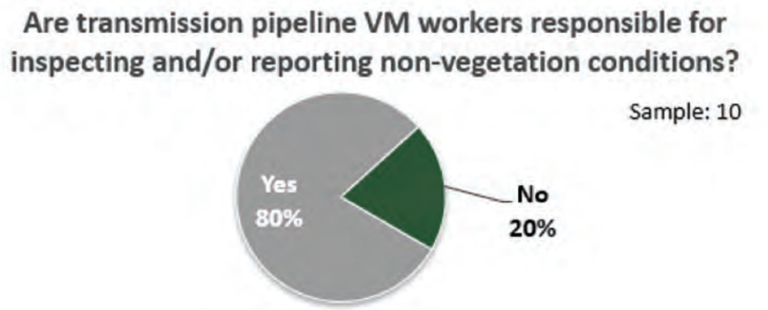

Figure 4. Inspection of Non-Vegetation Conditions

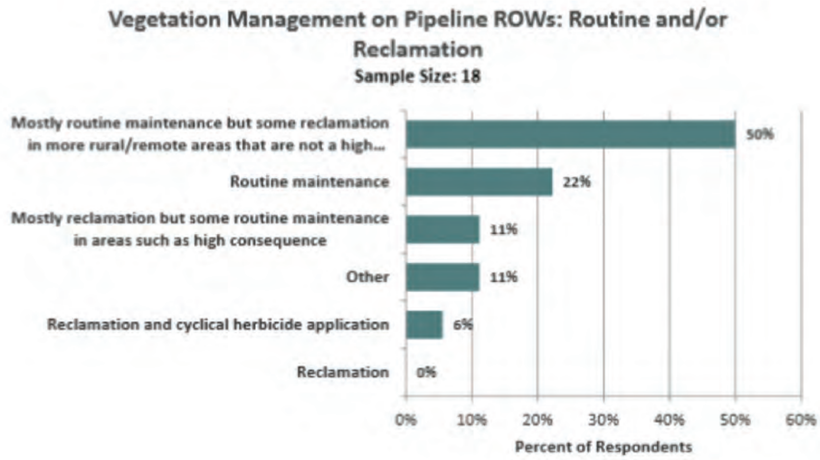

Figure 5. Work Classification

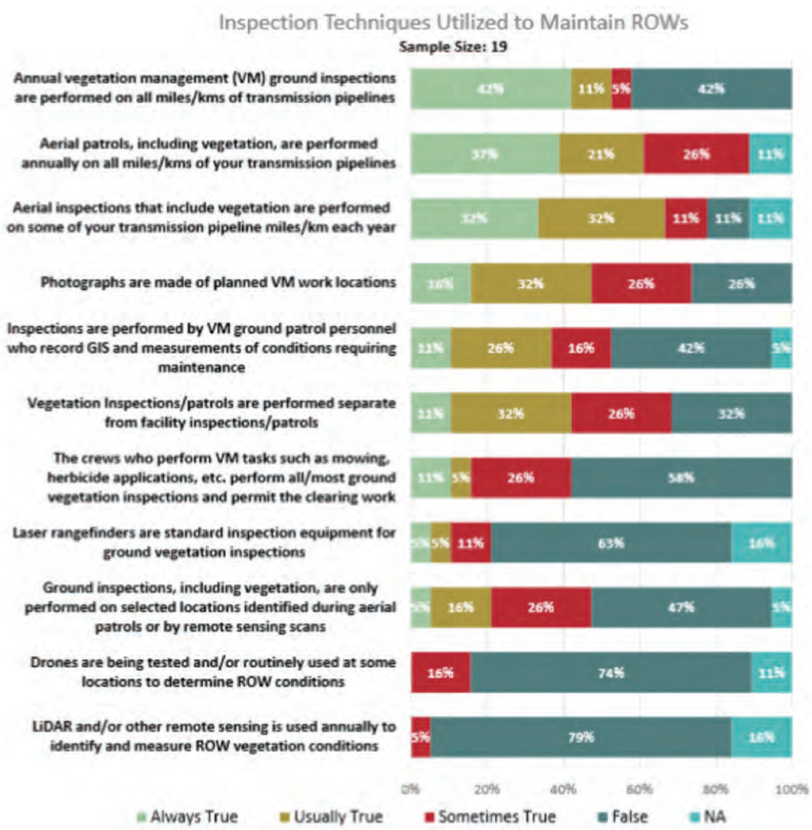

Figure 6. ROW Inspection Techniques

Finance and VM Budgets

The annual VM expenditures for participating pipeline operators ranged from less than $100K to more than $2.8 million (Figure 7). The average VM cost per mile is $765 with a range of $17 to $2,800 (Figure 8).

TPVM Plan

Among responding utilities, VM is entirely in house. Mowing, cutting, and herbicide crews are predominately contracted (Figure 9).

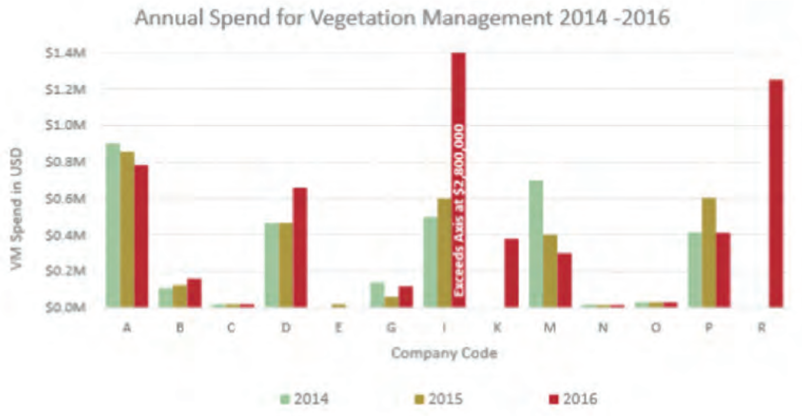

Figure 7. Annual Spending for VM

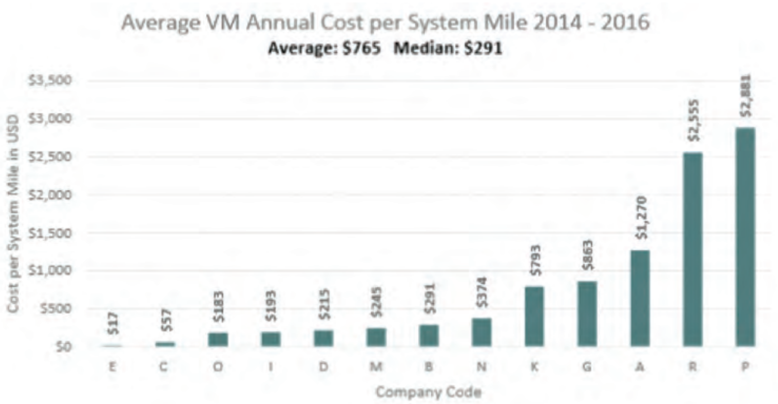

Figure 8. VM Cost Per Pipeline System Mile

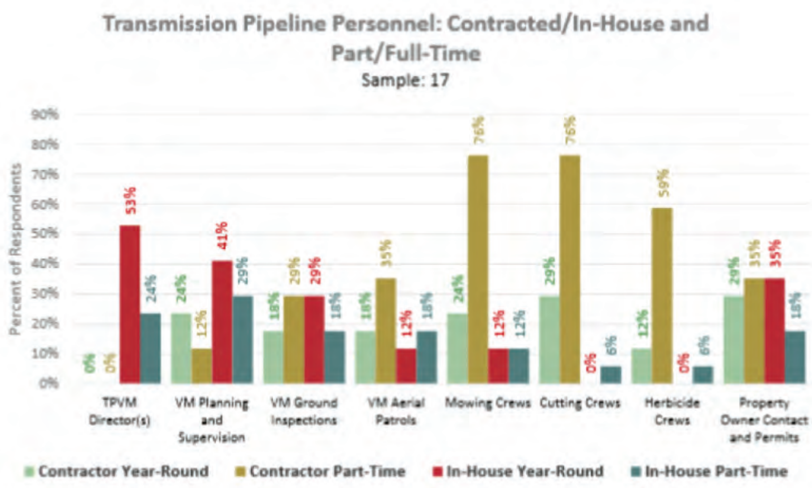

Figure 9. Transmission Pipeline Contracted vs. In-House Human Resources

The most important reason respondents cited for justifying their VM programs was public and work safety, followed by regulations and operational reliability. The least important was cost (Figure 10).

Reliance of responders on standards and BMPs emphasized compliance with pipeline-specific standards and guidelines and less emphasis on arboricultural ANSI standards (Figure 11).

Safety

The overwhelming majority of VM programs investigate safety incidents (Figure 12).

More than 70 percent of responding utilities rely on contractors to ensure safety and compliance standards, while 24 percent have adopted the arboricultural ANSI standards Z133 and A300 (Figure 13).

DISCUSSION

The 2017 pipeline survey found evidence that TPVM programs are not highly organized operations. Those who perform VM tasks are typically a mix of in-house employees who have duties other than VM and contract vegetation workers who are part time or, often, not working year-round for the same pipeline owner. Generally, the work is supervised by a responding pipeline company employee with a degree in Forestry or a related field. Many are Certified Arborists. Several participants could not identify a single point of contact for VM information. Many of the utilities indicated that operations managers or field operations staff were responsible for maintaining the condition of ROWs in their local area. Moreover, participants reported that a significant percentage of their pipeline ROWs are reclaimed instead of maintained. On average, the expenditures for VM per mile of pipeline ROW in the survey participant group are only a quarter of what is spent on average for a mile of electric distribution ROW management (Porter

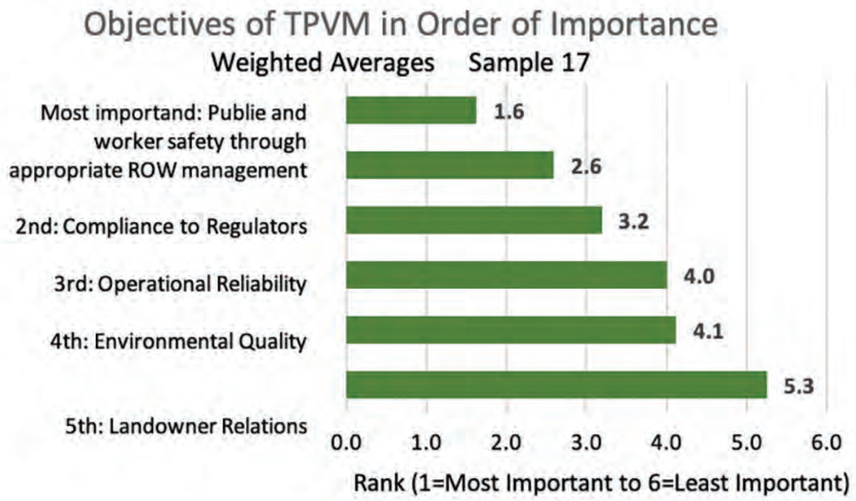

Figure 10. Transmission VM Objectives in Order of Importance

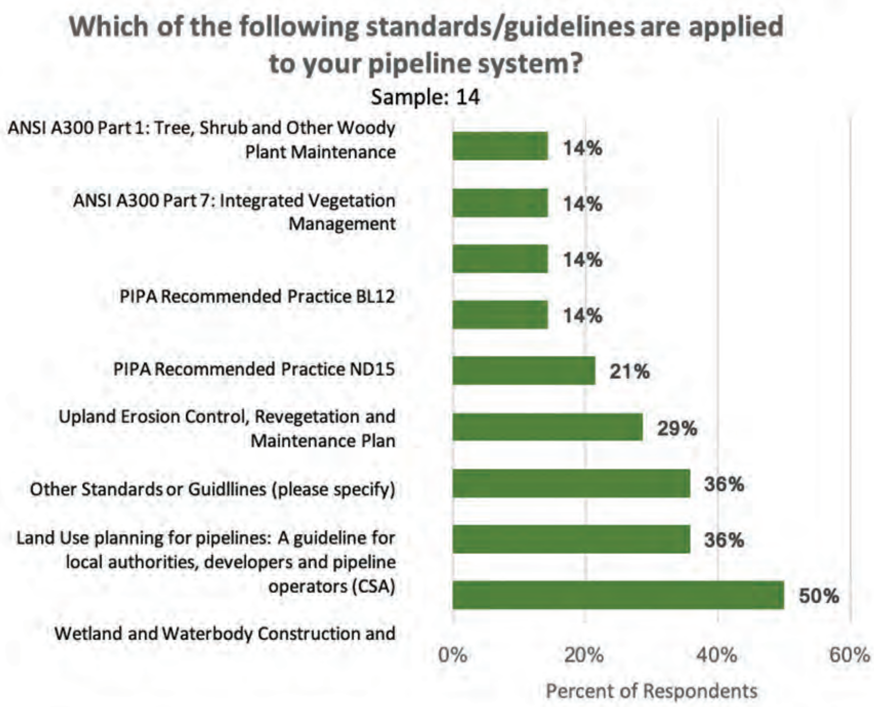

Figure 11. Standards and Guidelines Applied to Pipeline VM Programs

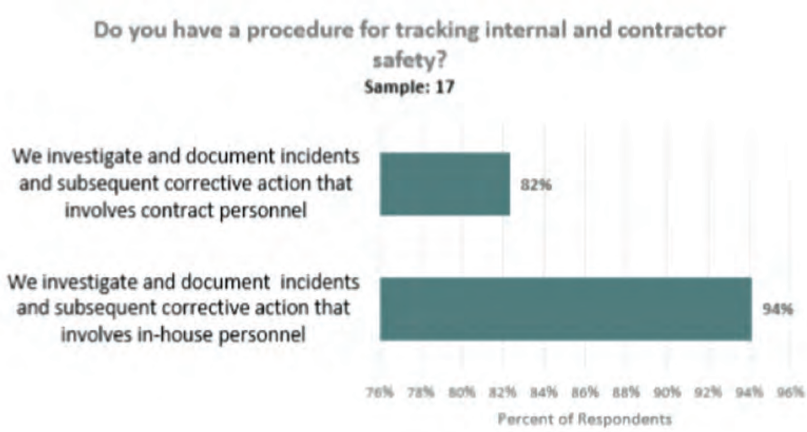

Figure 12. Safety Procedures

and Cohen 2016 and 2017).

Responders could benefit from more centralized and cohesive programs that are informed by industry BMPs. For example, Figure 2 indicates that reclamation of overgrown ROW is frequently the standard rather than a preventative maintenance. Only 20 percent of companies reported their ROWs are usually free of trees, whereas maintenance is focused on trees at the edge or off-ROW. Sixty percent of companies said this is sometimes true, and the remaining 20 percent reported this is not true. This suggests broad room for improvement among participating utilities, organizational structure, and funding could be at the core.

At the same time, many responding pipeline operators utilize the same VM tools that are used for high-voltage transmission corridors. Inspections, work plans, and tracking are electronically captured and communicated. IVM is the primary methodology for VM planning and decision-making (Miller 2014). Forty percent of responders said it is always used. Generally, participating VM programs intend to prevent trees and vegetation that is more than a specified height from establishing on ROWs in order to maintain clear sightlines for pipeline markers and to identify the pipeline ROW as a place that is off-limits for activities that could compromise pipeline safety and operation. Eighty percent of responders indicated VM personnel are expected to report non-vegetation conditions such as illegal or suspicious activity on or near the ROW. This includes construction, digging, or heavy equipment. Environmental conditions are also carefully monitored and vegetation workers are expected to be on the lookout for potential washouts, erosion, or exposed pipe. These responses show that the foundation exists for more successful VM programs.

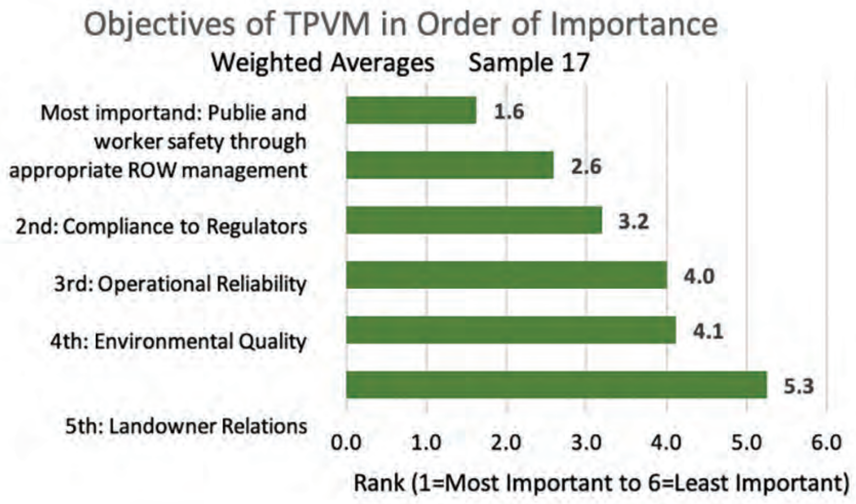

Figure 13. Safety Programs

Pipeline operators should be aware of the possibly of roots interfering with their facilities. Tree roots have been proven to compromise pipe coating, which protects against corrosion. Dynamic Risk Assessment Systems performed a "Tree Root Interference Assessment" for PG&E in 2011–2014 (Nidd et al. 2011). The final report found tree roots adversely affect pipeline integrity by damaging the pipe coating. Coating damage was observed at 75 percent of sites with 38 percent corrosion. The report also found it is unlikely that tree roots will result in an accelerated corrosion condition, but no evidence was found where tree roots caused stress corrosion cracking. Additionally, the study found that tree roots are unlikely to cause adverse effects to cathodic protection and monitoring capabilities. In 53 sites excavated, no structural damage to the pipe was observed, although one location showed potential for damage if the tree was sufficiently impacted by seismic activity, high winds, or lightning. Certain species of trees have a high likelihood of impacting the coating, whereas other species have a low likelihood. This knowledge could help prioritize VM work (Nidd et al. 2011).

Whether or not VM is playing a role in pipeline integrity, it should not influence the extent that pipeline owners implement VM programs. It should be recognized that vegetation is a perennial problem for pipeline maintenance and that a standard of care is warranted. Without it, vegetation will become a matter of reclamation.

CONCLUSIONS

In general, responding utilities had the foundation of good VM programs. The most common programmatic justification given for pipeline VM was public and worker safety, followed by regulatory compliance, reliability, and cost—in that order. However, responding utilities' programs had deficiencies, and would benefit from greater centralization, increased funding, and more emphasis on ANSI A300 and International Society of Arboriculture (ISA) BMPs.

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Danger. Hazard. Risk.

A Review of Terminology Used by Electric Utilities to Characterize the Threat From Trees

Geoffrey Kempter

Keywords: ANSI A300 Standards, Danger Tree, Hazard Tree, Tree Risk Assessment.

"Danger tree" and "hazard tree" are commonly used terms. The term "danger tree" is taken more from traditional forestry, describing trees that pose a threat to workers, and "hazard tree" more from arboriculture, describing trees that pose a threat to their surroundings. Following the 2003 blackout, and in response to North American Electric Regulatory Corporation (NERC) regulations, the ANSI ASC A300 Committee developed a standard for integrated vegetation management (IVM), which included consensus-based definitions for "danger tree" and "hazard tree" with respect to utility infrastructure. In the late 2000s, ASC A300, the Utility Arborist Association (UAA), and the International Society of Arboriculture (ISA) developed standards and best management practices (BMPs) that emphasized using the term "tree risk." In addition, the ISA Pacific Northwest Chapter developed a tree risk assessment credential, which was eventually assimilated into the International Society of Arboriculture (ISA) Tree Risk Assessment Qualification (TRAQ) program. Canadian and U.S. government forestry agencies also continue to develop guidelines for assessing "hazard" and "danger" trees, and NERC VM standard FAC-003 continues to use the term "danger tree." Depending on the source, there are many definitions, some widely disparate. However, "risk" is becoming the preferred term in arboriculture based on emerging international trends and standards in risk management. This paper reviews current and past literature, identifies trends, and provides recommendations for current practitioners.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Electric utilities manage millions of trees adjacent to utility facilities across North America. In so doing, they operate within both the disciplines of forestry and arboriculture (Blair 1939). Indeed, many utilities have forestry departments, and many utility tree managers have degrees in forestry, yet the professional organization that defines the profession is the Utility Arborist Association (UAA), and the professional credentials most often pursued are the International Society of Arboriculture (ISA) Certified Arborist and ISA Utility Specialist. While utilities manage large populations of trees (like traditional foresters), trees adjacent to powerlines are generally managed individually following arboricultural standards and practices (Kempter 2004).

With roots in forestry and arboriculture, it is perhaps not surprising that the utility industry characterizes threats from trees with terminology from both disciplines, including "danger tree," from forestry (Occupation Safety and Health Administration [OSHA] 1994) and "hazard tree," predominantly from arboriculture (Matheny and Clark 1991). Indeed, workers in both fields are subject to similar risks, and both take significant measures to protect their workforces and the public from harm. More recently, with the publication of ANSI A300 Part 9, Tree Risk Assessment in 2011, and the introduction of the ISA Tree Risk Assessment Qualification (TRAQ) credential in 2013, the term "tree risk" has become more widely used in arboriculture.

How the threat from trees has been characterized and defined by electric utilities has evolved with time. The objectives of this paper are to review current and past literature to examine how the utility industry has characterized the threat from trees, discuss current trends, and provide recommendations for today's practitioners.

INDUSTRY TERMINOLOGY

Forestry

In general, U.S. and Canadian government forestry publications use the term "danger tree" when describing trees that "present a hazard" to forestry workers (OSHA 1994; Taupin and Barger 2005). Various publications that describe danger trees and steps workers should take to avoid injury or death while on the job are available from state, provincial, and federal sources (USFS)

The U.S. Forest Service (USFS) uses the OSHA definition of "danger tree," as follows:

- A standing tree that presents a hazard to employees due to conditions such as, but not limited to, deterioration or physical damage to the root system, trunk, stem or limbs, and the direction and lean of the tree. The tree may be dead or alive" (OSHA 2011).

In its 2012 publication *Hazard Tree Guidelines for Forest Service Facilities and Roads in the Pacific Southwest Region*, the USFS stated that the term "hazard tree" had typically been used for trees occurring near buildings or recreation areas, and "danger tree" for trees near roads. Other USFS publications differ slightly in their interpretation of the terms "danger" and "hazard," but the overall pattern is that danger trees threaten timber industry workers and operations (forest roads and work sites) and hazard trees threaten recreational forest users and facilities (developed sites in forested areas and "in campgrounds and around buildings and other areas frequented by the public") (USFS 2012, 2014, 2016).

Where wildlife habitat is a concern, "danger trees" may also be classified as "wildlife trees." Trees that meet certain criteria regarding size, condition, and location may be designated and protected as wildlife habitat (University of Northern British Columbia 2012)

In some cases, trees that cannot be safely removed with conventional means are safely mitigated with explosives, even in fire environments (USFS 2011).

Arboriculture

The arboriculture industry traditionally favored using the term "hazard" when characterizing the threat from trees to people and property. Several important publications from the 1980s and 1990s highlight this:

- In its 1988 *Pruning Standards for Shade Trees*, The National Arborist Association (now the Tree Care Industry Association [TCIA]), recommended "hazard pruning… where safety considerations are paramount," and that "…Hazard pruning shall consist of the removal of dead, diseased, decayed, and obviously weak branches…." (National Arborist Association 1988)
- In 1991, the ISA published *A Photographic Guide for the Evaluation of Hazard Trees in Urban Areas*. The publication included a numeric evaluation form and rating procedure (Matheny and Clark 1991).
- In an undated publication titled *Tree Hazards*, Dr. Alex Shigo identified 13 conditions that could lead to catastrophic failure of trees or tree branches. The publication was ostensibly directed at homeowners, but is still relevant as a training tool for professional arborists (Shigo n.d.).
- In 1995, ANSI A300, Part 1 Pruning stated that reasons for pruning included (among other things) "reducing hazards" (ANSI 1995).

Trend Toward Use of the Term "Risk"

Around 2000, professional arborists began favoring use of the terms "risk" and "risk assessment" instead of "hazard" and "hazard tree." This reflected an overall trend in the legal, insurance, and other industries, as well as the International Standards Organization (ISO) to improve accuracy when describing risk from any source, which therefore permits mitigation resources to be better distributed. In general, a hazard is any potential source of harm, whereas risk is the likelihood that a hazard will cause harm (Campaign for Accuracy in Public Health Research). Arboriculture industry publications and qualifications began to reflect this approach:

- The 2001 and 2008 revisions of *ANSI A300, Part 1, Pruning*, changed reference of "hazard" to "risk" (ANSI 2001, 2008).
- In 2005, the Pacific Northwest Chapter of the ISA developed the "Tree Risk Assessment Course and Exam," which included a numeric tree risk evaluation procedure (Dunster 2005).
- In 2011, *ANSI A300 Part 9, Tree Risk Assessment* was published (ANSI 2011).
- In 2011, the ISA published a BMP for tree risk assessment (Smiley et al 2011).
- In 2013, the ISA initiated the TRAQ program to provide arborists with advanced training in assessing tree risk. The course teaches the use of objective and subjective data to characterize the relative risk posed by trees to targets (Dunster 2013).

Electric Utilities

Varying Characterizations

There has been little consistency in how utilities characterize the threat from trees; in fact, the terms "danger tree" and "hazard tree" are sometimes used interchangeably, or they can have quite different meanings altogether.

- In his 1939 book, *Tree Clearance for Overhead Lines*, George Blair did not use the terms "hazard tree" or "danger tree," although the term "hazard" and "danger" appear in descriptions: "Dead wood overhanging or otherwise adjacent to conductors is an imminent hazard…" and "…Such limbs are a constant source of danger to persons and property, also to trees of which they are a part…." (Blair 1939).
- In *Ragland v. Alabama Power* (1978), a property owner sued for damages when healthy trees growing adjacent to a powerline were removed by the utility. The term "danger tree" was used to describe "…Trees of such size and contiguity to the transmission line right-of-way (ROW) that, if they fell, they would strike and likely damage or endanger the lines on that ROW." The Alabama Supreme Court found in favor of the utility, setting a precedent for characterizing "healthy and disease free trees" within striking distance of lines as "danger trees" (Ragland v. Alabama Power 1978).
- Simpson and Van Bossyut (1996) described the "Danger Tree Mitigation Project" on Eastern Utilities, which found that removing "structurally unsound trees and performing stormproof pruning" significantly improved reliability; however, other than describing removal of structurally unsound trees, the term "danger tree" was not explicitly defined (Simpson and Van Bossyut 1996).
- The California Forest Practice Rules (1999) described "danger tree" as "any tree located on or adjacent to a utility ROW or facility that could damage utility facilities should it fall…" with the following stipulations:
  - o The tree leans toward the ROW.
  - o The tree is defective because of any cause, such as: heart or root rot, shallow roots, excavation, bad crotch, dead or with dead top, deformity, cracks, or splits.
  - o Any other reason that could result in the tree or a main lateral of the tree falling (California Forest Practice Rules 1992).
- Guggenmoos (2003) characterized trees as "powerline hazards" because of any number of "structural defects," and that they should be removed as part of a "hazard tree program" (Guggemoos 2003).

2003 Blackout

Following the 2003 northeast blackout that was initiated by tree-line contact and that affected 50 million customers in Canada and the U.S., the North American Electricity Regulatory Corporation (NERC) focused attention on utility vegetation management (UVM). Because there was no consensus standard or best practice for UVM at that time, the UAA requested that the Accredited Standards Committee (ASC) A300 develop a standard for integrated VM (IVM). The committee agreed, and in 2006, *ANSI A300 Part 7 Integrated Vegetation Management, a. Utility Rights-of-Way* was published. The standard defined "hazard tree" as "a structurally unsound tree that could strike a target when it fails…." and "danger tree" as "a tree on or off the right-of-way that could come into contact with electric supply lines...." (ANSI 2006).

Further Characterizations

Guggenmoos and Sullivan (2010) further refined the terminology, defining a danger tree as "any tree which, on failure, is capable of interfering with the safe, reliable transmission of electricity, and hazard tree as "a danger tree that has both a target and a noticeable defect that increases the likelihood of failure" (Guggenmoos and Sullivan 2010).

Some practitioners maintain that the term "danger tree" should be reserved for a tree located off the ROW, generally along the edge, alive or dead, and that would likely fall or bend toward the facility and contact it, especially those that are diseased or otherwise damaged, or are severely leaning (K. McLoughlin, *personal communication*, September 2018).

DISCUSSION

The use of terms such as "danger tree" and "hazard tree" can lead to misinterpretation because the definitions are inconsistent, or even confusing. For example, according to the definitions in the 2006 ANSI A300 IVM Standard, all hazard trees are danger trees, but not all danger trees are hazard trees. Or, counterintuitively, a large tree with multiple defects, leaning toward a powerline, and an adjacent tree that is perfectly sound that is also within striking distance of the powerline, would both be characterized as "danger trees," even though one poses far more risk than the other. Indeed, the use of the terms "danger" either "hazard" attract attention, and imply a problem, but without any indication of how significant a problem.

Interestingly, "DANGER," "WARNING," and "CAUTION" are each "signal words" recognized by the U.S. Environmental Protection Agency (EPA) in classifying the risk of exposure to a chemical agent. Products with the "DANGER" signal word are the most toxic (National Pesticide Information Center). In general, people have been conditioned to associate terms like "danger" with a worst-case scenarios, which may or may not be appropriate, depending on the circumstances.

The 2012 revision of ANSI A300 Part 7 (IVM) dropped terms "danger tree" and "hazard tree" from the body of the standard due to the 2011 implementation of ANSI A300 Part 9 (Tree Risk Assessment), which described a methodology for characterizing the relative amount of risk posed (ANSI 2011, 2012).

CONCLUSIONS

In general, the timber industry and OSHA have used the term "danger tree" to describe trees that pose a threat to forestry workers. Increasingly, USFS is using "hazard tree" when describing incidental threat in high-use areas such as campgrounds. Arboriculture has adopted the term "risk" and uses descriptors such as "extreme," "high," "moderate," and "low" to categorize the relative level of risk posed. Electric utilities generally have used both "danger tree" and "hazard tree," with meanings often overlapping, and with ambiguous and confusing results.

OSHA has defined "danger trees" as those that pose high risk to workers, and the forestry industry has adopted this terminology. Considering this, it is not unreasonable to suggest that the arboriculture and electric utilities work toward adopting this usage in their safety communications.

The insurance and legal fields increasingly use "risk" and "risk mitigation" as more accurate terms. Given the ever-increasing effects of climate change, destructive pests, and wildfire, which are all significantly affecting the health and stability of trees, there is a growing need for more accurate characterization of the risk posed by trees in all settings. The utility industry should work toward incorporating modern risk management terminology regarding trees that are growing near utility facilities.

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The wire zone/border zone (WZ/BZ) model recognizes two areas within an electric transmission right-of-way (ROW) that differ in terms of vegetation management (VM) objective. Compatible vegetation within the WZ is largely herbaceous. Low-growing woody vegetation is included in the BZ. In actual practice, the WZ/BZ model has been inconsistently adopted. It is not uncommon to see the WZ extending across the entire width of ROWs. This paper presents factors that may assist practitioners in determining an appropriate wire zone.

Establishing an Empirical Basis for Wire Zone Width on an Electric Transmission ROW

John W. Goodfellow

Keywords: Border Zone, Wire Zone (WZ/BZ).

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

The wire zone and border zone (WZ/BZ) model has been described as a best practice for vegetation management (VM) on electric transmission rights-of-way (ROW). The WZ is that area below and adjacent to the alignment of transmission conductors and managed for the establishment of a low-growing compatible community dominated by herbaceous plans such as grasses, sedges, forbs, and limited, low-growing, woody shrubs. The border zone extends from the outer edges of the wire zone to the cleared edge of the corridor and is managed for a diverse community of compatible herbaceous and woody plants including shrubs and small trees.

The WZ is that area within a transmission ROW that has the least ground clearance from conductors. Managing for low-growing compatible vegetative cover types is an effective way of mitigating the risk of an incompatible stem reaching a height great enough to initiate a fault from energized conductors and reduce the risk of violation of minimum vegetation clearance distances (MVCD) on the bulk power system (≥200 kiloVolts). An incompatible stem emerging from a low-growing plant community in the wire zone is more likely to be detected during condition assessment inspections. Finally, maintaining herbaceous plants in the WZ improves ease of access for inspection and repair.

Early reference of a WZ-like concept first appeared in the 1950s (Niering 1958), and has been generally applied by the industry in subsequent decades. The WZ/BZ concept was formally described in the mid-1980's by Dr. William Bramble and Dr. William Byrnes (Bramble et al. 1985, 1986) as an outcome of their work on the long-term Pennsylvania Game Lands 33 project. The model continued to be refined through the turn of the century with increased recognition of the BZ where woody shrubs and even small-stature trees increased the cover type diversity (Ballard et al. 2004; Yahner and Hutnik 2004). In 2007, a paper proposing significant enhancements to the WZ/BZ model was published (Ballard *et al.* 2007). That paper identified the relatively simplistic nature of the WZ/BZ model as a problem and proposed significant refinements. These included adding a three-dimensional spatial component to the model and stratifying the WZ into an "exclusion zone" around structures, a "critical wire zone" in those areas within a span with least clearance, and an "effective border zone" in those areas below conductors with sufficient ground-to-conductor clearances to allow taller shrubs and small compatible trees to grow.

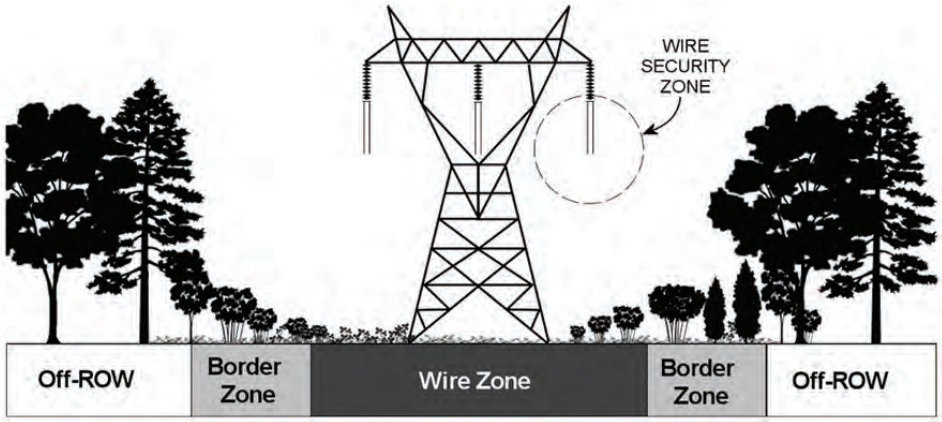

Figure 1. Depiction of the WZ/BZ model (adapted from Ballard et al. 2007)

Inclusion of a transitional BZ between the WZ and edge of the cleared corridor, composed of a wider range of compatible species, increases habitat richness and diversity. All plant life forms—grasses, ferns, herbs, and shrubs—can suppress incompatible trees through interference (competition) and by providing habitat for seed and seedling predators. The intensity of competition is similar amongst a wide variety of plant cover types. However, the competitive abilities of compatible plant communities differ in their influence on trees mainly by the duration of interference effects, rather than intensity. This means that cover types including woody shrubs and small stature trees can be considered better competitors for trees because they are taller than other compatible plant life forms. Absolute reduction in tree density with shrub cover compared to other life forms is expected to be somewhat low, yet ecologically and operationally meaningful with hundreds fewer trees per hectare produced by shrub cover compared to other life forms (Goodfellow et al. 2017). The resulting reduction in incompatible stem density may result in lower costs for selective vegetation maintenance treatments performed in the BZ.

In actual practice, even the basic WZ/BZ model has been inconsistently adopted. It is not uncommon to see the wire zone extending across the entire width of an ROW, effectively eliminating a BZ of taller-growing compatible vegetation. The objective of this paper is to provide practitioners with an understanding of factors that should be considered in determining an appropriate WZ width within a transmission ROW.

ANALYSIS

Electric transmission line corridors are maintained to ensure safe and adequate clearances to energized conductors and to provide access to energy delivery infrastructure for inspection, maintenance, repair, and restoration of power should a problem occur. Tall-growing trees are incompatible with the purpose of the ROW, and if left to grow unchecked, may encroach to within MVCDs from energized conductors. This creates the potential for a tree-initiated ground fault, interruption, and outage. The fault pathway from the energized transmission conductor to ground includes both the tree and the air gap between tree and conductor. The conductivity of trees has been described in several references (Defandorf 1954; Hoffman 1984; Goodfellow 2007).

More recently, the dielectric strength of the air gap has determined (EPRI) and resulted in revisions to the MVCD's for transmission lines, as codified in NERC FAC-003.4. These distances are based on high voltage flash-over tests with trees located both below and beside energized conductors.

The MVCDs establish a quantitative basis for appropriate separation between energized transmission conductors and incompatible vegetation. They include a safety factor and anticipate short-term switching over voltages that can significantly exceed normal, steady state 60 Hz operating voltages. For example, on a 230 kiloVolts (kV) transmission circuit the phase to ground (or a tree) voltage potential is 133 kV, and the switching impulse withstand voltage was determined to be 395 kV.

Table 1 illustrates the relationship between the minimum design height of conductors above the ground and the distance below and beside conductors that is to remain clear of tree growth. The MVCD envelope around transmission conductors comprises the wire security zone. The difference between these two measures begins to define the theoretical maximum (*not-to-exceed*) height of vegetation in the WZ. In actual practice, vegetation maintenance would be well before incompatible stems reached this height. It is also clear that woody shrubs and short stature trees that mature at heights less than these not-to-exceed heights are compatible with the intended use of the site.

It is also important to recognize the dynamic nature of the transmission system. Conductors change position due to sag and sway (i.e., "blowout"). Potential change in ground clearance is a function of span length and conductor tension, and varies with conductor temperature, which is affected by factors such as ambient temperature, electrical load, and wind. The dynamic repositioning of conductors is most pronounced at mid-span. Advanced technology makes it possible to model conductor behavior withstanding a variety of loading and weather conditions.

Nominal Voltage (kV)	Minimum Ground Clerance[1]	Minimum Vegetation Clearance Distance[2]	Not-to-Exceed Height[3] of Vegetation
765 kV	13.0 m (42.7 ft)	3.6 m (11.8 ft)	9.4 m (30.9 ft)
500 kV	10.4 m (34.0 ft)	2.1 m (6.9 ft)	8.3 m (27.2 ft)
345 kV	8.8 m (29.0 ft)	1.3 m (4.3 ft)	7.5 m (24.7 ft)
230 kV	7.7 m (25.2 ft)	1.2 m (3.9 ft)	6.5 m (21.3 ft)
138 kV	6.8 m (22.2 ft)	0.7 m (2.3 ft)	6.1 m (19.9 ft)
115 kV	6.5 m (21.4 ft)	0.6 m (2.0 ft)	5.9 m (19.5 ft)

[1]NESC 232.c.1C Vertical clearances over cropland, pastures, forestry sites, etc.
[2]NERC FAC-003.4
[3]Minimum NESC over ground clearance less FAC-003.4 MVCD

Table 1. Comparison of appropriate tree-conductor and over-ground clearances for transmission lines on undeveloped sites

The position of vegetation relative to conductors changes as woody plants increase in height each growing season. The maximum height expected for species of woody plants is a consideration in determining their compatibility with the objectives of both the WZ and BZ.

DISCUSSION

Transmission ROWs are typically managed using the principles of integrated VM (IVM), which are intended to create, promote, and conserve stable plant communities that are compatible with overhead transmission lines, and to discourage incompatible plants that may pose a risk to the reliable operation of the transmission facility. Incompatible tree species growing in the WZ below conductors present the greatest risk of a grow-in incident. The risk can be mitigated by managing for a community of herbaceous species. The low-canopy height of plant communities of this nature makes it easier to identify invasion of incompatible trees that might become established below conductors. A WZ composed of herbaceous species and, in some cases, small-stature shrubs, also provides access for condition assessment inspections and repairs, as does WZ-like vegetative cover around supporting structures.

The operational benefits of a WZ of low-growing vegetation are not uniformly distributed across and along an ROW corridor. Conductor heights are typically greatest, and the potential for both vertical and horizontal displacement minimized at and near structures. The opposite is true at mid-span. This argues for a WZ of variable width, as well as a complementary BZ composed of woody shrubs and, in some cases, short-stature trees that present little risk to transmission conductors. Managing for a wire zone across the entire width of a transmission ROW misses this point and requires unnecessarily intensive VM.

As described, the physical factors that need to be considered include the potential position of conductors above ground and horizontal off-set within and along the ROW, and the expected mature heights of compatible vegetation. This provides a means of applying simple geometry to determine the outer limits of an appropriate WZ.

Sophisticated imaging technology such as light detection and ranging (LiDAR) combined with engineering tools make it possible to accurately determine the position of conductors within a span under a variety of temperature and wind conditions. This level of precision may not be necessary. A simplified two-step clearance mechanism addressing the matter of conductor sag and deflection is being used in Australia (ISSC3 2016). In this case, the assumption is that conductor displacement within one-sixth (1/6) of a span's length closest to each structure is less than it would be in the middle two-thirds (2/3) of the span.

The other factor to be considered when determining an appropriate WZ width is the expected height growth of incompatible trees. The early detection of incompatible trees is easier in low-growing WZ cover. Incompatible stems can be hidden within a taller canopy of compatible woody shrubs. In either case, the annual height growth of these incompatible species will inform decisions related to condition assessment inspection and preventive maintenance intervals.

Finally, the risk of an incompatible tree in the WZ growing within MVCD varies by site type, land use, and in some cases, restrictions as to VM practices, such as a requirement that trees below transmission lines be pruned rather than removed.

CONCLUSIONS

The wire zone within a transmission ROW doesn't need to extend edge to edge; there is room for a border zone. In its simplest form of the WZ/BZ model, a WZ below and offset from conductors can be established, allowing a BZ zone along ROW edges. A more sophisticated approach is to vary WZ width within the ROW in a manner that reflects the dynamic nature of conductors in long spans.

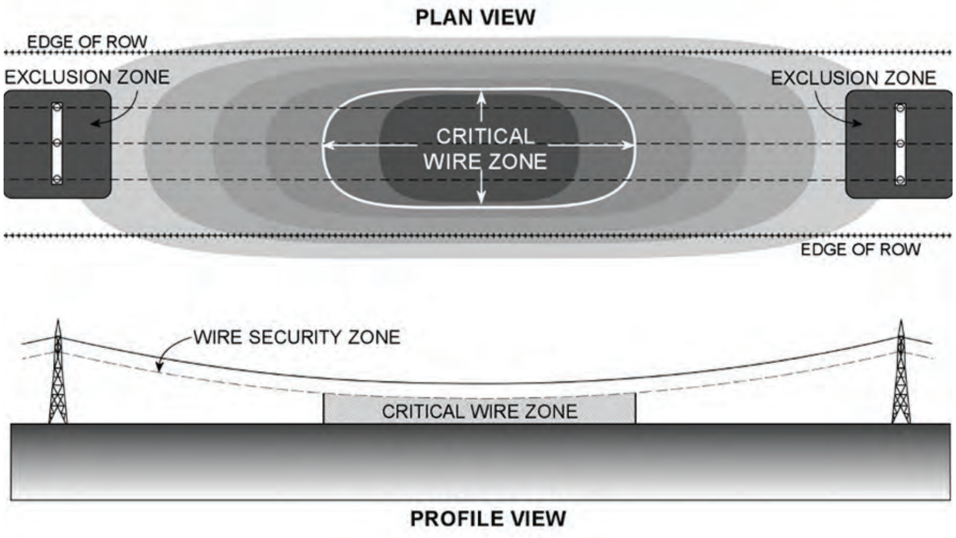

Figure 2. Spatial depiction of a transmission span depicting a variable WZ (adapted from Ballard et al. 2007)

It should also be noted that while the WZ/BZ concept is recognized as a best management practice (BMP), there may be situations where it is not suitable. For example, it may be inappropriate in areas of known wildfire risk where transmission ROWs represent fire breaks, and a BZ could provide ladder fuels to the adjacent forest canopy.

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AUTHOR PROFILE

John W. Goodfellow
John Goodfellow has 40 years of experience in the utility industry, having held positions of responsibility for VM, T&D operations, maintenance, engineering, and construction at three electric and gas utilities. He is recognized as a leading authority on utility VM (UVM) and reliability, and currently manages an active portfolio of VM-related research projects focusing on electrical characteristics of tree-conductor contacts, tree biomechanics, and IVM practices. He is chair of the ROW Stewardship Council's Technical Advisory Committee responsible for IVM accreditation requirements for "ROW Steward" recognition.

Goodfellow received a Bachelor of Science degree in Environmental Resources Management from SUNY College of Environmental Science & Forestry, and a Bachelor of Science in Forestry from Syracuse University.

Future Vegetation Management "Observatories"

The Value of Industry & Academic Partnerships in Understanding Ecological Impacts of ROW VM and Engaging Students of All Disciplines in Practical Environmental Issues

Chris Halle, Carolyn Mahan, David Krause, and Eric Brown

Keywords: Evaluation, Pollinator, Other.

The longest continuous study of the effects of right-of-way (ROW) vegetation management (VM) on local ecosystems began on Pennsylvania State Game Lands (SGL33) in 1953 (e.g., Aurora Consulting 2013; Bramble and Byrnes 1983; Holt and Orr). More recently (since 2015), an industry/university collaboration has begun to establish similar long-term VM "observatories" in substantially different environments in the western U.S. In general, the findings from the eastern and western sites seem to support the idea that modifying the habitat can be beneficial (or at least not harmful) for certain wildlife and pollinator species. ROW study funds have also been combined with other sources of funding to begin new studies on the ROW sites, involving "non-traditional" disciplines such as computer science and engineering.

With the increased membership in the Utility Arborist Association (UAA), and the establishment of the Tree Research Education and Endowment (TREE) Fund Research Endowment, the industry has some choices to make about ROW research into the future. This panel will spend a few minutes each summarizing their individual thoughts on ROW research and future directions, and then open the floor to audience discussion. We hope to explore "next steps" with the help of audience participation, particularly focusing on improving student outreach, expanding research opportunities, increasing community awareness, and leveraging industry associations to help recruit trained students into industry careers.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

The longest continuous study of the effects of right-of-way (ROW) vegetation management (VM) on local ecosystems began on Pennsylvania State Game Lands (SGL33) in 1953 (e.g., Aurora Consulting 2013; Bramble and Byrnes 1983; Holt and Orr). Although the initial proposal was to study the efficacy of herbicides in VM, the study has grown with time to include effects on wildlife, pollinator utilization, and other variables. The ROW habitat created through large tracts of forest appears to support increased abundance of small mammals, birds, and pollinators (e.g., Bramble et al. 1992; Bramble, et al. 1997; Bramble et al. 1999; Forrester et al., 2005; Yahner et al. 2002; Yahner et al. 2003; Yahner 2004). Similar studies have been conducted at a companion site, Green Lane Research and Demonstration Area (GLR&D), in southeastern Pennsylvania since 1987. Researchers at Pennsylvania State University continue the studies today, providing invaluable insights for understanding the response of plants and animals to VM on ROW.

Utility companies across the country have used results from these ongoing studies to develop best practices, provide information on impacts, permitting, etc. However, many professionals have questioned whether the results are applicable to other areas of the U.S. Especially questionable is the application of results to California ecosystems, with its much drier and more variable Mediterranean climate, more diverse habitats, and high diversity of species. California is recognized globally as a biodiversity hotspot, one of 34 sites on earth that contain 60 percent of the plant and animal species.

To address this issue, in 2015, Sonoma State University (SSU) and Pacific Gas & Electric (PG&E) began exploring the idea of establishing long-term research on the effects of ROW VM in California. Initial studies were undertaken as part of the Nature!Tech Collaborative, which explores how light detection and ranging (LiDAR) and other technologies can be used to enhance academic research into VM practices. Studies included LiDAR-based biomass estimates, microclimate sensor development, wildlife movement, and pollinator use of the ROW at SSU's Fairfield Osborn Preserve (Clark 2016; Diaz and Halle 2015; McGuire 2016a, 2016b; McGuire and Farahmand 2016; Romero and Clark 2016; Wininger 2016; Wininger and Rank 2015; Zhong and Halle 2015).

In the rest of this paper, we explore some of the key findings of the eastern and western research sites, and provide recommendations for continuing to expand the research into the future.

METHODS

Eastern U.S. Sites

To test the environmental effects of ROW maintenance methods, six mechanical and herbicidal treatment sites (with replicates) were established. These treatments included: hand-cutting (control), mowing, mowing plus herbicide, stem-foliage spray, foliage spray, and low-volume basal spray. In addition, the treatments were managed to include an approximately 15-meter (m) (50 feet) border zone. This approach to VM typically produces a tree-resistant, forb-shrub-grass cover type in the wire zone and a tall shrub cover type in the border zone. The treatment effects on vegetation and wildlife communities (via multiple surveys, live trapping, and vegetation inventories) were compared to each other and to the adjacent, mature, mixed deciduous forest.

In 2015, vegetation diversity on all treatments was examined in light of Lepidopteran host plant availability. Plant species documented on all treatments were compared to on-line databases (primarily the Museum of Natural History-London, UK) of host plants for Lepidopteran larva. All Lepidopteran species were then compared to appropriate range maps to create a master list of species that potentially use plants on the powerline ROWs within our study treatments.

Western U.S. Sites

To test the various integrated VM (IVM) treatment options, three sites were established in different ecosystems. The "low elevation" site is a mixture of grasslands and oaks, the "mid-elevation" site is a mixture of oaks, bay laurel, and grasslands, and the "high elevation" site is a mixed conifer forest. In contrast to the eastern sites, the treatment options have been broadly grouped as "mechanical" and "herbicide" treatments, as some of the sites are different enough that controlling the treatment more rigorously might have been a challenge. Each of the sites contains a "mechanical-only" plot as well as a "mechanical plus herbicide" plot. The surrounding areas are also surveyed.

Vegetation in the plots is mapped annually. Pollinator surveys are conducted every two weeks from spring through the fall. In addition, recent funding from the TREE Fund is used to provide small amounts of seed money to researchers from fields that do not normally study ROW issues (e.g., computer science professors, engineering professors, etc.).

RESULTS

Eastern U.S. Sites

In the past 60+ years of research, our study has found that deer, small mammals, birds, reptiles, and even butterflies—considered a true test of environmental impact—were using the early successional habitat created and maintained by vegetation clearing (Bramble et al. 1997, Yahner et al. 2002, Yahner et al. 2007, Yahner 2004, 2012]. In particular, early successional communities of native birds were thriving in the ROWs (Yahner et al. 2002). These early successional bird communities are declining throughout the eastern U.S. and many species that reproduce in the ROW (e.g., eastern towhee, field sparrow) are on the Audubon society's conservation watchlist (Yahner et al. 2004). In addition, we noted American woodcock persisting and breeding on our treatment plots. American woodcock is a gamebird that is in dramatic decline throughout the eastern U.S. (NRCS 2007).

The inclusion of a border zone method of managing the ROW at SGL33 appears to increase the use of powerline ROWs by salamanders. Several studies have indicated the forest fragmenting features like roads, ski-slopes, and ROWs impeded movement of forest salamanders (Lannoo 2005). In our treatment plots, red-backed and spotted salamander were both observed using the border zone habitat—thus minimizing the fragmenting effects of the ROW.

In 2015, we documented 35 species of plants in our late spring inventory of vegetation at SGL33. These plant species potentially support the larval stage of 245 species of native Lepidopterans (butterflies and moths). Species of plants compatible with ROW management (e.g., non-trees) support more than 50 percent of these potential species. In particular, goldenrod (*Solidago*), Virginia creeper (*Parthenocissus quinquefolia*), dogbane (*Apocynum cannabinum*), witch hazel (*Hamamelis*), bracken fern (*Pteridium*), and blueberry (*Cyanococcus*) support a variety of sphinx, tiger, and io moth species. Butterflies such as gray hairstreak (*Strymon melinus*), striped hairstreak (*Phyciodes pulchella*), and spicebush swallowtail (*Papilio troilus*) all depend on host plant species that are compatible with ROW maintenance.

Western U.S. Sites

The western sites have only recently been established, so long-term trends are still being observed. The longest observed western site (which is treated as a full IVM site, including both mechanical trimming and herbicide application) has been observed for three years. In general, pollinators utilize the managed ROW more than the surrounding areas. However, native bees have a slight preference for the nearby unmanaged area. This contrasts with a site previously studied by PG&E along the American River, where native bees overwhelmingly preferred the ROW. This difference is really due to the surrounding ecosystem and the differing management goals. Along the American River, the ROW was cleared of invasive plants; the remaining ROW flowering plants appealed more to the native bees than honeybees.

Fire clearly plays a big part in western ecosystems. One of our sites (Eldorado National Forest) was chosen because it burned in October 2014. Another site (Pepperwood) burned in October 2017. Although the fire was not very hot and moved through the area quickly, the brush piles left at Pepperwood to create habitat acted as a kiln, and baked the ground underneath. The site was covered with tall grass by the time vegetation surveys were done again in May 2018, although the species were different from the previous year. Comparing the fire-affected sites of Pepperwood and Eldorado as they are managed into the future will continue to be a focus of the study.

Perhaps some of the most exciting aspects of the western studies have been the projects that were funded using small amounts of seed money. The seed money is used to encourage "non-traditional" ROW research by helping to fund equipment and publications costs. Two of the projects that have been started with this seed funding are: (1) low-cost, networked microclimate stations, and (2) the development of a computer algorithm to automatically screen "false alarms" from wildlife camera images. The microclimate stations were originally developed as part of a graduate thesis (McGuire 2016a, 2016b; McGuire and Farahmand 2016), and are of interest to local winegrowers. The new computer algorithm began as a simple, undergraduate-guided class project, and provides an effective way to reduce the manual screening time for wildlife camera images, particularly those images where the camera motion sensors are triggered by moving vegetation and cloud shadows (Halle, et al. 2018).

Into the Future

As demonstrated above, both the eastern and western research sites are contributing to the understanding of the impact of VM on local ecosystems. In general, the findings support the idea that modifying the habitat can be beneficial for wildlife and pollinators, depending on the species and the environment. The investigators studying the long-established eastern sites and the newer western sites perform public outreach, train student interns, create collaboration among academic departments, and try and leverage other funds to expand the research interest in ROW issues.

Because of time and geographic constraints, however, these study sites seem to exist largely in isolation. The investigators generally only exchange information on research methods and best practices occasionally, at conferences such as ROW 12. In addition, there are multiple sites throughout the U.S. (and the world) that could benefit from an exchange of ideas on a more regular basis. Finally, with an increase in the number of students being trained on ROW issues, it is worth discussing methods to more effectively recruit the students into industry careers.

To help foster community conversation in these topics, this presentation will be in a panel format. Each panelist will take a few minutes to provide an overview of his/her interest and expertise in ROW issues, and then questions and comments will be actively encouraged from the audience. (For a list of panelists, please refer to the author biographies of this conference proceeding.)

The following general list of topics is provided in the hope of stimulating interesting questions and audience feedback:

- *Industry Internships*: Student interns that pass through these programs have valuable experience and often get offered research positions at other institutions or agencies. Industry partners could also benefit from these programs by making an effort to place recently graduated interns into appropriate positions within their respective companies. Formal internships that combine ROW research with industry needs would also benefit both the interns and the industry.
- *Effective Interaction with Industry Associations*: The Utility Arborist Association (UAA) is an effective association for providing "two-way" feedback—investigators often receive good advice from UAA members after presentations, and the industry partners are updated on the latest research findings. The TREE Fund also encourages public presentation of research results, and actively funds new studies in IVM. Is there a way to more effectively utilize the fundraising and outreach capabilities of the UAA and the TREE Fund?
- *Academic Outreach*: Increased effort to involve faculty and students of all disciplines would help to expand and strengthen the breadth of research on ROWs. Small seed grants to encourage "non-traditional" research on ROW issues is certainly one effective technique. In addition, encouraging faculty to require their students to become members of professional organizations such as the UAA would help to highlight the value of real-world experience to the student population.
- *Increased Collaboration*: Regularly planned "working conferences" to allow researchers from different sites to gather, synthesize results, and plan next steps would help to strengthen the ROW results and lead to better understanding across a wide range of ecosystems. One way to achieve this is to set up the network of sites across the U.S. (and possibly worldwide) as a giant networked "field station". The spatial footprint of such a large collection of sites would open up the networked "field station" to studies of large-scale issues such as climate change, while the individual sites would still be able to pursue investigation into local ecosystem effects of VM. In addition, collecting all of the observations from such a "field station" in a central location would allow researchers from many locations to become involved in ongoing ROW studies.

CONCLUSIONS

As previously mentioned, valuable insights continue to be gained in ROW issues by the established network of sites in the eastern U.S. and the newly established sites in the western U.S. This discussion panel will be about grappling with next steps. Can the management of the separated research sites be improved? Should the industry and academic community continue with the model of funding separate research sites, or can we improve on that model?

ACKNOWLEDGMENTS

The project in the eastern U.S. was initiated on SGL33 (Centre County) in central Pennsylvania with several partners including Pennsylvania Electric Company (now First Energy Corp.), the Pennsylvania Game Commission, The Pennsylvania State University, DuPont, AmChem (now Corteva), and Asplundh Tree Expert, LLC. This year (2018) marks the 63rd year of the original "five-year project" that has maintained its relevance for six decades.

The western U.S. study was initiated with funding from PG&E in 2015. We would like to thank Eric Brown and Peter Beesley for their efforts in making the project happen. More recently, funding has been continued by the TREE Fund. The UAA has provided some excellent direction and suggestions for reaching out to industry partners and the wider VM community.

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AUTHOR PROFILES

Chris Halle

Dr. Chris Halle has worked with earth observing systems for more than 30 years, including managing and leading cross-disciplinary research teams to address complex large-scale projects for industry. His areas of expertise include environmental observation and sampling, data quality control, algorithm development, and data synthesis and presentation. As the Center for Environmental Inquiry Nature!Tech Program Lead, he creates industry/academic research collaborations on environmental and technology projects. He assists faculty in scoping and developing projects suitable for classroom instruction, and supervises students undertaking long-term monitoring projects on CEI lands. Halle is particularly interested in turning spatially separated stations into true research networks, and has previously performed such feasibility studies for the National Marine Sanctuaries.

Carolyn Mahan

Dr. Carolyn Mahan, is a professor of biology and environmental studies and co-chair of the Environmental Studies program at Penn State Altoona. Her research interests include the study of biodiversity in threatened ecosystems, the effects of human-modified landscapes on wildlife, and the behavioral ecology of squirrels. Her work has been published in a variety of scientific journals, including *Environmental Management, Global Change Biology, Conservation Biology*, and *Journal of Wildlife Diseases*. Dr. Mahan has served on the board of directors of the Pennsylvania Wildlife Society and The ClearWater Conservancy and she is past-president of the Pennsylvania Biological Survey.

David Krause

David Krause is a VM specialist for Asplundh. In addition to his bachelor of science degree in Wildlife Biology, he has been involved with ROW VM for 41 years. His professional affiliations include ISA, Mountain Lake VM Council, WV VM Association, National Roadside VM Association, Responsible Industry for a Sound Environment, and is a certified pesticide applicator. He also was recipient of the UAA *Education Award* in 2009 for industry leadership in providing training in stewardship and best management practices (BMPs).

Eric Brown

Eric Brown is currently the VM Program Manager for Sacramento Municipal Utility District (SMUD), as well as the UAA Vice President. Brown and his colleagues were twice awarded the Richard A. Clarke Champion Award for Environmental Leadership, for the American River Pollinator Partnership Project (2014), and the Electric Transmission ROW Stewardship Accreditation (2015). Outside of the UAA, Brown has been actively involved in the North American Transmission Forum (NATF) since 2009, leading and participating in VM Peer Reviews across North America. Brown was a driving force in expanding long-term VM studies from the eastern U.S. to the West Coast.

Vegetation management (VM) is a regulatory and safety priority for utilities which impacts landowners within and adjacent to right-of-way (ROW) corridors. Understanding the corridor owner's property rights for the corridor and adjacent properties is key to developing and implementing a sound VM plan. The integration of public involvement and ROW components aimed at making impacted landowners and stakeholders a part of your VM plan helps to develop and maintain "good neighbor" landowner relationships and allows for effective and efficient VM practices.

Getting Along with Your Neighbors

James Prossick and
Blandon Granger

Keywords: Distribution Line, Landowners, Public Involvement Stakeholders, Right-of-Way (ROW) Corridor, Transmission Line, Utility Corridor, Vegetation Management (VM).

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Appropriate VM for electrical transmission and distribution (T&D) utility corridors is a key priority of all electric utilities' asset management and maintenance. It's an important aspect of operation plans too, as it preserves safe service without disruptive outages or putting people or private property at risk due to fire risk or electrocution. Within the last decade, an important factor in executing an effective VM plan has become landowner engagement and long-term relationship building with the in-corridor and adjacent property owners or "neighbors" of operating utility corridors. This requires a new focus on integrated services utilizing the expertise of right-of-way (ROW) and public involvement professionals.

Historically, VM was treated as a simple upkeep task, often performed by outside contractors with limited oversight by the utility corridor owner. The contractor may have managed most or all of the property owner relations, including damage claim assessment. The interpretation of the property rights that the electrical utility has to operate in corridor and outside for VM purposes were provided to the VM contractor in general terms by the owner's staff, leaving the contractor to secure any additional corridor access or temporary property rights needed to complete the vegetation removal or trimming on their own. This loose process had propensities, which led to breakdowns in landowner relations and trust in the utility corridor because of misunderstanding about the need for or extent of vegetation removal and trimming, perceived misuse of private property, and unresolved damage claims. This did not help promote a good neighbor policy for many utility corridor owners and, in many cases, resulted in more landowner resistance toward the next occurrence of required vegetation maintenance.

There has been a parallel but juxtaposed rise of the risks to electrical power facilities from the growing incidents of extreme weather events

Figure 1.

(wildfires, hurricanes, windstorms, tornados, winter storms, and so forth) and individual landowner or organized opposition groups concerned about property rights infringement and distrust of public projects and entities. Concerns from environmental groups regarding traditional clear-cut VM practices and regulations as well as public pressure generated by these environmental stakeholders have added complexity to how utility corridor owners balance safety and stewardship of their corridors in their VM plans.

These factors have at times resulted in corridor VM practices by utility corridor owners that have added to the risk levels for power outages and damages to electrical facilities and private property, resulting in changing national, regional, and local VM regulatory requirements. These factors have also caused increases in corridor owners' potential direct liability for electrical utility failures to the general public they service, and for direct damages to private property owners, related to the utility's VM practices.

Electrical power utility corridor owners have begun responding to these challenges with integrated teams of ROW, public involvement, arborists, and contract VM specialists. These teams have assisted in the drafting and implementation of more refined VM plans that include landowner and stakeholder education and integration via focused corridor management practices that capitalize on the shared risks of the utility owner and the public and application of new technology.

BACKGROUND

Within the last several years, the U.S. has been plagued by power outages generated primarily by wildfires, hurricanes, tropical wind, and winter storms. That trend continues in 2018, as witnessed by the more than 60 large wildfires concurrently burning throughout the U.S. this past August, primarily in the West.

Outages due to storm events have impacts throughout the U.S., with the primary risk areas being the East Coast and Gulf regions of the U.S. Wildfire risk also exists across the U.S., but the west and southwest regions, including Colorado, have been hardest hit.

The main national regulatory agencies are the Federal Energy Regulatory Commission (FERC) and North American Electric Reliability Corporation (NERC).

FERC is an independent agency that regulates the interstate transmission of natural gas, oil, and electricity. FERC also regulates natural gas and hydropower projects. One of its primary functions is to protect the reliability of the nation's high voltage interstate transmission system through mandatory reliability standards.

As part of the fallout of the Northeast Blackout of 2003, the Energy Policy Act of 2005 authorized the FERC to designate a national Electric Reliability Organization (ERO). On July 20, 2006, FERC issued an order establishing NERC as the ERO for the U.S. Prior to being the national ERO, NERC's guidelines for power system operation and accreditation were referred to as Policies, for which compliance was strongly encouraged yet ultimately voluntary. NERC has worked with all stakeholders in the past several years to revise its Policies into Standards, and now has authority to enforce those standards on power system entities operating in the U.S., as well as several provinces in Canada, by way of significant financial penalties for noncompliance.

NERC was also designated with the responsibility to develop and enforce standards to ensure the reliability of the Bulk Power System, including the Reliability Standard that addresses VM on ROWs - Reliability Standard FAC-003-4 – VM.

FERC regulations and NERC VM requirements relate only to high voltage transmission lines above 200,000 volts (200 kV) and some transmission lines between 100 200 kV. These are the only powerlines subject to the Reliability Standard FAC-003-4.

The U.S. electric system is segmented for regulatory purposes into T&D categories based on the voltage of the facilities, with high-voltage lines being classified as transmission lines and lower-voltage lines classified as distribution lines. Transmission corridors generally have lines strung on high steel towers or very large wooden structures, often encompassing multiple lines within the corridor. Distribution lines are usually 100 kV or lower voltage (usually between four and 36 kV) with the lines running on much smaller wooden or metal poles most often in developed urban areas.

The majority of VM activities directly affecting homeowners, emphasizing tree trimming in particular, is along distribution lines, not transmission lines. These distribution corridor VM practices are subject only to state and local requirements, without any oversight by either the FERC or NERC under the Reliability Standard FAC-003-4.

A partial list of regional and state regulatory entities are as follows.

Regional Entities

- Florida Reliability Coordinating Council (FRCC)
- Midwest Reliability Organization(MRO)
- Northeast Power Coordinating Council (NPCC)
- Reliability First (RF)
- SERC Reliability Corporation (SERC)
- Texas Reliability Entity (Texas RE)
- Western Electricity Coordinating Council (WECC)

State Regulatory Entities

The National Association of Regulatory Utility Commissioners (NARUC) is a nonprofit organization dedicated to representing the state public service commissions that regulate the utilities providing essential services such as energy, telecommunications, power, water, and transportation. NARUC maintains a list of every state's regulatory commission available on its website: *https://www.naruc.org/about-naruc/regulatory-commissions/*

DISCUSSION

According to NARUC, as excerpted from their May 14, 2018 memo, "State Commission Staff "Surge" Call: Evaluating Reliability Investments" in 2017. Extreme weather resulted in $350 billion in damages across the U.S., with 16 events causing at least $1 billion worth of damage each, according to a recent report on grid resilience. A recent Grid Strategies LLC study on grid resilience argued that investments in the distribution system are the most cost-effective way to reduce the likelihood and duration of outages. As the parties evaluating utility expenditures on grid-hardening, state commissions need to know what works and how to direct ratepayer money to the most effective solutions.

As extreme weather events become more frequent and intense, commissions will be under more pressure to oversee cost-effective reliability investments. Experiences in Alabama, Florida, California, and New Jersey offer valuable lessons for other states. As new grid hardening options emerge, NARUC will assist commissions in sharing outcomes and elevating best practices for replication.

Alabama

Alabama frequently deals with high-impact weather events. The Alabama Public Service Commission works closely with Alabama Power, the state's only regulated electric utility, to improve reliability. In 2011, tornadoes caused 412,000 customers to lose power (some as long as seven days) at a total cost of $191 million. Hurricanes and winter storms in 2017 caused five significant outages, with restoration generally taking between one and three days.

Tree trimming is an important strategy for Alabama Power to help improve the reliability and resiliency of its electric grid. The utility has a target of performing inspections of transmission poles every six years and distribution poles every 10 years. Alabama Power also conducts storm simulation and training exercises for its staff, maintains predetermined staging areas with necessary equipment to enable quick restoration, and replaces older cables and wires with new materials offering better reliability and quicker repairs after faults.

Florida

In 2004 and 2005, eight major storms caused about $2 billion in utility restoration costs in Florida. Restoration after each of these events took up to 18 days. Following those storms, the state legislature ordered the Florida Public Service Commission (Commission) to look at what should be done to enhance the reliability of Florida's T&D grids during extreme weather events. Utilities, city officials from around the state, university researchers, and other stakeholders provided information on ways to mitigate future storm damage and customer outages. The Commission issued various orders regarding pole inspections and reporting requirements. The Commission also adopted rules to encourage undergrounding of distribution facilities and amended existing rules regarding transmission construction standards.

After about a decade with no major hurricanes, Florida experienced four major storms in the past few years, the biggest being Hurricane Irma in 2017. Irma impacted all 67 counties in Florida and caused 6.7 million customers to lose power. Power was restored to the majority of customers within 10 days. Many outages came from trees outside utility ROWs. Following Irma and other storms in 2016 and 2017, the Commission opened a docket to review hurricane preparedness and restoration actions. The Commission was reviewing and discussing staff's findings at an internal affairs meeting scheduled in June 2018.

That information has been memorialized in the commission report entitled "Review of Florida's Electric Utility Hurricane Preparedness and Restoration Actions 2018," which contained key findings relating to the critical link between VM and landowner perception and relations.

Three Key Findings in Florida's Electric Utility Hurricane Preparedness and Restoration Actions Report:

1) Rising customer expectations are that resilience and restoration will have to continually improve.
2) The primary causes of power outages came from outside the utilities' ROWs, including falling trees, displaced vegetation, and other debris.
3) VM outside the utilities' ROWs is typically not performed by utilities due to lack of legal access.

Commission Actions, Legislative Considerations, and Stakeholder Comments

Meetings with local governments regarding VM and the identification of critical facilities.

Revision of VM policies to improve the ability of electric utilities to conduct VM outside of ROWs to reduce outages and restoration costs.

Regarding VM, the comments mainly focused on improving communication between stakeholders and utilities about where and when tree trimming occurs, as well as better public education concerning tree trimming.

In Summary from the Commission Report

VM coordination/proactive tree trimming has been a key initiative of the Commission. Each year, investor-owned utilities (IOU) trim a certain percentage of their total lateral and feeder miles as part of their hardening plans. However, the trees trimmed comprise only those that are in the utilities' ROWs. Utilities identified that a major contributor to outages continues to be vegetation outside of the utilities' ROWs. Therefore, more frequent tree trimming by utilities within ROWs would not alleviate this outage cause. Tree trimming outside of a utility's ROW requires coordination and cooperation with local government and customers.

Legislative Considerations: Revision of VM policies to improve the ability of electric utilities to conduct VM outside of ROWs to reduce outages and restoration costs.

Enhance statewide public education regarding tree trimming and problem tree placement and removal on private property. This program could be similar to the "Right Tree, Right Place" initiative already used by several utilities.

The "Right Tree, Right Place" initiative is a program adopted nationally by many utilities to promote a balance between environmental responsibility and reliable electric delivery. The program's goal is to educate consumers through in-person trainings, websites, and printed materials about powerline-friendly tree planting practices that help minimize the number of outages caused by tree interference with powerlines.

California

California faces a different issue: wildfires. In 2017, California experienced the worst fire year to date, with $13 billion in total suppression, insurance, and recovery costs incurred. Fires are becoming less frequent, but more widespread, with most fires started by the Santa Ana and Diablo hot dry winds across the state. Climate change is expected to lengthen the season for these wind patterns, exposing the state to increased fire risk.

The California Public Utilities Commission's (CPUC) goal is to institute policies to lessen the risk of utility-owned assets starting or spreading wildfires. Vegetation and equipment inspection are critical to keeping risk low. After fires in 2007 resulted in more than a million evacuations, CPUC started engaging with California Department of Forestry and Fire Protection (CAL FIRE) to map high-risk areas and improve vegetation and inspection practices in targeted locations. In conjunction with CAL FIRE and independent consultants, CPUC developed and adopted a "CPUC Fire-Threat Map." The CPUC Fire-Threat Map contains three tiers: Tier 1 – existing regulations deemed to be sufficient, Tier 2 – elevated risk (to people and improved property) of catastrophic wildfire from utility ignition, and Tier 3 – extreme risk (to people and improved property) of catastrophic wildfire from utility ignition.

In addition, CPUC adopted regulations for High Fire Threat Districts (HFTD), which include Tiers 2 and 3 from the fire threat map, and Zone 1 High Hazard Zones (HHZs) from a separate, independently developed (i.e., not specific to any CPUC purpose) map of tree mortality from a joint U.S. Forest Service (USFS) and CAL FIRE effort in response to tree mortality/bark beetle related issues. The new regulations include VM programs and inspection requirements (reducing the time between inspections for assets in high-risk locations).

San Diego Gas & Electric and Pacific Gas & Electric (PG&E) both identified wildfires as their highest risk in CPUC mandated risk assessment mitigation phase plans. These plans also outlined pilots and investments in mitigating fire risk that CPUC had not specifically ordered.

California is also dealing with questions around inverse condemnation following the last season of wildfires. Property owners have the ability to sue utilities, as government-regulated monopolies, for reimbursement for damaged property. Even if the utilities are found not to be negligent, utility-owned equipment still affects fires and landowners may be able to sue for damages. The state legislature will determine whether regulated utilities can be held responsible for damages.

New Jersey

Grid hardening in New Jersey started in response to Hurricane Irene in 2011, which caused three million customers to lose power for approximately a week, primarily from overhead line damage due to heavy, wet snow. The Board of Public Utilities noticed that not all regulated utilities were responding to outages in a uniform manner or as quickly as they should. The Board issued a report with more than 100 recommendations for utilities' storm response and general infrastructure requirements just before Superstorm Sandy in 2012, which knocked out electrical power to more than 12 million customers for up to 10 days and caused damage to gas utilities.

The Board revised its VM rules in 2015. The new rules required vertical clearing to get rid of overhang, more frequent vegetation inspections, and specific capabilities for utility employees doing vegetation inspections. Following many tree-related outages during four Nor'easter storms in early 2018, the Board is looking into additional VM efforts.

The findings and recommendations identified above from the various state public utility commissions and boards illustrate many of the concerns generating changes in VM plan development. Some of the key factors to consider in development of these plans are:

1. Assessing potential risks to the corridor from vegetation issues
2. Defining the legal boundaries, property interests, and easement rights within and adjoining the corridor
3. Understanding current regulation for VM practices
4. An effective stakeholder and landowner outreach plan defining external and internal communication protocols
5. Using new technology to better manage VM practices in utility corridors

We will talk about all of these factors and focus in on factors 3 and 4 to show how a better understanding of property interests in and around utility corridors and public engagement, along with a consistent plan to improve landowner relations, can reduce risks and liability while providing better access for vegetation maintenance activities.

METHODS

Assessing potential risks related to VM practices is the second factor in development of a plan. The issues related to acts of nature have been laid out in the Discussion section above, but other factors such as events caused by humans—e.g., improper planting or removal of vegetation in or near power corridors, vehicular accidents felling vegetation, and starting fires—along with poor health of vegetation leading to increased fall potential are also risk factors to consider. The other risk is liability: who is responsible for the outage and damages caused by the outage? This risk is real and happening now to utilities. California courts have determined utilities must pay all damage costs if utility equipment was involved in a fire, whether the utility was negligent or not. In June of 2018, PG&E said it will incur a $2.5 billion pre-tax charge related to deadly wildfires in Northern California last year. That charge does not include potential government penalties or fines, or the impacts of additional fires where PG&E may also be found liable. Utilities are seeking relief from this liability through legislative actions.

Next, it is imperative to well-define private property and easement rights as well as adjoining property and easement corridor boundaries in and adjacent to power utility corridors. Understanding easement rights and boundaries for properties within and adjacent to T&D corridors is imperative to development and implementation of sound VM plans, and trained ROW professionals are best suited to lead this effort. This includes collection and detailed analysis of current easement rights as they relate to VM and clear definition of easement corridor boundaries and adjacent corridor property ownerships and boundaries as they have changed with time. Once compiled, this information needs to be added to an integrated lands database mapping system to be useful for VM.

The clear identification of these property interests and boundaries into an easy-to-use, readily accessible lands system provides the following benefits to a comprehensive VM plan:

- Accurately defines current rights and locational limits for vegetation maintenance
- Allows for accurate identification of risk locations and speedy responses to called in risks or other public complaints and inquiries
- Provides accurate match to corridor easement, segment, or pole numbers to adjoining property locations, facilitating accurate public notices and property owner contacts for vegetation maintenance operations and damage claim settlements.
- Acts as a record repository for VM field operations, logging in the dates staff were on-site, issues observed, and actions taken.

Understanding current regulation for VM practices in relationship to the easement corridor types being managed is the next critical item to consider in developing a VM plan. The Discussion section above explained that transmission line VM plans are regulated by the NERC Transmission VM NERC Standard FAC-003-2 and distribution systems' VM are regulated by state public utility commissions and any other city or county regulations that may exist in the utility's service area. These guidelines provide the framework for the utility corridor owner's VM plan. Other government agencies and state and local environmental laws may also impact VM practices.

Integration of a sound public involvement and landowner outreach plan, along with internal and external communication protocols, into the overall VM plan make up the essentials of Factor 4. The basic practices for a sound public involvement program will be implemented with specific objectives.

The specific objectives of the public involvement plan should, at a minimum, include the following:

- External and internal communication protocols
- Basic public contact information for reporting observed vegetation risks or for questions
- A system to collect and analyze public feedback
- Notification process for general information and by VM activity
- Public education of the need for VM within and adjacent to the corridor
- Process description for securing additional rights, and owner's right of refusal, for vegetation maintenance on private property

Setting a single point of contact for various public involvement and landowner outreach is critical to long-term successful landowner relations to facilitate appropriate VM activities. Defining the external communication protocols will allow for the utility to employ ROW and public involvement staff skilled in landowner relations and negotiations to achieve more consistent relations with property owners adjacent to the corridor. Setting a defined internal communication structure, including any contractors used for VM, will allow more control over VM activities and should lead to minimal landowner complaints and reduced damage claims.

Using New Technology to Better Manage VM Practices is a Critical Element in the Overall VM Plan

Leveraging technology to connect all

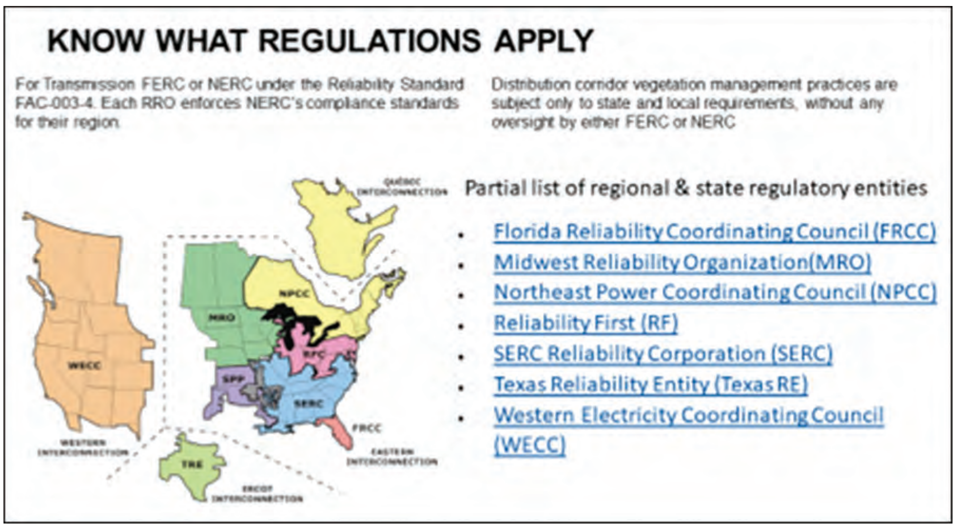

Figure 2.

the integrated disciplines working together on vegetation maintenance provides seamless internal and public communications. Using innovative, technology-driven devices and systems to facilitate VM practices can help provide more useful information on future vegetation maintenance needs while also reducing impacts to the public.

Some of the systems currently being used include:

- Integrated geographic information system (GIS) land rights data systems
- Light detection and ranging (LIDAR) survey
- Drones
- Mobile device access and apps

Integral to this process is assembling, analyzing, and cataloging land rights information for power utilities and companies' network of T&D corridors into an easily usable data and mapping platform that can take advantage of these modern technology tools.

Some of the key components of this process are:

- Assembling and digitizing legacy paper documents and maps
- Reviewing systemwide property rights for:
  - o Potential title gaps or missing documents
  - o Determining if sufficient rights exist for VM
- Establishing survey or near survey grade digital boundary mapping for conveyance documents and pole and tower location
- Linking corridor mapping and lands information to adjacent owner public mapping and lands information
- Developing an efficient GIS land rights data system that utilizes modern technology tools

A GIS land rights data system built on these fundamentals provides for development, implementation and management of an effective VM Program. Each of the various corridor segments can be analyzed from a land rights perspective to determine if sufficient widths exist to meet current safety and regulatory requirements and if the historical rights granted are sufficient or if new property rights should be acquired. This systematic approach gives power companies and utilities an understanding of possible land rights constraints and liabilities related to appropriate VM practices. It also allows for a way to rank those risks for corrective action within budgetary constraints.

Figure 3. Analyzing the corridor using LIDAR

The ability to engage and notify the public of upcoming VM activities, manage the field personal performing those activities, track their progress, and manage any damage claims are also vastly improved by the use of an efficient GIS land rights data system and modern technology tools.

Using the GIS land rights data systems land ownership information gives the opportunity to easily notify impacted property owners of upcoming activities and also to focus in on areas where there are chronic VM issues for more long-term education outreach programs. In addition to aiding in preventative public outreach activities, a GIS land rights data system linked to public landowner data also provides the ability to quickly respond to emergency situations that is impossible using paper file and mapping systems. This accelerated ability to correctly respond locationally and tap into past VM data already stored on the system immediately reduces liability costs and improves public trust.

Field personnel linked to the GIS land rights data system via their mobile devices provides some important advantages. The workers in the field can access lands information to be sure they have the appropriate rights to conduct the activity at hand, time stamp activities in the field should contentious damage claim or trespass situations arise, and provide detailed linked photographic or video evidence of on-site locations before and after conditions for future use. With time, this collected data is expected to provide cost savings through improved efficiencies in determining where the next round of VM activities are most needed, and to help pinpoint problematic or high maintenance areas of concern.

LIDAR survey and drones can be utilized to identify where vegetation issues exist with little or no interruption to the private property owners in or adjacent to the corridor. This information can be used to provide more targeted field work reducing cost and private property owner inconveniences. This same process can also help provide status on ongoing field activities. Storing the mapping and video data linked to specific corridor locations yields important before and after data to help risk ranking for future VM activities and with any damage claims that may be filed.

RESULTS

VM, along with all corridor management activities, has historically been underfunded and understaffed. This has resulted in misuse of the utility corridors by others and a dangerously low level of preventive maintenance by some utility corridor owners. This, in turn, has increased general liability specific to vegetation and other poor corridor management practices to all power providers. Combining these now-apparent dangerous past business practices with current regulatory requirements and often conflicting environmental laws and public environmental sentiment has immensely increased corridor owners and their rate payer's financial liabilities. This has resulted in a renewed interest in developing a sound overall asset management plan, including a reassessment of current VM practices.

To gain perspective on the current state of VM practices and to truth the assembled research, a series of questions were sent to 37 active members of the International ROW Association's Electrical Utility Committee. This committee is recognized as one of the leading bodies in ROW issues as they relate to the operations of electrical utilities. These members were all ROW professionals working directly for private and public electrical utilities, some with only transmission and some with both T&D services. There were 10 respondents to the survey registering a 27 percent response rate from the group. Respondents were from across the country, from the Midwest and Plains states to both East and West coasts, including areas where critical issues such as wildfires and major storm events are issues. The hope was to get an industry snapshot of the current state of the following critical items.

1. Potential risks to the corridor from vegetation issues
2. Importance of defining property interests within and adjoining the corridor
3. Concerns over current regulation for VM practices
4. What role ROW and public involvement staff play in VM programs
5. What technology is being used to for VM in utility corridors

A summary of those questions and results are as follows:

Q1. List your top three risks and challenges for VM – Response Summary:

- Fifty percent of respondents indicated concerns or issues with adequacy of easement rights with eight out of 30 primary concerns dealing with easement-related topics.
- Thirty percent of respondents indicated concerns with landowner relations and education.
- Encroachments, outage, retaining qualified personnel, and cost concerns were each listed by 20 percent of the respondents as a primary concern
- A wide variety of vegetation-specific concerns were listed by 30 percent of respondents
- Other concerns listed were terrain, schedule, and safety.

Q2. Do you currently use any the following technology tools to assist with your VM - yes or no

Technology	GIS Land Rights Data System	Mobile Device Access	LIDAR Survey Services	Drones
Yes total	10	7	5	3
No total	0	3	5	7

Q3. Are current environmental laws or environmental public perception hindering implementation of a sound VM plan?

Yes = 5 No = 4

Non-Response = 1

The issues listed as environmental impediments to VM practices are as follows:

- The aerial spray program has caused public concern because no matter how much information has been presented to the public through newspaper articles, ads, and at public meetings. There are almost always complaints of over-spraying or toxic spray that is harming the public in some way.
- Bat (and migratory bird) restrictions continue to limit schedule for clearing
- Currently unable to apply herbicides, as part of an integrated VM (IVM) program, to effectively manage vegetation in national forests, although national forests would like to be able to apply herbicides to manage invasive species on non-electric ROWs.
- Riparian areas can constitute a challenge to efficient practices occasionally.
- At times this can impact work scope and timing. It's primarily an issue on federal lands, but has begun to improve slowly. This needs additional attention beyond the 2016 Federal Memorandum of Understanding (MOU) and Omnibus Bill inclusions.

Q4. Does your organization provide sufficient budget and staff for VM?

Yes = 7 No = 2

Non-Response = 1

Q5. Does your current VM plan include public involvement and stakeholder outreach?

Yes = 6 No = 3

Non-Response = 1

"We follow state requirements for written notifications as well as additional notifications for projects to remove incompatible vegetation that may have otherwise been trimmed in the past."

Q6, Part A: Can you effectively implement your VM plan with current easement rights?

Yes = 4 No = 6

Non-Response = 0

Q6, Part B: If not, are you securing additional easement (permanent or temporary) rights to effectively implement your VM plan?

Yes = 6 No = 4

Non-Response = 0

Q7. Are you using outside contractors or in-house staff for:

VM field work: Outside (9) In-house (5)

Public involvement activities: Outside (4) In-house (9)

Landowner liaison and damage claim settlements:

Outside (6) In-house (9)

**Note many organizations use a mix of outside and inside staff for these functions*

Q8. What involvement does your ROW group have in landowner relations and damage claim settlement for VM?

- The majority of the landowner damage claims are settled by either the forestry group or a ROW contractor.
- ROW is responsible for landowner notification and damage settlements, as necessary.
- Realty acquires both temporary and permanent rights where required. Contractors are required to pay their own damage claims for work they have performed.
- ROW management only provides copies of existing easements and interpretation of the rights granted. The Forestry department handles customer relations concerns related to VM.
- None. It's a separate department.
- It depends where the line is that we are maintaining. If it's in an area where it could be controversial, landowner relations is heavily involved; otherwise, we leave it with the contractor.
- The "outside" tree contractor will make initial landowner contacts and will complete if there are no issues or problems. Our ROW agents will handle all the difficult situations that might involve any payments or if the issue could possibly need legal action.
- ROW group has 100 percent responsibility for landowner relations and damage settlements.
- VM primarily covers these unless the damages are significant and it gets escalated.

Q9. Does your organization currently insure or plan to insure for liability issues regarding power outages, property damage claims, or fires due to VM issues.

Yes = 2 No = 6

Non-Response = 2

CONCLUSIONS

The results of our preliminary research are that major weather and natural events such as wildfires, especially in urbanized areas, are the catalysts that exacerbated poor VM practices and put power delivery companies and utilities at extreme risk for outages and liabilities to the public for damages. Survey responses from ROW professionals within the power industry show these issues have been recognized and corrective actions and implementation of better management practices have been undertaken to reduce outage and liability issues, but more needs to be done.

The two major issues that still require much work and are on the preventative side of the VM equation are:

1. Improving understanding of current corridor property interest and acquiring additional interests to meet the new needs of safe VM practices.
2. Education and improved communications with utility corridor landowners, adjacent landowners, and the general public.

Modern technological advances, such LIDAR survey, drones, and mobile device field access have become important tools in the field. The number one technological innovation used for VM is GIS land right data systems, but it appears from the overriding concern with understanding of current corridor property interests that many of those systems may require updating.

Specific environmental regulations also seem to be a barrier to sound VM practices in many cases. Those issues would also require stakeholder engagement with the regulatory authorities and landowner outreach to show the need for better balance of environmental and VM concerns as well as to reduce outage and liability risks.

Funding for most of the power organizations surveyed was stated as sufficient and 60 percent of respondents included a public involvement component. All but one of the power delivery organizations that responded to our survey indicated that ROW was involved in the VM process. The level of involvement varied, but in nearly all cases ROW was responsible for two key items: Identification of existing property rights and settlement of damage claims.

Due to recent general liability claims against utilities for damage liability due to supposed poor VM practices primarily related natural events and storms, respondents were was asked if additional liability insurance was being used. Only 20 percent of the organizations responding to the survey responded

"yes."

It appears that attention is being paid to better VM practices by power delivery organizations, resulting in better funding and use of technological aids, but there needs to be continued improvement in understanding and expanding of corridor property rights related to landowner education and involvement to offset the rise in outage and liability risks associated with VM practices.

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James Prossick

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Jim Prossick has 37 years in the ROW field, the last 13 spent as a Section and WA Area Manager for HDR. As a senior project manager and licensed appraiser, he collaborates with engineering, environmental, public involvement, and permitting disciplines to site numerous linear projects via detailed ROW analysis and cost estimating. He assembles successful ROW teams delivering asset management, title research, valuation, and acquisition services for linear projects throughout the U.S. He has worked as a property manager for county and city government and helped numerous clients evaluate corridor property interests and develop corridor management plans. Jim has achieved the International ROW Association's Senior Agent SR/WA designation and is an at-large member on their International Electric and Utilities Committee and Asset Management Community of Practice. He has made numerous presentations for IRWA, EUCI, and the NW ROW conference.

Helicopter Tree Pruning on Transmission Corridors in Western Coniferous Forests

Mark Stewart

Keywords: Helicopter, Heli-Saw, Right-of-Way (ROW) Pruning, Electric Transmission ROW.

Conifer trees growing along the edges of electric right-of-way (ROW) corridors tend to develop greater limb growth on the front side of the trees facing the corridor—where there is less competition for light—than on the back side of the trees facing dense canopy closure. At the same time, heavy snows in low-elevation coniferous forests tend to load up limbs on the line-side of the corridor trees. These conditions, along with high winds or saturated soils, can cause the trees along powerline ROWs to lean or fall into the lines. To address this issue, Pacific Gas & Electric (PG&E) conducted helicopter "heli-saw" pruning along 92 kilometers (km) (57 miles [mi]) of transmission corridor. Pruning is performed with a small, four-seat helicopter with a 30-meter (m) (100-foot [ft]) support pole carrying a vertical six-m (20-ft) long bank of eight 0.8-m (30 inch [in]) diameter circular saws below the helicopter. The saw blades are operated by a gasoline-powered hydraulic pump, which powers motors at each blade. The helicopter slowly flies along the edge of the corridor, with the saws pruning limbs up to five inches in diameter from the sides of the trees. No trees are felled during this process.

Conducting heli-saw work involves unique advantages and challenges for environmental and species protection, agency approvals, safety, and public perception.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Numerous outages have occurred along the Pacific Gas and Electric (PG&E) transmission rights-of-way (ROWs) between California's central valley near Redding and coastal communities near Eureka. A significant number of outages occurred in coniferous forests of these coastal mountain ranges from 600 to 1,500 meters (m) (2,000 to 5,000 feet [ft]) in elevation, particularly in heavy winter snows and saturated soil conditions, causing trees and limbs to break off or tip into the lines. A secondary cause of outages has been gusty, high winds blowing individual limbs out of the first row of trees bordering the ROW or blowing down trees that had disproportionate limb weight on the line side of the trees.

PG&E has identified certain transmission lines that have experienced these types of outages and has a dedicated Reliability Improvement Program to remove as many trees as possible with characteristics that may lead to outages. Given the large land area associated with this program, it will take several years to complete the full scope of the work on all identified lines. As an interim step to support reliability improvement in the near term, heli-saw pruning was conducted on selected lines to manage risk until ground crews can more fully to treat the ROW edges by removing trees.

Forty-seven kilometers (km) (29 miles [mi]) on two 60 kiloVolts (kV), and 45 km (28 mi) on one 115-kV transmission line were prioritized for heli-saw pruning operations. This work was particularly sensitive because much of the ROW traversed two national forests and a state park. Work was conducted in February 2017, December 2017, and January 2018. This paper will provide an overview and basic understanding of project scope, considerations, and costs of helicopter tree pruning as a management tool for ROW managers who maintain corridors through coniferous forests.

METHODS

An established heli-saw company was selected, which has experience pruning conifers along electrical transmission corridors and an excellent safety record. The helicopter company's pilot and safety officer conducted preliminary line flights, several weeks in advance of work, to determine potentially hazardous situations and possible helicopter service landing locations.

PG&E provided maps of the line sections to be worked, obtained contracts, and received approvals, including working with managers at the National Forests and a state park. In addition, PG&E sent notification letters to all private landowners where operations would occur and conducted environmental reviews of work areas.

When heli-saw work started, the helicopter would typically fly for two hours, then return to the landing for servicing and to change pilots. PG&E representatives conducted on-site visits for quality control and to ensure that work met the desired specifications. Following completion of heli-saw pruning in each line section, a second contractor was brought in with a towable chipper to clean up limbs along driveways, fence lines, irrigated pastures, and other locations as requested by landowners.

RESULTS

Ninety-two km (57 mi) of transmission corridor were successfully pruned by heli-saw at a reasonable cost. The risk of tree-caused outages from snow loading and limb failure has been significantly reduced, and no outages of this type have occurred in the work areas since they were completed. PG&E will continue to use heli-saw pruning as a feasible pruning tool along transmission lines where conditions are suitable. It does not eliminate the need for ground crews to inspect for and remove trees with lean, forked tops, or other hazardous characteristics near the lines, but it greatly reduces the amount of work that ground-based crews need to complete.

DISCUSSION

Public Safety

Public and worker safety was always a primary consideration. Sections of line were avoided that were within 15 m (50 ft) of paved county roads and state highways to prevent limbs from falling onto these roads. Where pruning was performed along and over driveways and gravel roads, the safety officer was stationed on the ground as a spotter with helicopter radio contact to stop vehicles from using the roads while pruning was occurring, and to communicate any safety issues to the pilot. Immediately after pruning was finished, the spotter would drive the road or driveway and remove any limbs that had fallen into them or onto adjacent fences.

Work Scope

Pruning specifications along the first 45 km (28 mi) section called for pruning all limbs at or above line height at 6–7 m (20-24 ft) from the conductors. The helicopter would fly in a relatively straight line, making up to three passes across each area, pruning the top six m (20 ft), then dropping down to cut the next six m (20 ft), and so on. The saws typically cut from 15 cm (six inches) to one m (3 ft) out from the main tree trunk. Limbs are not cut flush to trunks to prevent the saws from getting stuck in the trunks.

Pruning specifications were changed slightly on the second line section. The first row of trees bordering the ROW did not grow in a straight line parallel to the conductors but varied from 6–9 m (20-30 ft) from the conductors, all with heavy limb weight on the line side. To accomplish pruning close to the trunks on trees which stood slightly further from the lines, the helicopter had to fly slower in a more zig-zag pattern to account for trunk locations. This achieved better results in eliminating line-side limbs, but slightly reduced production and increased the costs.

Pruning specifications were adjusted again for the third line section, which traversed old-growth and second-growth redwood stands. They had a narrower corridor, along with longer limbs growing higher alongside the lines. The concern was that long, pruned limbs might bounce out of the trees onto the lines, or the leafy ends of the limbs act as a sail, allowing cut limbs to fall into the lines. In these situations, the pilot was instructed to cut the outer section of limbs first, then do a second cut closer to the trunk to reduce limb lengths. In locations where limbs extended nearly over the wires, the pilot would skip over them, noting the locations, and a climbing crew was sent in later to remove the skipped limbs by traditional methods. In corridors with numerous limbs close to conductors, the power could be turned off during heli-saw pruning to avoid cross-phase outages. A follow-up inspection flight occurs immediately following pruning to verify the conductors are cleared before turning the power back on. This wasn't necessary on this project, as there were only a few locations along the line where limbs needed to be double cut or skipped.

Limitations

The helicopter could operate during light rain and snow showers, if there was still good visibility. Work was suspended several times during heavy snow showers. Light, steady winds up to 32 km (20 mi) per hour were suitable for helicopter operations. However, stronger or gusty winds can cause too much helicopter or saw movement, which increase safety risks, so operations were ceased in those conditions.

The minimum service landing size needed was 24 m by 46 m (80 ft by 150 ft). Landings were located at existing landings or staging locations, so no grading or ground disturbing work was needed. All servicing and refueling operations required adequate spill and containment materials onsite, as well as minimum 30-m (100-ft) setbacks from watercourses in case of refueling spills. The landing locations were determined by the helicopter contractor, who prepared maps and obtained approvals from the landowners before use. Because the work occurred during the winter, landing locations were selected adjacent to all-weather roads to provide consistent fuel and service truck access.

Listed Species, Limited Operating Periods, and Protections

Most of the line sections treated were in listed bird species habitats. Heli-saw pruning was completed prior to February 15 in marbled murrelet and northern spotted owl critical habitat to avoid nesting season. One river canyon with historic Eagle nesting season (starting in January) required heli-saw operations in February. A biologist conducted ground-based surveys of known eagle nests, and found them to be inactive, so heli-saw work proceeded. If active eagle nests had occurred, heli-saw pruning would have waited until September.

Agency Approvals

On U.S. Forest Service (USFS) land, a helicopter flight plan, listed species maps, and environmental protection measures were provided to the USFS for review. The information was reviewed by USFS environmental specialists, Public Information Officers, and District Rangers. Approvals to proceed were obtained within three weeks on the first project. The first project was executed as planned, so USFS reviews and approvals for subsequent projects took less than one week. The U.S. Fish & Wildlife Service (USFWS) was consulted for heli-saw work in eagle and listed bird critical habitat. USFWS representatives were satisfied with the work and protection measures listed, and approval to proceed was received within two weeks of consultation. State Parks representatives toured a completed heli-saw area on nearby private lands and gave their approval to proceed on State Parks land within one week.

Federally and state-required flight plans and safety plans were filed by the helicopter company with the appropriate agencies, along with U.S. Forest Service air operations and PG&E air operations. There were no delays caused by filing of the plans.

Comparison to Pruning By Climb Crews—Safety, Speed, Access, and Weather

Approximately 80 km (50 mi) of the area worked was in rugged, mountainous areas, located up to three hours from normal tree crew bases, and considerable hiking distances from roads. The helicopter crew stayed at an RV campground within a 10-minute drive of the first pruning area and a helicopter service landing. All the heli-saw work was within a 10-minute flight of service landings, so minimal pruning time was lost from travel.

Weather delays for the heli-saw were minimal, and work was able to immediately resume after rain or snow stopped. Snow on limbs did not reduce productivity as most of it blew off from rotor wash. Work proceeded in areas with two feet of soft snow on the ground, which would have slowed standard tree climb crews to nearly a standstill. The heli-saw pruned 561 trees per day. A six-person climb crew, with three climbers and three groundmen in these locations, could prune approximately 50 trees per day.

Using the heli-saw for pruning work with these access issues improved crew safety by reducing tree crews hiking into steep, rugged terrain, and improved efficiency by reducing crew travel time.

The heli-saw can quickly prune limbs higher in trees than climb crews can reach. This helps reduce the potential for limbs to grow out over the lines.

Public Perception and Notification

The northwest coast area of California is well known for its cannabis-growing activities. Helicopters are not well-received by growers, as their operations are easily seen from the air. Consequently, PG&E takes extra precautions when using helicopters for inspections or construction to notify landowners and the public through a variety of methods, depending on the time of year that flights will occur. Newspaper notices, local radio advertisements, PG&E banners on the bottom of helicopters, and work notification letters are frequently used. The heli-saw pruning operations occurred in the months of December through February, between growing seasons, when landowner sensitivities were not as high. Letters were sent out to all landowners where heli-saw work would occur, listing a PG&E contact name and phone number who was familiar with the operations. A small number of landowners phoned back, mostly out of curiosity, but also to find out when work would occur, so they could move livestock into areas away from powerlines. There were some follow-up calls from landowners to PG&E requesting additional limb chipping near access roads to reduce forest fuel loading. There were no objections to the work, and numerous positive comments were received from landowners and agencies.

Risks

One outage was caused by heli-saw operations in 92 km (57 mi) of work. The outage occurred when a four-cm (1.4-in) diameter limb, two-m (seven-ft) long blew or fell across two phases of the line at a pole cross-arm and had to be removed by a line crew. The incident occurred in a section of dense, long limbs that were significantly higher than the lines. Following the outage, the process was changed to cut the outer section of long high limbs first, then do a second cut closer to the trunk to reduce limb lengths. No other outages occurred after that.

Costs and Electrical Reliability Improvements

An average of five km (three mi) per day were pruned, along both sides of 92 (57 mi) of corridor, with production rates of 3–8 km (2–5 mi) per day, dependent on stand density and weather conditions. Numbers of pruned trees were counted at several sample locations and extrapolated to conclude that pruning occurred on an average of 187 trees per mile of corridor. Helicopter costs ranged from $8,000–$12,000 per mile, depending on average stand densities. This worked out to approximately $54 per tree. Seventy-six km (47 mi) of line have endured a full winter, and 16 km (10 mi) have endured a half winter. There have been no subsequent outages caused by trees which were pruned by heli-saw. It is believed that the outage causing characteristics of the pruned trees have been substantially mitigated, resulting in significant electrical reliability improvements.

CONCLUSIONS

Results of the three pruned areas show that heli-saw pruning is an effective tool for eliminating line-side limbs along electric transmission lines to reduce storm-caused tree and limb failures. It can be achieved quickly, at reasonable costs, with minimal environmental impacts, and minimal resistance by the public.

AUTHOR PROFILE

Mark Stewart
Mark Stewart is a California Registered Professional Forester #2308 since 1986. He is a Licensed Timber Operator and commercial timber faller for five years, owning a forestry consulting, timberland management, and watershed monitoring business for 19 years. He holds a Bachelor of Science degree in Forest Products Management and an additional Bachelor's degree in Forest Products Business Management at the University of Idaho, graduating in 1981. He is a Member of California Licensed Forester Association.

In 2010, Stewart was hired by the VM Department with PG&E, the largest electric utility company in California. He is currently an Expert Program Manager overseeing the Transmission Reliability Improvement program, the VM Timber program, and the Federal Electric Regulatory Commission (FERC) electric relicensing team.

He held the position of team lead who developed the VM Timber program for the PG&E VM Department. Additionally, Stewart developed safety materials for logging near powerlines and conducted "Logging Near Powerlines" safety presentations at Forest VM and Professional Foresters conferences.

Herbicide Impacts on Pollinators: Current State of Knowledge and Best Management Practices

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Keywords: Herbicide, Maintenance, Pollinator, Restoration, Utility Lines.

Rights-of-way (ROW) provide valuable habitat for pollinators, particularly within areas that are highly altered by urbanization and agriculture, but ROWs are often intensively managed for infrastructure reliability, safety, and access. Herbicides are frequently used to assist with control of incompatible vegetation. The objective of this study was to better understand the potential direct and indirect effects of herbicides and adjuvants on pollinators and pollinator habitat through a literature review and industry outreach. Direct effects may occur when pollinators are directly exposed to herbicides and adjuvants. Acute lethal doses for herbicide active ingredients on honey bees are established in the U.S. prior to product registration, but may represent only a partial measure of harmful effects on honey bees and other pollinators. Inert ingredients like adjuvants are considered proprietary and therefore require minimal testing and regulation, but some studies link inert ingredients to adverse effects on pollinators. Overall, information related to the acute and sublethal direct effects and exposure pathways of herbicides and adjuvants on pollinators represents a significant data gap. Indirect effects to pollinators occur when herbicide overspray or off-target drift damages non-target plants, such as nectar sources and host plants. This review summarizes findings from previous studies, which will be used to develop best management practices (BMPs) for use by ROW vegetation managers. BMPs include the current state of knowledge and appropriate recommended tools, timing, and techniques to minimize potential direct and indirect effects on pollinators.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Pollinators are presently a focus of significant global attention as they decline in abundance due to factors such as degradation and loss of habitat, pesticide use, and disease. Land managers are evaluating ways to preserve and promote pollinator habitat on public and private lands through habitat restoration and implementation of vegetation best management practices (BMPs). Infrastructure corridors, such as road and electric transmission rights-of-way (ROW), provide valuable habitat for pollinators, particularly within areas that are highly altered by urbanization and agriculture. Naturalized or semi-naturalized ROWs provide essential habitat elements—food, water, shelter, and nesting sites—for pollinators and other wildlife. ROW also provide important ecological linkages between disjunct habitat patches, such as parks and preserves, during seasonal migrations and daily foraging.

Routine maintenance of vegetation is conducted under powerlines to comply with North American Electric Reliability Corporation (NERC) regulatory standards, and typically includes removal of trees and tall shrubs, herbicide applications, and routine mowing. Herbicides are a component of integrated vegetation management (IVM), a BMP that is used to manage for low-growing vegetation beneath powerlines. Herbicides are also frequently employed for ecological restoration to enhance long-term plant community structure, function, and composition. In this context, herbicides may be used on a large (landscape) scale to remove existing undesirable vegetation on disturbed landscapes for conversion to a more desirable plant community and/or wildlife habitat. On a smaller scale, herbicides may be used to selectively treat undesirable and invasive species that degrade vegetation quality and ecosystem function. Herbicides are therefore a valuable tool when used according to manufacturer's instructions, BMPs, and in an ecologically sensitive manner. This study evaluated some of the herbicides and adjuvants potentially used in ROW VM programs by conducting a literature review. The potential impacts of mowing and other non-chemical VM activities were also briefly evaluated, but not a primary focus of this study.

Herbicide formulations are comprised of an active ingredient and co-formulants, such as adjuvants that are added to an active ingredient to enhance pesticide activity. The non-formulated form of an active ingredient is referred to as the *technical* form. Direct effects may occur when pollinators are directly exposed to herbicides and adjuvants, such as during or immediately following application of an herbicide formulation. Acute lethal doses (LD50, or median dose; the amount of a material to kill 50 percent of a test population) for herbicide active ingredients on honey bees are established in the U.S. prior to product registration, but these tests may represent only a partial measure of harmful effects on honey bees and other pollinators (Desneux et al. 2007). Co-formulants include "inert" ingredients, like adjuvants, to enhance performance of the active ingredient. Billions of pounds of pesticide co-formulants are used and released into U.S. environments annually. However, in most states, mandated tolerances (e.g., LD50) are not established and residues are largely unmonitored (Mullin 2015). Overall, information regarding the acute and sublethal effects of both herbicides and co-formulants on arthropod physiology and behavior represent a significant data gap in the literature.

Indirect effects to pollinators occur when herbicide overspray or off-target drift damages non-target plants that are beneficial to pollinators. Indirect effects on habitat are readily observable in the field, identified as changes in floral diversity and abundance, plant community composition, and vegetation structure. Use of BMPs related to applicator qualifications and training, proper herbicide selection, application type and timing, and adaptive management can greatly reduce potential for indirect effects.

This study is not an endorsement for or against use of herbicides or any other VM activity for ROW management. The reader is encouraged to consult the cited studies, and conduct additional research and outreach as necessary to gain a full representation of relevant background information pertaining to his or her VM or pollinator habitat program.

METHODS

Methods used to discover relevant literature consisted primarily of a (i) literature search using an online academic database, (ii) internet searches using Google and Google Scholar, and (iii) follow up of relevant citations.

Literature Review

The literature search focused on pollinators, herbicides, adjuvants, VM, and pollinator habitat. EBSCO*host*, an online academic research platform, was used to query relevant research articles and publications. More than 25 unique key word combinations were searched in EBSCO*host* using Boolean operators. An internet search for peer-reviewed research was also conducted using Google and Google Scholar. Each of the herbicides for which studies were available were also queried in the National Pesticide Information Center database (*http://npic.orst.edu/*) and the U.S. Environmental Protection Agency's (EPA) Office of Pesticide Programs Pesticide Chemical Search website (*https://iaspub.epa.gov/apex/pesticides/f?p=chemicalsearch:1*) to search for relevant background studies related to pollinators.

Outreach and Expert Interviews

Outreach was conducted with the intent of obtaining additional information to supplement the data collected from the literature review. A web-based survey was sent to 33 experts, identified through internet search, including entomologists, ecologists, university extension specialists, herbicide manufacturers, and VM specialists.

RESULTS

The results from the literature review are grouped into three broad categories below:

1. Potential direct effects
2. Indirect effects
3. General VM

Potential Direct Effects

Direct effects of herbicides and co-formulants may occur when:

1. A pollinator comes into direct contact with chemicals comprising an herbicide formulation, most likely during or shortly after application. For a liquid formulation, this may occur during active spray operations up to when the spray mixture dries on vegetation.
2. A pollinator ingests chemicals or residues from an herbicide formulation when foraging in treated areas. For a liquid formulation, exposure may occur in a relatively limited window, depending on the chemicals applied before:
    a. A plant (flower) senesces or dies from herbicide activity and/or is no longer attractive to pollinators
    b. Before the chemicals associated with a formulation—any residues degrade in the environment. Some herbicides have a longer half-life and potential for residual activity in the environment than others. Co-formulants may halt degradation of active ingredients (Johnson and Percel 2013) and detection of herbicide residues may vary between nectar and pollen (Thompson et al. 2014).

Direct effects may have unique impacts depending on the type of pollinator and potential exposure pathways. For example, bees that consume herbicide residue during foraging may transport contaminated nectar back to the nest and expose larvae to herbicides. Mullin et al. (2015) found approximately 70 percent of the pesticide active ingredients and 100 percent of other formulation ingredients searched for during an analysis of beehive samples. Honey bees may be particularly sensitive to chemical exposure during foraging as they rely on high functionality of sensory and integrative nervous systems for navigation (Desneux et al. 2017). Other pollinators may experience varying levels of exposure effects depending on mobility, foraging and feeding behavior, and social interactions.

Direct effects are generally classified as either acute or sublethal. Acute toxicity is defined as the adverse effects of a substance that results either from a single exposure or from multiple exposures in a short period of time. Acute toxicity measurements for pollinators have relied on determination of lethal median dose (LD50) or lethal concentrations (LC50) of a single active ingredient, primarily to honey bees, but may represent only a partial measure of harmful effects overall. Sublethal effects are defined as physiological or behavioral effects on individuals that survive exposure to a pesticide applied at a dose or concentration that is sublethal or lethal. Desneux et al. (2017) summarized potential sublethal effects of pesticides on beneficial arthropods. They noted that environmental risk assessments of pesticides on honey bees mainly considered the survival of adult bees exposed to pesticides within a relatively short time frame (days), and sublethal effects are generally not considered. Examples of sublethal effects of pesticides cited by Desneux et al. (2017) include impaired learning performance, changes in behavior (including foraging and feeding), bee colony establishment, and neurophysiology, as well as interference with feeding behavior through repellent, antifeedant, and reduced olfactory capacity effects.

Herbicide Active Ingredients

The definition of an herbicide active ingredient is an ingredient which will prevent, destroy, repel, or mitigate any pest, will alter the growth or maturation or other behavior of a plant, cause the leaves or foliage to drop from a plant, or accelerate the drying of plant tissue (EPA 1987). The U.S. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) requires that all herbicide products sold or distributed in commerce be registered by the EPA.

Glyphosate

The active ingredient glyphosate has been extensively investigated for its potential to produce adverse effects in nontarget organisms. It is an aromatic amino acid inhibitor commonly used in agrosystems for broad spectrum weed control. Several studies have examined interactions between glyphosate and pollinators. Boily et al. (2013) fed honey bees a sucrose solution spiked with varying sublethal doses (maximum of 0.04 percent of LD50, or 28 micrograms/bee) of a commercial *formulation* of glyphosate (trade name Weathermax® 240) in a period of 10 days. Levels of acetylcholinesterase (AChE), an enzyme involved in neurotransmitter function, as well as protein concentration and body mass, were measured in test bees for comparison between parallel in-field and laboratory studies. No significant effects on hyperactivity or mortality were noted between the test group and control group. Significantly lower AChE was observed in the glyphosate test subjects, but the potential impacts on neurological function were not clearly stated.

Thompson et al. (2014) analyzed worst-case exposure rates of a glyphosate *formulation* (trade name unknown; manufactured by Monsanto, St. Louis, MO) to honey bee brood as part of a two-stage experiment. In stage one, a commercial formulation of glyphosate was applied once to flowering plants to determine the likely field exposure levels to foraging bees. Higher levels of glyphosate were observed in pollen compared to nectar, but levels declined rapidly with time both in pollen and nectar. In stage two, spiked sucrose water was fed to larvae at worst-case scenario exposure rates determined from the stage one applications. No significant effects were observed on brood survival, weight, or on adult bee mortality. Zhu et al. (2015) assessed acute toxicity of various pesticides, including a glyphosate *formulation* (trade name unknown), on honey bees. Test conditions were simulated to mimic likely exposure pathways during field spraying. Glyphosate was applied a rate of 3.7 liters (L) (125 ounces [oz]) per 0.4 hectares (ha) (one acre), or near the maximum label application rate. Overall, glyphosate killed less than one percent of worker honey bees and the authors concluded that glyphosate has very minor or no acute toxicity to honey bees based on 48-hour mortality data.

Herbert et al. (2014) administered field-realistic doses of *technical* glyphosate to honey bees and attributed reduced sensitivity to sucrose and learning performance of bees to chronic glyphosate exposure. The authors hypothesized potential implications, including reduced sensitivity to nectar reward, resulting in forager bees potentially serving as a source of constant inflow of nectar with glyphosate traces that could be spread to nest mates, stored in the hive, and result in long-term effects on colony performance. However, the potential implications were not quantified during the study. Balbuena et al. (2015) investigated the sublethal effects of *technical* glyphosate on the ability of honeybees (*Apis mellifera*) to perform homeward flights. They found that honeybees fed with the highest concentration of glyphosate experienced impaired cognitive abilities relative to control bees, which affected ability of impacted bees to successfully navigate back to the hive. Helmer et al. (2015) found that exposure of caged honeybees to field-realistic doses after days of the active ingredients atrazine, metolachlor, and *technical* glyphosate through contaminated syrup may alter the carotenoid-retinoid system of honey bees, thus altering bee behavior.

Motta et al. (2018) analyzed the effects of glyphosate exposure on honey bee gut microbiome. The study exposed adult worker bees from a single hive to varying field levels of *technical* glyphosate. Compared to the control population, worker bee gut microbiome was adversely affected by glyphosate before and after colonization, and exposure prior to colonization increased mortality rates when worker bees were also exposed to a pathogen. The study utilized a relatively limited sample size (15 bees per group) and only analyzed bees that returned to the hive. In addition, a lack of adverse effects was observed within the group that received the highest concentration (10 milligrams [mg]/L) after three days, while other test groups showed more pronounced effects at lower concentrations.

Studies on the effects of *technical* glyphosate on honey bees for EPA registration indicates practically no toxicity to honey bees on an oral basis (EPA 2004a) and acute basis (EPA 2004b; EPA 1985). Glyphosate formulations can be toxic to honey bees if formulated with a N-methyl-2-pyrrolidone (NMP) co-solvent and to aquatic organisms if formulated with a polyethoxylated tallow amine surfactant (Mullin 2015).

Dicamba and 2,4-D

Dicamba (benzoic acid herbicide) and 2,4-D (phenoxyaliphatic acid herbicide) are synthetic auxin growth regulator herbicides primarily used for selective broadleaf weed control. Both dicamba and 2,4-D are formulated as commercially available ester and amine salt formulations. Esters have higher vapor pressures than amines and are more susceptible to volatilization, especially at higher temperatures. Lower volatility formulations generally represent the newer and preferred formulations for use in ROW and other sensitive environments where off-target damage is a concern.

Bohnenblust et al. (2013) found that dicamba was not directly toxic to larvae of painted lady butterfly (*Helicoverpa zea*) or corn earworm (*Vanessa cardui*). In addition, corn earworm showed no negative effects when feeding on soybeans dosed with drift-level rates of dicamba. In contrast, Freydier and Lundgren (2016) found that the *active ingredient* dicamba significantly increased lady beetle mortality and reduced body weight, and both herbicides reduced the proportion of males in the Lady Beetle population. Survival of female spring Tiphia wasps (*Tiphia vernalis*) was not reduced by exposure in the lab to turf cores with the active ingredients oryzalin, pendimethalin, and a combination product of 2,4-D, dicamba, and mecoprop (a multi-herbicide) (Oliver et al. 2006). However, male wasp mortality was higher after exposure to oryzalin, pendimethalin, and the multi-herbicide compared to the control. Older studies on dicamba were also reviewed. Morton et al. (1972) fed dicamba to newly emerged honey bees at concentrations up to 1,000 parts per million (ppm) and noted no significant difference in survival between test and control groups. Stevenson (1978) evaluated the toxicity of *technical* dicamba to worker honey bees from contact and ingestion pathways. Less than half of the bees died at all doses tested, resulting in a contact LD50 greater than 100 micrograms/bee and oral LD50 greater than 10 micrograms/bee. A reference cited in the National Pesticide Information Center's Dicamba Technical Fact Sheet (Bunch et al. 2012) indicates dicamba is moderately toxic to practically non-toxic to honey bees.

Recent studies on the effects of 2,4-D on pollinators are limited. Those available are dated (Almer-Jones 1964) or use relatively high concentrations relative to other studies (Moffett and Morton 1975a). The acute oral dose (LD50) of all forms of *technical* 2,4-D on honey bees established for product re-registration through the EPA indicates practically no toxicity to honey bees (EPA 2005), but effects on bee longevity may vary according to dose and 2,4-D form (WHO 1989).

Graminicides

Grass-specific herbicides (graminicides) may be used in pollinator habitat restoration to reduce non-native and invasive grasses that compete with desirable grasses and wildflowers. Two common graminicides, common names sethoxydim and clethodim, are both grass meristem destroyers (cyclohexanedione herbicides) used to selectively control annual and perennial grasses. Russel and Schultz (2010) mimicked the recommended timing and mixture rates of field applications to evaluate the effects of two graminicides (active ingredients fluazifop-p-butyl and sethoxydim) and a non-ionic surfactant (Preference®) on the larvae of Puget Blue Butterfly (*Icaricia icarioides blackmorei*) and Small Cabbage White Butterfly (*Pieris rapae*). Survival of Small Cabbage White Butterfly was reduced under controlled applications by 32 percent with sethoxydim and 21 percent with fluazifop-p-butyl. In addition, wing size and pupal weights of Small Cabbage White Butterfly were reduced, and Puget Blue Butterfly experienced a 21 percent reduction in development time from date of treatment to enclosure. A study on *technical* sethoxydim on worker honey bees for EPA product registration indicated practically no toxicity to honey bees (EPA 1991a). No studies were discovered for clethodim during the literature search.

Imazapyr

Imazapyr is an amino acid inhibitor (imidazolinone herbicide) used for broad spectrum weed control. Aquatic formulations of imazapyr are commonly used in wetlands and near shorelines. A study by Stark et al. (2012) exposed first instars of Behr's metalmark butterfly (*Apodemia mormo langei*) to recommended field application rates of *formulations* of triclopyr, sethoxydim, and imazapyr. These herbicides reduced the number of adults that emerged from pupation by 24-36 percent.

Triclopyr

Triclopyr is an auxin growth regulator herbicide used for selective broadleaf weed control and is commonly used for ROW VM, particularly for control of woody plants. Triclopyr is formulated as either an ester, amine salt, or choline salt formulations. Like dicamba and 2,4-D, the ester formulation is more susceptible to volatilization than the amine salt and choline formulations. No studies were encountered for any forms of triclopyr during the literature search. The acute oral dose (LD50) of *technical* triclopyr on honey bees established for product registration through EPA indicates relatively no toxicity for the amine formulation (EPA 1991b) and practically no toxicity for the ester formulation (EPA 1990).

Metsulfuron Methyl and Chlorsulfuron

Metsulfuron methyl and chlorsulfuron are amino acid inhibitors (sulfonylurea herbicides) primarily used for selective control of broadleaf weeds. Kjaer and Heimbach (2001) tested three insect-plant interactions for the effect of selected sulfonylurea herbicides (metsulfuron-methyl, chlorsulfuron, and tribenuron-methyl). There were no significant effects on the survival and the relative growth rate of the three insects when treating the host plants with sulfonylurea herbicides. Samsoe-Petersen (1995) evaluated the toxicity of metsulfuron methyl to eggs of Rove beetle (*Aleochara bilineata*) and observed a 15 percent decrease in egg hatching, but no effects on mortality of adult beetles, following direct spray application at 0.067 percent (20 percent active ingredient). The acute oral dose (LD50) of *technical* metsulfuron methyl on honey bees indicates relatively no toxicity to honey bees (EPA 1984). No studies were discovered for chlorsulforon during the literature search. The acute oral dose (LD50) of *technical* chlorsulfuron on honey bees indicates relatively no toxicity to honey bees (EPA 1992).

Other Herbicides

Other herbicides cited in the literature as having potential adverse effects on pollinators, but not typically used for ROW management, include:

- Oliver et al. (2006) studied oryzalin and pendimethalin, selective pre-emergent herbicides used for control of annual grasses and many broadleaf weeds in turf and landscapes.
- Helmer et al. (2015) studied atrazine and metolachor, a non-selective herbicide used for control of annual broadleaf and grass weeds in crops.

Herbicide Formulations

For studies on herbicide formulations, it is difficult to assign causes to effects from active ingredients, "inert" ingredients, or a combination of the two. For example, Freydier and Lundgren (2016) found that lady beetle (*Coleomegilla maculata*) larvae were found to be negatively affected by commercial *formulations* of 2,4-D and dicamba. While lady beetle is not a pollinator, it is a beneficial insect that is commonly used as an indicator species for pesticide safety. This study determined that the LC90 of the commercial formulation of 2,4-D was 13 percent of the label rate. The inactive ingredients were believed to be a key driver of the toxicity to lady beetle. Stark et al. (2012) compared effects of three herbicide formulations on Behr's metalmark butterfly and found similar adverse effects among each formulation. Since each herbicide has a different mode of action the researchers speculated that the effects were due to "inert" ingredients or indirect effects on food plant quality.

"Inert" Ingredients

Many modern herbicide formulations utilize proprietary adjuvants and "inert" ingredients to enhance performance. "Inert" ingredients are defined by the EPA as any intentionally added ingredient in a pesticide product which is not pesticidally active (EPA 1987). "Inert" ingredients represent a substantial portion (by volume) of many major commercial products. Uses are not monitored at the federal level, residues are largely unmonitored, and there is little publicly available information regarding chemical make-up and toxicity in the environment (Mullin 2015). Since "inert" ingredients are not classified as pesticides, they are not required to be registered, and therefore do not carry honey bee warning labels. However, the lack of disclosure on formulation ingredients and the lack of adequate methods for analysis limits the assessment of chemical exposure on bees (Mullin 2015).

"Inert" ingredients, also referred to as co-formulants, are often used to increase systemic movement of pesticides in both plants and animals. Adjuvants, a common type of "inert" ingredient either formulated with active ingredients or added during mixing, are any product added to a spray solution to enhance or modify its performance. Activator adjuvants directly enhance the activity of the herbicide's active ingredient and include surfactants, wetting agents, sticker-spreaders, and penetrants (Bakke 2007). The term "inert" for these ingredients is somewhat misleading because these ingredients may be biologically or chemically active (Cox and Surgan 2006).

Surfactants are added to pesticides to aid the penetration of the active compound through the waxy layer on plant surfaces (herbicides) and insect exoskeletons (insecticides) by reducing surface tension. Surfactants are commonly selected based on efficacy on target plants and toxicity to aquatic organisms. For example, Roundup®, one type of formulation of glyphosate, is not registered for use in aquatic settings since the polyethoxylated tallow amine surfactant is highly toxic to aquatic organisms (Mullin 2015). Tallow amine co-formulants (Mullin 2015) and several surfactants have oral toxicity and/or when applied topically to honey bees in laboratory trials (Goodwin and McBrydie 2000). Some surfactants have been shown to repel honey bees (Moffett and Morton 1975b) and about one-third of non-ionic, organosilicone and other surfactant spray adjuvants at up to a 0.2 percent aqueous solution have been shown to deter or kill honey bees (Mullin et al. 2016).

Four types of co-formulants are discussed below:

NMP

NMP, a co-solvent used in some commercially available glyphosate formulations, is a frequent pollutant within the beehive (Mullin et al. 2015) and is moderately toxic to honey bees (Mullin 2015). Zhu et al. (2014) found that NMP was found to have high oral toxicity to larval honey bees down to a concentration of 0.01 percent (100 ppm).

Alkylphenol Polyethoxylated and Nonylphenol Ethoxylate

Chen and Mullin (2014) found that two commercial adjuvants (with alkylphenol polyethoxylate) reduced the learning performance of forager honey bees (Chen and Mullin 2014). Nonylphenol ethoxylate (NPE), a widely used non-ionic surfactant in North America, was detected in every hive sample analyzed. The highest levels of NPE were found in wax (which may accumulate with time), then pollen, then honey. Residues of octylphenol ethoxylate (OPE), another widely used non-ionic surfactant, were less frequently detected as lower residue levels in samples.

Organisilicones

Organosilicone surfactants are herbicide additives used to reduce surface tension and improve herbicide absorption. They are typically comprised of blends of silicone with non-ionic or other surfactants, and typically cause greater reduction in surface tension than either nonionic surfactants or crop oil concentrates. Chen et al. (2018) note that more than 453 million kilograms (one billion pounds) of organosilicon surfactants are produced globally per year, making them a major component of the chemical landscape to which bees are potentially exposed.

Ciarlo et al. (2012) observed changes in learning behavior of honey bees after oral ingestion of four organosilicone adjuvants. A comparable reduction in learning was not seen in bees treated with non-ionic surfactants, although percent conditioned responses were generally lower than those observed in the control bees. Only one of the non-ionic surfactants induced significantly lower positive learning responses at more than one trial. However, organosilicone surfactants are used up to one percent (10,000 ppm) in spray tank mixes and can impact olfactory learning required for foraging in honey bees, independent of active ingredients (Ciarlo et al. 2012). Impairment of olfactory learning may have implications for foraging efficiency at the colony level and may impact social interactions.

An organosilicone adjuvant incorporated into pollen and fed to nurse bees in a closed swarm box experiment had no effect on honey bee queen development at a concentration of 200 ppm (Johnson and Percel 2013). Chen and Mullin (2013) analyzed the presence of three trisiloxane (silicone-based) surfactants in honey, pollen, and beeswax samples. They found trisiloxane surfactants in every beeswax sample and 60 percent of pollen samples analyzed and recommended further investigation on the potential consequences of these adjuvants on overall bee health.

A more recent study by Mullin et al. (2015) showed that honey bees are sensitive to organosilicone surfactants, nonylphenol polyethoxylates, and NMP. The effects of these co-formulants included learning impairments for adult bees and chronic toxicity in larval feeding bioassays. Honey bee exposure to organosilicone surfactants and a virus resulted in significantly heightened levels of Black Queen Cell Virus, demonstrating that these "inert" chemicals can potentiate viral pathogenicity in honey bee larvae (Fine et al. 2017).

Methylated Seed Oil and Crop Oil Concentrates

In the study by Ciarlo et al. (2012), none of the crop oil concentrates tested caused significant reductions in learning in honey bees.

Indirect Effects

Indirect effects are associated with changes in vegetation and habitat, such as the reduction or removal of flowering and host plants. A prominent example is the large decline in the monarch butterfly (*Danaus plexippus*) population, whose larvae feed exclusively on milkweed plants. There has been a large decline in common milkweed (*Asclepias syriaca*) in agricultural fields and edges in the Midwest due to widespread usage of glyphosate with introduction of genetically modified (GM) glyphosate-tolerant corn and soybeans. The loss of milkweeds is a major contributor to the decline in the monarch butterfly (Pleasants and Oberhauser 2013).

Reduced health of nectar and host plants impacted by herbicide may also be important. Bohnenblust et al. (2016) observed that dicamba herbicide applied at sublethal, drift-level rates to alfalfa (*Medicago sativa*) and boneset (*Eupatorium perfoliatum*) delayed onset of flowering and reduced the number of flowers of each plant species. Plants that were affected by herbicide drift were visited less often by pollinators. However, plants that did flower produced similar-quality pollen in terms of protein concentrations. Results of another study indicate that dicamba can indirectly influence the performance of some caterpillar species and the mechanism may be attributable to altered plant nutritional content, such as reduced plant biomass and total nitrogen content (Bohnenblust et al. 2013). Kjaer and Heimbach (2001), in a study of three insect-plant interactions for the effect of selected sulfonylurea herbicides, found no significant effects on the survival and the relative growth rate of three insects, but the host plants had significantly reduced root and shoot growth rate.

Glaeser and Schultz (2014) evaluated the effect of the graminicide fluazifop-p-butyl on the behavior and demographic responses of the Silvery Blue Butterfly (*Glaucopsyche lygdamus*). An early spring herbicide application decreased the vertical grass structure, but did not have a net effect on adult behavior, egg deposition, larval density, pupal weight, or ant-tending associations. The authors concluded that appropriate herbicide application timing is likely key to avoiding adverse effects on vulnerable butterfly life stages.

Hahn et al. (2014) studied the effects of herbicides on host plant quality for three plants, narrowleaf plantain (*Plantago lanceolata*), common plantain (*P. major*), and tall buttercup (*Ranunculus acris*). Plants were treated with sublethal rates of either a sulfonylurea *formulation* (mesosulfuron methyl and iodsulfuron methyl) or a glyphosate *formulation* and the development of cabbage moth (*Mamestra brassicae*) larvae was observed. Only the combination of the sulfonylurea *formulation* on tall buttercup showed adverse effects on larvae.

One potential corollary for the indirect effects of herbicide use on rights-of-way (ROWs) are studies at field edges and natural/semi-natural areas next to fields that may experience off-target damage. A study by de Snoo et al. (1998) found that unsprayed field margins had greater butterfly (*Lepidoptera*) abundance than sprayed margins. Frampton and Dorne (2007) found that restriction of herbicides in crop edges clearly had a positive influence on arthropod populations, and that exclusion of herbicides alone often had a greater effect than the exclusion of herbicides in combination with fungicides and/or insecticides. Egan et al. (2014) conducted a multi-year assessment of field-edge and old field plots to drift level concentrations of dicamba (one percent of typical application rate). They found that forb cover decreased in field-edge plots. Herbicide applications did not affect plant community structure in old-field plots, but did reduce flowering of important nectar sources. However, variability across sites limited formation of conclusions on the potential risk of dicamba drift to plant and arthropod biodiversity as some areas may be more susceptible to drift than others.

Prossera et al. (2016) conducted a thorough literature review of studies evaluating the indirect effects of herbicide applications on biota in field-edge habitats. The results of this study may be applicable to herbicide applications on ROW where drift or overspray may occur. They noted four primary information gaps of studies in edge-of-field habitats:

1. There is a lack of studies incorporating relevant exposure scenarios. Most studies examine the effects of herbicides on plants, but lack consideration of the indirect effects on animal species that are most likely to experience exposure in edge-of-field habitats.
2. Characterization of magnitude of exposure to account for varying ways that herbicides are applied (rate and method of application) as well as field conditions (such as height and density of vegetation) that may impact drift.
3. Study of linkages between direct effects on plants, indirect effects on animals, and population-level effects. The authors note that study of indirect effects is complex. For example, many studies quantify changes in abundance of invertebrates, but do not quantify changes in affected plant communities.
4. Studies conducted using relevant scenarios within the U.S.

The reader is encouraged to consult the study by Prosser et al. (2016) for a more thorough summary of potential indirect effects of herbicides on *Lepidoptera, Coleoptera* (beetles), and other invertebrates.

General VM

Typical VM practices to maintain safety, reliability, and access on ROWs may provide positive and negative benefits to pollinators. While ROWs have the potential to provide excellent pollinator habitat, not all pollinators have the same habitat preferences. For example, bees and *Lepidoptera* tend to have divergent habitat requirements (Davis et al. 2008). *Lepidoptera* diversity is maximized in large habitat blocks that minimize edge effects and have many host plants and nectar sources. Butterflies in powerline corridors were found to be most abundant in segments with vegetation of short and intermediate height (Berg et al. 2013). The number of flowers was the main factor that affected the abundance of most butterfly species. Higher butterfly species richness was observed in transmission line ROW that had more native plant species (Leston and Koper 2016).

Meanwhile, bees prefer linear habitat patches, or areas with high heterogeneity of habitats. Wild bees were more common in dense scrub than in nearby grasslands (Holden 2005). Dense scrub can provide both floral and nesting resources for bees (Russel et al. 2005). Transmission line corridors in forested landscapes provide important, managed early successional habitat for wild bees (Wagner et al. 2014). Allowing shrubs and brambles to spread within the corridor may enhance wild bee habitat. Woody vegetation removal in managed and unmanaged field boundaries in Europe was observed to have varying and contrasting effects on various pollinator groups (Soderman et al. 2016).

Mowing of herbaceous vegetation may have a significant impact on pollinators through direct mortality, particularly during egg and larval stages (Xerces Society 2015). Mowing also results in a sudden removal of floral resources for foraging pollinators as well as host plants if not carefully timed. Overall, interspersion of diverse habitats and plant species will support more pollinators, but successful pollinator species management requires more refined information and significant data gaps exist in the understanding of how ROWs can benefit all pollinators (Wojcik and Buchmann 2012).

Outreach Interviews

Out of 33 survey invitations, only six responses were received within a three-week response period. While the survey participation rate was very low, the responses indicate a higher level of concern related to indirect effects of herbicides on pollinator habitat and use of BMPs to mitigate the risks of herbicide use on pollinators than to the direct effects of herbicides on pollinators.

As the overall response rate was very low, any additional follow-up is recommended to include a wider field of expertise, including specialists in ecotoxicology and ecological risk assessments, with arthropods as a primary research focus.

DISCUSSION

Numerous information gaps became apparent as the literature was reviewed and are worth noting to provide context for the study results. The reader should be aware of potential limitations when interpreting the results, including:

- Many co-formulants, such as adjuvants, are considered "inert" and proprietary, and therefore have undergone limited review and study in the U.S. Few herbicide active ingredients have been thoroughly studied to establish acute oral toxicities, exposure pathways, potential effects on larvae, and sublethal effects on pollinators.
- U.S. testing requirements for registration of an active ingredient, and lack of testing on "inert" ingredients, are major factors limiting availability of data. Most tests conducted by manufacturers to register a pesticide (including herbicides) with the EPA are performed with only the active ingredient instead of the full pesticide formulation (Cox and Surgan 2006). For the active ingredient, typically only the acute oral dose (LD50) for honey bees is provided. It is not appropriate to establish chronic (sublethal) effects from toxicity studies on lethal doses or concentrations of active ingredients. Tests in the U.S. are based on acute contact (Tier 1) but may also include foliar contact (Tier 2) and field toxicity (Tier 3) studies based on LD50 thresholds and if other studies indicate potential adverse effects. More stringent testing underway in other parts of the world may provide

additional information on sublethal effects and exposure pathways to technical ingredients and "inert" ingredients for a more diverse array of pollinators.

- Study design and methods vary between studies and studies are typically hypothesis driven. For example, test concentrations and exposure pathways vary between chemicals and studies, generally ranging from highly controlled administration of sucrose solutions spiked with a technical ingredient or herbicide formulation to in-field spraying to mimic field application scenarios. The literature generally lacks comparisons on the influence of the methods of herbicide applications on exposure potential (Prosser et al. 2016). Some studies may not use field-level exposure rates representative of typical ROW herbicide application scenarios. Overall, the type and magnitude of exposure is important to consider when evaluating the effects reported by available studies.
- Multiple formulations of an active ingredient are typically available commercially at any given time, including from multiple manufacturers, and formulations may change with time. Studies that exclusively evaluate an active ingredient should not be used to establish effects of a formulation. Likewise, studies that evaluate an active ingredient along with co-formulants should not be used to establish the effects for other formulations with the same active ingredient. This is because formulation ingredients may vary among and between manufacturers. Since most "inert" ingredients are considered proprietary, it may not be possible to attribute observed effects of a formulation to the active ingredient or to one of the "inert" ingredients within the formulation. In general, hazards of herbicides and "inert" ingredients to pollinators cannot be accurately predicted if technical ingredients are tested without formulation ingredients and if tests are conducted on a single pollinator species (Mullin 2015).
- Long-term studies examining the effects of regular, repeat applications or cyclical applications on plant communities and pollinator populations are lacking (Egan et al. 2014).
- Evaluations of the ecological linkages between the direct effects on plants and the indirect effects on plant-dependent communities and population dynamics are lacking (Prosser et al. 2016).
- Limited diversity of pollinators is studied. The pollinators most commonly encountered in the literature as research subjects are honey bees. Differences in the probability, frequency, and magnitude of potential exposures, as well as potential differences in foraging habits of wild bee species or other pollinators versus those of honeybees, may dictate species-specific responses to herbicides.

BMPs

Herbicides are an important tool for management of ROW. Proper planning and use of herbicides within a BMP framework, focused on preservation of pollinators and pollinator habitat, can reduce potential harmful effects of herbicides and improve pollinator habitat in the long term. Based on the results of this study, the following BMPs are recommended:

1. Apply principles of IVM. Utilize herbicides as one of several available tools in the toolbox to manage vegetation and habitats in an ecologically sensitive manner. Integrate principles of ecological stewardship to work towards development and sustainability of functional plant communities that are more resilient to disturbance.
2. Avoid or limit use of herbicide formulations with NMP and/or tallow-amine co-formulants.
3. Avoid use of organosilicone surfactants, alkylphenol polyethoxylates, and nonylphenol polyethoxylates pending further investigation of potential impacts on pollinators.
4. Apply low volumes of herbicides and adjuvants. Utilize targeted application techniques and properly calibrated equipment to limit effects on non-target plants.
5. Use the lowest concentrations of herbicides and adjuvants as recommended by product labels to achieve intended outcomes.
6. Use selective herbicides to limit effects on non-target plants.
7. Minimize use of herbicide formulations that are susceptible to drift and those with high residual activity when working in or near pollinator habitat.
8. Conserve compatible low-growing flowering shrubs to enhance pollinator habitat, as appropriate, based on ecoregion and VM goals.
9. Considering timing VM activities, including herbicide application and mowing, with periods of low flora resources and/or when pollinators may not be as active.
10. Utilize monitoring and adaptive management principles. Maintain flexibility in approach as conditions change between sites along a corridor and as condition change within a site with time.
11. Stay abreast of testing underway in other parts of the world (such as the European Union) that may provide additional information on acute oral toxicity, exposure testing, potential effects on larvae, and sublethal effects on pollinators.
12. Follow label directions and understand both legal and ecologically appropriate uses of an

herbicide.

The state of Washington is one of two states that requires adjuvants to be registered for use prior to sale. Testing is required to establish toxicity on aquatic life. Aquatic-approved adjuvants must be slightly toxic or practically non-toxic to fish and moderately toxic, slightly toxic, or practically non-toxic to aquatic invertebrates. Products that meet these standards are generally formulated without or with low concentrations of alkylphenol ethoxylates and without alkyl amine ethoxylates. While not tested for potential effects on pollinators, the list of aquatic-approved adjuvants at Washington State University Pesticide Information Center Online (http://picol.cahe.wsu.edu/LabelTolera nce.html) may serve as a useful starting point when selecting adjuvants for use in pollinator habitats.

CONCLUSIONS

Herbicide formulations consist of an active ingredient(s) and co-formulants, which are considered "inert" by the EPA. Active ingredients work to kill the target pest plant through a specific mode of action. The acute toxicity to honey bees and other organisms of only the active ingredient within an herbicide formulation are evaluated prior to approval and regulation by EPA. "Inert" ingredients, such as adjuvants, are added during the manufacturing process, or by the applicator during mixing, to enhance pesticidal activity. They are considered proprietary and therefore require minimal testing and regulation.

Herbicides and adjuvants may pose direct and indirect effects on pollinators. Direct effects may occur when a pollinator comes into direct contact with chemicals, or when a pollinator ingests chemicals or residues when foraging in treated areas. Studies on direct effects are relatively limited considering the wide-scale use of herbicides and large number of products commercially available. Most active ingredients evaluated as part of this study have relatively to practically no acute toxicity to honey bees based on laboratory testing conducted prior to EPA product registration, but other studies cite direct effects to pollinator for some of the active ingredients evaluated.

Acute toxicity studies may represent only a partial measure of harmful effects on honey bees and other pollinators. Potential sublethal effects of herbicides cited in the literature include impaired learning performance, changes in behavior (including foraging and feeding), bee colony establishment, and neurophysiology, as well as interference with feeding behavior. Adjuvants could also pose both acute and sublethal effects. Organosilicone surfactants may cause learning impairments and chronic toxicity. Alkylphenol polyethoxylated and nonylphenol ethoxylates are abundant in the environment, including honey bee hives, but potential impacts on pollinators are unclear.

Consistent evidence of cause-and-effect among studies on specific active ingredients and formulations is lacking. This may reflect a shortage of evidence rather than clear evidence for a lack of effects, given the relatively limited number of studies and the wide variety of study methods. The factors involved with direct effects are unclear because many chemicals may be involved. For example, some glyphosate formulations can be toxic to honey bees if formulated with a N-methyl-2-pyrrolidone (NMP) co-solvent, and to aquatic organisms if formulated with a polyethoxylated tallow amine surfactant.

Indirect effects are associated with changes in vegetation and habitat, such as the reduction or removal of flowering and host plants. The primary impacts of herbicides on pollinators are associated with these indirect effects on changes in vegetation and habitat. The potential direct and indirect effects of herbicides and adjuvants can likely be greatly reduced through employment of BMPs.

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Implementation of 65 Years of ROW IVM Research

Dave Krause

The scope of integrated vegetation management (IVM) has become increasingly complex, requiring a higher level of sophistication and effort in evaluating management choices and employing them in the field. Incorporating the beneficial results of research into this decision process helps validate environmental stewardship objectives for various rights-of-way (ROW) stakeholders. The Pennsylvania State Game Lands 33 (SGL 33) research project, commonly recognized as the Bramble and Byrnes Research Project, has provided a wealth of data comparing the impact of various VM techniques, including herbicide and mechanical methods on wildlife habitat. The information generated from this ongoing 65-year research project has helped guide decisions for implementing IVM and industry best management practices (BMPs) on utility ROWs.

Keywords: Integrated Vegetation Management (IVM), Native Plants, Pennsylvania, Wildlife.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

The Pennsylvania State Game Lands 33 (SGL 33) research project in central Pennsylvania began in 1953 in response to public concern about the impact of vegetation management (VM) practices on wildlife habitat within electric transmission rights-of-way (ROW). Integrated VM (IVM) is a comprehensive practice of analysis, planning, implementing, and quality assurance for improving VM. Initially, the SGL 33 research was focused on the impact of herbicides on wildlife habitat. Research has since expanded to include a wide range of wildlife species, including pollinators and long-term effect on plant cover.

Today, SGL 33 is the site of the longest continuous study documenting the comparative effects of herbicide maintenance on flora and fauna along an electric transmission ROW. Long-term studies, such as the SGL 33, are invaluable for an ecological understanding of the response of plant and animal communities to ROW management practices (Bramble, Byrnes, Hutnick, Liscinsky, and Yahner 1999). Similar studies have been conducted at a companion site, the effects of these "new" approaches to VM on plants and animals.

METHODS

To test the environmental effects of ROW maintenance methods, six mechanical and herbicidal treatment sites (with replicates) were established. These treatments included: hand-cutting (control), mowing, mowing plus herbicide, stem-foliage spray, foliage spray, and low-volume basal spray. In addition, the treatments were managed to include a 15.24-meter (m) (50 feet) border zone. This approach to VM typically produces a tree-resistant, forb-shrub-grass cover type in the wire zone and a tall shrub cover type in the border zone. The treatment effects on vegetation and wildlife communities (via multiple surveys, live trapping, and vegetation inventories) were compared to each other and to the adjacent mature, mixed deciduous forest practices (Bramble and Byrnes 1982). The data helps predict changes in plant communities by treatment type. Consideration should be given to treatment cycles as well due to various growth rates and succession of plants with time.

RESULTS

The importance of selectivity when controlling brush species as compared to bare ground was studied for decades prior to the establishment of SGL 33 project. Simply removing all vegetation for powerline maintenance would be counterproductive to ecology. The idea of plant-community management came to light (Egler 1949). Frequent use of ROWs by wildlife has been documented by the research of Bramble and Byrnes (Bramble and Byrnes 1972; Bramble 1974), where vegetation managed with herbicides create habitat for many game mammals, small mammals, and song birds. Creating strategic and tactical approaches for both the ROW vegetation manager and contractor is required as it relates to implementation into an IVM plan. Properly managed powerline ROWs provide habitat for early successional species of birds—many of which are on the Audubon watchlist due to dramatic declines. Vegetation diversity on the ROW also provides host plants to potentially 245 species of pollinators and thus positively impacts for the abundance and richness (Mahan 2018). Removing all woody vegetation that may impact electrical wires allows for development of an early succession habitat which can be selectively managed to minimize disturbance to pollinator species.

Utility vegetation managers can utilize information as an opportunity to communicate positive energy to work together with a more cogent and visible ROW message. This message needs to be communicated loudly, often, and consistently. They can strategically enhance wildlife habitat by incorporating VM to into specifications, work planning, and management. Contractor training opportunities are required for a deeper understanding of the impact of chemistry and dynamics of their properties when combining active ingredients. This points out the importance of plant identification as well as timing and resource deployment.

DISCUSSION

So how do we bridge the research information we have gleaned towards utilization in practice and what are the benefits? The evolution of analytics for vegetation management includes descriptive (numerical and graphical), predictive analysis and prescriptive (programming). These tools allow vegetation managers to strategically enhance wildlife habitat by incorporating results into vegetation management specifications, work planning, and management practices. They can also utilize research data as an opportunity to communicate a positive ROW message to various stakeholders with more cogent and information. This message needs to be communicated loudly, often, and consistently. Answering the concerns about direct or indirect effects of needed VM practices will help maintain all the tools needed in the future to achieve the cost-effective objectives for safe and reliable power delivery. Despite the difference in ecosystems across geographic areas of the world, the research data can help leverage general conclusions for IVM decision-making. It can also support initiatives such as the Memorandum of Understanding on VM for Powerline ROWs (EEI et al.).

Contractor training opportunities can provide deeper understanding of the impact of chemistry, dynamics of their properties when combining active ingredients, and differentiation of application methods. A desire for selectivity points out the importance of plant identification as well as timing and resource deployment.

CONCLUSIONS

Utility ROWs are not specifically managed for wildlife habitat, but rather electric reliability and safety. However, they *can* be managed in a way that conserves biodiversity and sustainability through implementation of best management practices (BMPs). VM plans can also provide the quality assurance to validate requirements such as stewardship accreditation or ISO 14001 metrics. The baseline data derived from research can provide value in addressing future questions or concerns about ecological impact or climate change as it relates to VM along ROWs.

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Implications and Guidance from the Literature for ROW Managers Looking to Promote Pollinator Habitat

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Rights-of-way (ROWs) have become an important early successional habitat for pollinators in the Northeast as the landscape has reforested and agricultural practices have intensified in the last century. A literature review was conducted to determine the current state of knowledge, technology, and practice for managing ROW corridor vegetation with the goal of promoting diverse pollinator assemblages. This review includes 36 studies from North America and Europe investigating powerline, roadway, pipeline, and railway ROWs. Most studies investigated Lepidoptera (butterflies and moths) and Apoidea (bees and sphecid wasps). Multiple publications related floral resources and shrub cover to pollinator abundance, richness, and diversity. Additional considerations included rare, threatened, or endangered species (RTE) surrounding landscape conditions, and nesting resources. In summary, most studies were observational in nature, and there was little experimental/conclusive evidence supporting one management technique moreso than another. Based on these publications, as well as investigator experience and insight, an eight-step process was developed to assist in managing ROWs for pollinators. However, the limited nature of the literature suggests managers should proceed with caution with on-the-ground learning and adaptive management as main objectives of intentional pollinator management on ROWs.

Keywords: Bees, Butterflies, Integrated Vegetation Management (IVM), Pollinators, Rights-of-Way (ROW), Vegetation Management (VM).

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Safe and reliable transmission of electricity is the main goal of vegetation management (VM) on electric transmission line rights-of-way (ROWs). Plant assemblages are managed to fully occupy the ROW and are kept low in stature, so trees and other vegetation do not cause ground fault disruption by growing up into the conductor space (NERC 2018). Various VM methods are used to create and maintain ROW vegetation, but mostly these methods can be categorized as chemical (herbicides) or mechanical (Gardner 2014). Chemical methods are usually least costly and most cost effective in the long run (Abrahamson et al. 1995; Nowak 2012), and especially so when an integrated VM (IVM) approach is taken to guide planning, decision making, and implementation of management endeavors (Nowak and Ballard 2005; Gardner 2014). IVM concentrates on the directed selective removal of undesirable trees and other plants (i.e., tall growing), leaving compatible plant assemblages to develop into complexes of shrubs, forbs, ferns, and grasses, which then inhibit subsequent reinvasion of the ROW by undesirable trees (Nowak and Abrahamson 1994; Nowak and Ballard 2005). Chemical and mechanical treatments can be applied separately or together to create different plant assemblages, depending on management objectives and the suite of plants and their life histories (Bramble et al. 1991). These varied plant assemblages can provide numerous ecosystem services, particularly associated with wildlife (Nowak 2002).

Powerline corridors are being recognized for their potential to support ecosystem services, with recent attention given to ROWs and pollinators (Wojcik and Buckman 2012). VM operations on ROWs already provide for pollinators that depend on early successional habitat (i.e., complexes of shrubs, forbs, ferns, and grasses), including bees and butterflies. Other elements of ROW habitat are beneficial to bees, including lower canopy cover (Grundel et al. 2010), increased incidence of bare ground accrued through VM and maintenance operations (Wojcik and Buchmann 2012), and an abundance of visual land marks, including roadways, for orientation (Wuellner 1999). Bumble bees (*Bombus* spp), currently believed to be one of the most at-risk bee genera, are reported to be quite successful in grassy areas between habitat types, due to their preference for nesting in abandoned rodent nests (Vaughan and Black 2007).

Roadsides and other linear ROWs provide many of the same benefits associated with powerline ROWs. In the U.S., roadside verges cover more than 4 million hectares (ha) (10 million acres) and provide connective corridors to habitat patches (Hopwood 2013). In many cases, ROWs may provide the only available native vegetation in a highly modified urban setting and are typically set aside from further development. This makes them particularly valuable habitat for pollinators, which is especially true when managed to promote native plant species using integrated roadside VM (IRVM). This method of treatment holds the same goals and procedures as IVM, but often includes an element of planting, which can be more cost effective (relative to other systems) as roadside verges are smaller and more easily accessible.

While not a substitute for wildlands, linear ROWs have the potential to provide a haven for many native fauna and flora within highly disturbed habitats, thus creating reservoirs for native species. As reforestation has taken place and agricultural practices have intensified in the course of the last 100 years, ROWs have become increasingly important habitat for pollinators in the Northeast. ROWs hold an extraordinary potential for the research and promotion of pollinator habitat. While already beneficial, improved habitat for pollinators may be possible on ROWs with adaptation and tailoring of traditional VM treatments.

Study Objective

The objective for this study was to determine the current state of knowledge, technology, and practice for managing ROW corridor vegetation with an eye to promoting diverse pollinator assemblages via habitat management. In winter 2016–2017, a literature review was conducted with development of an annotated bibliography containing references important to vegetation managers interested in understanding known and potential effects of management on insect pollinators. This list was then updated in the summer of 2018. The literature located was synthesized into a short overview describing possible practices for enhancing pollinator habitat on ROWs.

METHODS

A literature review was conducted in late 2016–early 2017 and updated summer of 2018 to gather published information on ROWs, VM, and pollinators (Nowak and Van Splinter 2017). The internet search engines Google™ and Google Scholar™ were searched using various combinations of the following keywords: bees, butterflies, electric distribution line, electric transmission line, railroad, railway, road, roadside, pollinators, right(s)-of-way, and vegetation management. Citation indices (papers listed in search engines as citing the paper of interest) were used to develop an exhaustive interconnected list of peer-reviewed published work. Conference proceedings from the series of Environmental Concerns on ROW symposia and the *Journal of Arboriculture and Urban Forestry*, both of which are usually not included in search engine databases, were manually searched for publications of interest.

RESULTS

A total of 36 publications were found

(Table 1) and categorized as follows:

- *PUBLICATION YEAR*: A decadal pattern of publications follows as 4, 11, and 22 publications in the 1990s, 2000s, and 2010s, respectively. Sixteen of the 21 recent publications (2010 to date) are from Europe (10 occurred in Scandinavian countries).
- *TOPIC*: A total of 24 papers were on butterflies and 15 on bees. Seven papers included alternate taxa and two examined nectar and pollen forage only.
- *TYPE OF STUDY*: Only six papers were manipulative field experiments, compared to 30 observational field studies.
- *STUDY SITE SIZE*: Average study site size varied between electric powerline ROWs and other ROW types, without respect to taxa. For electric transmission ROWs, the average size was ~1.5 ha, range=0.2–4.8 ha (Note: the average is about the area of a tower-to-tower span on an electric transmission line ROW). Average site size for other ROWs was ~0.05 ha and ranged from 0.02–0.1 ha. Therefore, previous studies have historically used site sizes based on physical barriers and management, but not necessarily a meaningful biological/ecological unit.
- *DISTANCE BETWEEN POLLINATOR SITES*: Very few studies published this information, but those that did reported distances of between 0.05 and 2 kilometers (km), with an average of just less than one km—this was similar for both electric transmission ROWs and other ROW types. This distance reflects the upper end of flight distance for larger bees, with a maximum of two km (Zurbuchen 2010), but is well under flight ranges for the introduced European honey bee (*Apis mellifera* Linneaus), which have been observed to average 5.5 km to more than 7.5 km flights on foraging trips (Beekman and Ratnieks 2001).
- *LANDSCAPE DISTANCE*: Again, few studies reported this information, but those that did differed between electric transmission ROWs and other ROW types, and without respect to taxa. This suggests distance was selected based on physical barriers rather than biological/ecologically meaningful distances. Electric transmission ROWs averaged ~1.3 km and ranged from 0.25–3 km, while other types averaged ~0.1 km, with a range of 0.01–0.2 km.
- *LOCATION OF WORK*: Of the 36 studies, 21 were published in Europe, with 16 recent (2010 or later) publications. Of all publications, 14 originated in Scandinavian countries (Finland=6, Norway=2, Sweden=5). Fifteen publications were conducted in North America, with only five being recent (within the last 10 years). Many of these were from the eastern United States (Connecticut=2, Maryland=2, New York=2, Pennsylvania=2, South Carolina=1, multiple states=1), and only two were conducted in Canada (Manitoba).
- *POLLINATOR SAMPLING METHODS*: For bees, approximately half of studies utilized pan traps. Of these, two also utilized sweep netting. Other studies used a variety of techniques, such as observational plots and variety of sweeping techniques. There was no clear standardization for sampling bees on ROWs as, even within pan trap studies, colors chosen were variable. Butterfly sampling, however, was extremely consistent with 19 of the 21 studies, sampling only Lepidoptera, and utilizing some form of the Pollard and Yates (1993) method (standardized transect walks with on the wing and as needed capture identification). The two studies not using this method were focused on a specific target taxon (Karner blue butterfly) and used presence/absence records with on the wing identification by site.
- *LENGTH OF STUDY*: Out of 36 studies, 22 made observations in only one season, while 30 were made two years or less. Only three studies were conducted for four years or more, of which one collected only vegetation data, and one examined only a single species (Karner blue butterfly).

To summarize, there has been a recent increase in electric transmission line ROW research on pollinators, mainly focused on butterflies, but some on bees, and primarily in Europe. Very few (seven) examined taxa outside of these two groups, thus limiting conclusions that can be drawn about pollinators in general. Additionally, standardized sampling of bees and alternate taxa have yet to emerge, making comparisons among studies difficult for groups apart from Lepidoptera. Most past studies have been observational in nature, with only a handful of manipulative experiments that can be used to connect VM techniques and pollinators in a cause-and-effect manner. This means VM activity should proceed cautiously, informed by research to date in terms of types of activity, but with a view towards documenting/understanding whether activities are working across systems at operational scales. Common pollinator site sizes are approximately 1.5 ha on electric ROWs. However, caution should be used when deciding plot size as this unit is most likely chosen out of convenience rather than ecologically meaningful information.

DISCUSSION

Five general areas of information for management of pollinators on electric transmission line ROWs emerged from a review of the literature: rare, threatened, and endangered (RTE) species (Table 2); landscape considerations (Table 3); floral resources (Table 4); shrub coverage (Table 5); and extraneous factors within the ROW environ (Table 6). This information was assembled into a series of guidelines presented as a time sequence of considerations for managing a ROW for pollinators (Text Box 1).

Step 1: Site Selection and Definition

A ROW pollinator site should be chosen to produce ecologically meaningful habitat changes with management via manipulation of vegetation. It may be that the whole length of the ROW is to be managed for pollinators. It would likely be useful, however, to manage smaller sites within the ROW with a variety of approaches, one site being compared to the next, depending on existing vegetation and desired future vegetation/habitat given the pollinator species of interest and the surrounding landscape.

The appropriate size at which to manage pollinators should vary with the focal taxa. Considering many pollinators, (e.g., butterflies and hoverflies), move across habitats for their entire adult lives. Most bees, however, are central place foragers, meaning once they establish a nest, they must forage around that nest. Additionally, their foraging distance is limited by their body size (Greenleaf et al. 2007), which can range from as little as 100–200 meters (m) for small bees such as *Megachile rotundata*, up to more than a km for larger-bodied bees, (e.g., *Bombus terrestris*) (Zurbuchen et al. 2010). Therefore, flight range can be used as a gauge for pollinator site size and or distance among multiple treatments. For examples, the smallest area of management to encompass the entire range of a small bee—the most limited pollinator home range—would be a circle with a radius of 100 m, or a patch a little more than three ha.

Step 2: RTE Species

ROWs, in various contexts, have been shown to support RTE pollinators (Table 2). For butterflies, this includes the iconic Karner blue butterfly (*Lycaeides melissa samuelis*), (Smallidge et al. 1996; Lowell and Lounsbury 2002), as well as numerous RTE prairie grassland (Ries et al. 2001; Lampinen et al. 2018) and mire specialist butterfly species (Lensu et al. 2011; Komonen et al. 2013). *Epeoloides pilosula*, a globally rare cleptoparasitic bee, thought to be previously extinct, was rediscovered along a powerline corridor (Wagner and Ascher 2008), and numerous rare and endangered Hymenoptera species have been found along roadside verges (Heneberg et al. 2016). When considering RTE pollinators, it is essential to first determine if there are any protected pollinator species of interest, either because they are known users of a ROW, or because there is interest in promoting possible future use of a site by those species. Site conditions may need to be modified to specifically address habitat requirements of the RTE pollinator in question, requiring further research and a targeted management plan. These species, if found, should be a primary focus of pollinator management.

If no individual species are identified, it may be beneficial to select a priority pollinator group. We suggest asking, "Who is most important to our area and our stakeholders?" While generalist bees are more efficient pollinators and particularly important for many agricultural crops (Waser et al. 1996), butterflies are charismatic and attract positive attention to conservation work. While the diversity of pollinating insects is great, there are substantial differences among groups with respect to life history. Moron et al. (2014) found different pollinator taxa are affected by different environmental conditions. Bee populations were correlated with nesting habitat availability, while butterflies were most influenced by native host plant availability for their larvae, and hoverflies were influenced by forest presence in the surrounding landscape. This means different taxonomic groups require different conditions, some of which may be at odds with one another. For example, though research is limited, invasive exotic plants (e.g., honeysuckle) may benefit generalist bees (Stout and Morales 2009), while butterflies seem to be negatively associated with their presence (Leston and Koper 2016) as they outcompete native plants needed for their often host-specific larvae or nectaring provisions. It may be circumstances require prioritizing one group over the other.

Step 3: Landscape Considerations

Many pollinators move in and out of ROWs from distances of 100 m to more than one km (see Step 1). Several studies have emphasized the importance of surrounding landscape on pollinator populations (Table 3). Moron et al. (2014) found hoverfly (*Syrphidae*) species richness increased significantly with proximity to woodland cover within 200 m of the ROW. Additionally, species richness of diurnal Lepidopteran species has been positively associated with percent forested land within 50 m of the ROW (Saarien et al. 2005; Valtonen et al. 2006). And while a few studies have found no significant effect of landscape on Lepidopteran species (Berg et al. 2011; Lampinen et al. 2018), these studies did suggest floral resources these pollinators rely on are affected by surrounding landscape characteristics. Furthermore, landscape heterogeneity has been shown to be an important driver in Hymenopteran assemblages (Heneberg et al. 2016), as well as Lepidopteran (Lanham et al. 2002; Kalarus and Bakowski 2015), helping promote diverse and stable pollinator populations within the ROW.

A ROW can contribute to pollinators at its fullest if the local landscape—that area of land surrounding the ROW site for up to one km away—does not have food and cover habitat (including shelter and nesting elements) that can be provided on the ROW. For example, a ROW passing through a forested area may need to provide a mix of shrubs, forbs and grasses to support local pollinators. In contrast, in a landscape of early-successional plant assemblages outside of the ROW, including semi-natural pastures, a ROW with more forbs than shrubs or grasses may be more valuable. The key to this step is to know ROWs managed for pollinators will likely be most effective if done so in the context of landscape management, along the lines of the axiom, "Think globally, act locally," which can be equated for pollinators on ROWs to "Think landscape, but act on the ROW one site at a time."

Step 4: Floral Resources

One aspect clearly known about floral resources for pollinators via the literature is pollinator ROW sites should have diverse assemblages of shrubs and forbs which flower throughout the season—from the time of pollinator emergence in the spring (with flowering usually by shrubs or trees) until the first killing frost—in order to maximize food-based habitat value. This is supported by numerous studies (Table 4) where flowering plant richness, diversity, and density/abundance have been documented to increase species richness and abundance of bee and butterfly assemblages within a ROW. Native plant species richness has been specifically tied to butterfly species richness and abundance in several studies (e.g., Saarien et al. 2005; Moron et al. 2014). This association seems less important for bee species, with some studies reporting an increase in abundance, but not species richness, of bees with increasing floral richness (Anderson et al. 2017), and some indicating species richness of bees is more closely linked to floral abundance (Hopwood 2008; Hill and Bartomeus 2016).

Floral richness may be closely tied to site productivity and proximity to seed sources (Eldegard et al. 2017), making identification of potential pollinator sites of top priority to minimize management efforts. Numerous approaches may be taken to increase floral species richness and abundance throughout the growing season. However, recommended treatment methods for increasing richness and abundance of flowering species are still conflicting. Mowing annually or biennially has been shown to promote abundant and diverse floral resources, in comparison with less intensive mowing regimes; however, the benefits of repeated mowing may lessen with time (Noordijk et al. 2009). In comparison, Russell et al. (2018) indicate the benefits of IVM increase with time. This effect was especially pronounced in the spring, suggesting the increase in shrub cover at IVM sites provide early season resources not present in other management types, most of which seek to minimize woody species cover. It should be noted that not all needed plant-based resources are flower based, as some pollinators need plants for cover (i.e., shelter and nesting), like woody plants with hollow stems for nesting. For more information on this, please see Steps 5 and 6.

Step 5: Shrubs

Shrubs and compatible trees may be critically important early season sources of flowers or nesting habitat (especially for bees). The most compelling evidence for this is the observational study by Russel et al. (2018), comparing IVM operationally managed sites with annually or biennially mowed sites. They documented sites utilizing IVM significantly differed from mowed sites in number of live and dead woody stems >3 millimeters (mm). The bee assemblages within IVM sites contained a significantly greater abundance of stem and cavity nesting bees, and greater abundance, richness, and diversity of bee species in early spring, with this effect diminishing through the season—suggesting the value of these shrubs as early season resources.

Though apparently beneficial, the ideal proportion of shrubs to forbs for pollinators is not well understood. The literature examined in Table 5 indicates, in comparison with areas containing no shrubs (e.g., tall grass systems mowed annually), areas with some shrubs have a greater abundance of cavity nesting and parasitic bees (Russell et al. 2005; Russell et al. 2018), as well as increased bee species richness and abundance (Moron et al. 2014). They also appear to create unique habitat for some Lepidopteran species (Berg et al. 2011; Berg et al. 2013). However, when examining habitats with various degrees of shrub cover, those with fewer shrubs had greater richness and abundance of pollinator species, for both butterflies (Berg et al. 2013; Komonen et al. 2013) and bees (Moron et al. 2014). Therefore, we estimate the ideal shrub cover may be as high as 30 percent, though it is likely to be lower. A good guideline to follow is shrubs and trees should not be managed to increase to a point significantly excluding other flowering plants (e.g., forbs—defined here as an herbaceous flowering plant that is not grammanoid—grasses, sedges).

Step 6: Nesting Resources

Several studies, most notably Munguira and Thomas (1992), Hopwood (2008), and Moron et al. (2014), indicate pollinators can be limited by nesting resource availability (Table 6). Depending on the focal taxa, what constitutes a nesting resource can vary widely. For example, there are ~4,000 native species of bees in North America, and of these ~30 percent are solitary wood nesters, ~70 percent are solitary ground nesters (Vaughan and Black 2007) and <50 species are social nesters, including bumble bees—who often utilize abandoned rodent nests—and a few species of sweat bees (Halictidae). This means for bees, the presence of bare ground primarily, and to a lesser extent pithy stems, dead wood, and abandoned rodent nests are essential within managed habitat. Hopwood (2008) found availability of bare ground was linked to healthy vegetative assemblages within restored roadsides. Similarly, Russell et al. (2018) found IVM sites had significantly higher bare ground cover values when compared to episodic mowing.

For butterflies, increasing nesting habitat means providing larval food sources (e.g., monarchs and milkweed, Karner blues, and blue lupine). An increase in abundance, species richness, and diversity of Lepidopteran species is correlated with larval host presence (Munguira and Thomas 1992; Moron et al. 2014). Apart from maximizing native plant species richness to provide for a wide array of butterfly species, planting may be required if a target pollinator species is desired. For example, two case studies of successful plantings of blue lupine are documented in reference to pipeline (Lowell and Lounsbury 2002) and powerline ROW management (Smallidge et al. 1996). For more about planting, see Step 7.

Step 7: Select a Treatment Method, Then Act

Based on the literature, there is no support for one type of treatment versus another with reference to pollinators and their habitats. Mowing has been examined in quite a few studies, and has been shown, in the short term, to increase abundance and diversity of flowering plants (Noordijk et al. 2009). However, the benefits of repeated mowing may decrease with time, as a few species begin to dominate the system. Chemical methods have been used to successfully limit the number of undesirable tree species, which have been negatively associated with pollinator species richness and diversity (Bramble et al. 1997; Lensu et al. 2011; Komonen et al. 2013). Additionally, selective use of herbicide through IVM has been observationally associated with increased nesting resources for bees, and suggested to provide an increase in early season floral resources for pollinators (Russell et al. 2018). Restoration of roadside verges through planting of native vegetation has been successfully achieved, to the benefit of bee species richness, abundance of ground nesting bees, and floral species richness and diversity (Hopwood 2008), as well as for butterflies (Ries et al. 2001). However, managers are cautioned when considering planting as a management tactic, except with specific requirements, due to the limited nature of published evidence, as well as to high costs associated with planting.

Mechanical and chemical methods, as well as cultural methods (e.g., planting) have been used to increase pollinators on ROWs through effects of positive changes in habitats. What is most important is whether the treatment can increase and conserve abundance of flowering shrubs and even more importantly, forbs, in addition to providing nesting resources and other life history requirements (e.g., water, shelter, or nesting). Effectiveness of these treatments can be most easily understood through monitoring (see Step 8).

Step 8: Final Step

It is important in VM to monitor resulting habitat conditions and outcomes from a treatment to learn/understand if what was desired and expected was produced. This is a normal, “continuous improvement” / “environmental management system” approach to stewarding ROW systems. This step is critically important for pollinator management. Considering there is a significant pool of published research, with some factors for management well-known (e.g., more flowers/more species of flowers=more pollinators), much about managing ROWs for pollinators is only scantly based in scientific evidence. As more studies are completed, it is critically important to disseminate research considering the above steps, particularly Steps 3, 5, and 7, on landscape, shrub, and treatment method effects, respectively. Additionally, some questions remain to be answered: 1) whether to remove invasive/exotic plants—only one study addressed this topic and indicated bees benefit from foraging on IE plants; however, butterflies did not, and 2) how to standardize sampling methods for pollinator groups. Standardized methods of sampling for diurnal Lepidoptera are well established in the literature (Pollard and Yates 1993); however, this is not true for other taxonomic groups—most notably bees, for which many studies have been conducted with little overlap in sampling methods.

CONCLUSIONS

Finally, it is the Electric Power Research Institute’s (EPRI) intent to continue with a pollinator research program in the next three or more years to address all of the above steps using a series of observational and experimental studies across North America. What is presented above (Steps 1–8) are based on the existing peer reviewed literature and is preliminary only. All steps need to be carefully and critically applied and evaluated with an open mind to learn from experience and research, and adaptive management utilized to improve future management of ROWs for pollinators.

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Note: Additional literature listed in Table 2

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Table 1. Stepwise Guidance for Vegetation Managers

STEP 1 – Site Selection and Definition. A ROW pollinator site should be chosen to produce biologically/ecologically meaningful habitat changes with management via manipulations in vegetation conditions. A minimum site size of three hectares is recommended.

STEP 2 – Rare, Threatened, and Endangered (RTE) Species: Account for RTE Pollinators. Determine if there are protected pollinator species of interest, either because they are known users of a ROW, or because there is interest in promoting possible future use of a site by those species. If none are present, selecting a focal taxon to manage for may be useful.

STEP 3 – Landscape Considerations: "What Can Pollinators Get From the Local Landscape (and What Can ROW Additionally Offer)?" Many pollinators move in and out of ROWs from distances of 100 to more than 1,000 m. A ROW can contribute to pollinators at its fullest if the local landscape—land surrounding the ROW site for up to one km away—does not have food, shelter, and/or nesting elements (i.e., critical habitat), that can be provided on the ROW.

STEP 4 – Floral Resources: Maximize Richness and Abundance of Flowering Plants (flower counts specifically—it seems it is all about the number of different types of flowers!) Throughout the Growing Season. This much is clearly known about floral resources for pollinators via the literature: a pollinator ROW site should have a diverse assemblage of shrubs and forbs that flower throughout the growing season to maximize food resources.

STEP 5 – Shrubs: "Bee" (Be) Attentive—It Seems You Can Have Too Few in Some Places, and Elsewhere Too Many Shrubs on a ROW. Shrubs and compatible trees may be critically important early season sources of flowers or nesting resources (especially for bees), but they should not be managed to the significant exclusion of other flowering plants (e.g., forbs).

STEP 6 – Nesting Resources—Consider the Need for More than Just Food. Pollinators can be limited by nesting resource availability. For bees, this means presence of bare ground primarily, and to a lesser extent, pithy stems, dead wood, and abandoned rodent nests. For butterflies, this often means providing larval host food sources (e.g., monarchs and milkweed), which may require planting if a target species is desired.

STEP 7 – Select a Treatment Method, Then Act. Based on the literature, there is little support for one type of treatment versus another with reference to pollinators and their habitats. What is most important here is whether the treatment increases/conserves abundance of flowering shrubs and, most importantly, forbs.

STEP 8 – Final Step – After Acting: Monitor, Evaluate, and Then Improve. It is important in VM to monitor resulting conditions and outcomes from a treatment to learn if what was desired and expected was produced. While there is a significant pool of published research, with some factors for management known (e.g., more flowers=more pollinators), much about managing ROWs for pollinators is only scantly based on scientific evidence and requires further examination.

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Table 3. "Rare Species" Summary Statements Developed from the Published Literature on Pollinators and Electric Transmission Line ROW VM.

Powerline corridors in Sweden were observed to harbor more rare butterfly species as compared to other land cover types in forest-farmland landscapes (Berg et al. 2011).

Roadside verges, maintaining steppe-like habitat, supported several critically endangered and vulnerable species of bees and wasps. These habitats contained the greatest proportion of specialist bees and red-listed species in comparison to other open anthropogenic habitats (Heneberg et al. 2016).

Powerline clearings provided suitable alternative habitat for grassland species of plants and butterflies, including several rare or threatened species (Lampinen et al. 2018).

Disturbance of a population of Karner blue butterfly during installation of a pipeline in Wisconsin was successfully restored, and likely enhanced, as a result of careful planning, planting, and monitoring throughout the project (Lowell and Lounsbury 2002).

IVM was linked to an increase in parasitic and specialist bee species and bee abundance in comparison with episodic mowing regimes (Russell et al. 2018).

An increase in number of flowering plant species most benefits those species of Lepidoptera that are habitat sensitive compared with more cosmopolitan butterfly species (Ries et al. 2001; Saarien et al. 2015).

Species richness and abundance of butterflies was positively correlated with IRVM and habitat restoration practices on roadside verges. This is especially true for habitat-sensitive species which have more specific habitat requirement needs (Ries et al. 2001).

Blue lupine (*Lupinus perennis*) and associated nectar plants are critical habitat for the endangered federally listed Karner blue butterfly (*Lycaeides melissa samuelis*) on operationally managed powerline corridors in New York (Smallidge et al. 1996).

A globally rare, cleptoparasitic bee—*Epeoloides pilosula*—was thought to be extinct, but a single female was found on a powerline corridor in Connecticut (Wagner and Ascher 2008).

Table 4. "Landscape Considerations" Summary Statements Developed from the Published Literature on Pollinators and Electric Transmission Line ROW VM.

Abundance and diversity of butterflies on powerline corridors in Sweden were not affected by landscape composition (semi-natural pastures, forest-clear cuts), with local habitat appearing to be more important to butterfly assemblage composition than landscape patterns (Berg et al. 2011).

Powerline corridors in Sweden were documented as possible source habitat for butterflies in adjacent/nearby forest roads and pastures (up to 500 m from the powerline corridor) (Berg et al. 2016).

Increasing landscape fragmentation surrounding a clearing was strongly associated with species richness of shade-intolerant plant species on ROWs within a forested setting, suggesting ROW floral assemblage composition can be influenced by surrounding landscape up to two km away (Eldegard et al. 2017).

Hoverfly species richness was positively and significantly related to woodland cover within 200 m of pollinator plots (Moron et al. 2014).

Pollinator forage species richness, evenness, and diversity on ROWs increased significantly with proximity to forested or meadow habitat patches, especially if the distance to the patch was < 50 m (Wrzesien and Denisow 2016).

Heterogeneity of microhabitats can be a driver of a diverse Hymenopteran assemblage in comparison with other habitats providing similar nesting resources (Heneberg et al. 2016).

Species richness of diurnal Lepidopteran species was positively associated with percent forested land within 50 m of the pollinator plot (Saarien et al. 2005; Valtonen et al. 2006).

While species richness of grassland butterflies was significantly related to local environmental variables, species richness of grassland specialist plants, which many grassland butterflies are reliant on, was related to landscape-level variables (Lampinen et al. 2018).

Table 5. "Floral Resources" Summary Statements Developed from the Published Literature on Pollinators And Electric Transmission Line ROW VM.

Richness of plants in flower during sampling was positively correlated with abundance of bees and wasps, but not assemblage composition or species richness (Andersson et al. 2017).

Flowers from a wide variety of plant families were positively associated with several butterfly species on powerline corridors in Sweden (Berg et al. 2013).

Diverse shrub and forb cover on powerline corridors in Pennsylvania, as produced by both mechanical and chemical VM, resulted in diverse and abundant butterfly populations (Bramble et al. 1997).

Floral richness was positively associated with site productivity for shade tolerant and intolerant plant species, suggesting targeting of moderate to high productivity sites for pollinator promotion may be a beneficial strategy (Eldegard et al. 2017).

A wide variety of mechanical and chemical treatment methods can be used to enhance blue lupine (*Lupinus perennis*) plants on powerline corridors in New York, and by association, possibly lead to increased abundance of the federally protected obligate species, Karner blue butterfly (*Lycaeides melissa samuelis*) (Forrester et al. 2005).

Bumblebee richness and abundance increased with increased flower density associated with powerline corridors in Sweden (Hill and Bartomeus 2016).

Greater species richness and abundance of bees was associated with increased floral species richness and abundance across the growing season (Hopwood 2008).

Botanically diverse, structurally heterogeneous, early successional habitats provided by conventionally managed powerline corridors in South Carolina supported diverse butterfly and skipper assemblages (Lanham et al. 2002).

Higher plant species richness was associated with higher butterfly species richness on powerline corridors in Manitoba, Canada (Leston and Koper 2017).

Increases in butterfly species richness and abundance was closely associated with an increase in native plant species richness (Moron et al. 2014).

Annual or biennial mowing of prairie/grassland with hay removal was shown to promote abundant and diverse floral resources in comparison with less intensive mowing regimes or those that did not remove cut material (Noordijk et al. 2009).

Powerline corridors in Maryland were observed to have richer bee assemblages compared to annually mowed tall grass systems, including rare species, due in part to greater availability of floral resources (Russell et al. 2005).

Species abundance and richness for diurnal Lepidoptera species was positively associated with number of flowering plant species; this correlation was greater for those species classified as habitat sensitive (Saarien et al. 2005).

Forb species richness increased by cutting and removing trees from powerline corridors, which was associated with increased bee species richness in Norway (Sydenham et al. 2016).

Table 6. "Shrubs And Other Woody Plants" Summary Statements Developed from the Published Literature on Pollinators And Electric Transmission Line ROW VM.

Dwarf shrubs supported unique butterfly species on powerline corridors in Sweden in comparison to other vegetated land conditions (Berg et al. 2011).

Increased abundance of tall vegetation (~60 percent cover) on powerline corridors in Sweden were correlated with reduced butterfly presence, but some tall vegetation cover (~30 percent) may be associated with higher butterfly presence than found in semi-natural areas with less tall vegetation (Berg et al. 2013).

Shrubs, primarily blackberry (*Rubus allegheniensis*, a sub-shrub via some classifications), were documented as important flowering plants on powerline corridors in Pennsylvania supporting a diversity of butterfly species, particularly in early to mid-summer (Bramble et al. 1997).

An increase in trees (with hand-cutting, a mechanical treatment) on powerline corridors in Pennsylvania decreased species richness and abundance of butterflies (Bramble et al. 1999).

Shrub and tree cutting on powerline corridors in Sweden provided improved habitat for mire-specialists (wetland species) and non-mire butterflies (Komonen et al. 2013).

Tree cover was associated with decreased butterfly richness on mire powerline corridor sites in Finland (Lensu et al. 2011).

Bee species richness and abundance had a negative significant relationship with shrub cover; however, species abundance and richness were found to be greater on railway embankments than in managed meadows. This therefore indicated some level of shrub cover benefits this group (Moron et al. 2014).

Powerline corridors in Maryland had richer bee assemblages as compared to annually mowed tall grass systems, including more cavity-nesting bees and more parasitic bees, likely due to increased availability and diversity of nesting sites (including woody shrub stems) (Russell et al. 2005).

Positive significant increases in bee species abundance and richness, and more balanced proportions within life history groupings, were observed in sites with an abundance of live and dead woody stems, in comparison to sites containing significantly less woody cover. This effect was most pronounced in the spring—possibly related to early floral resource availability—and lessened through the growing season (Russell et al. 2005; Russell et al. 2018).

An increase in abundance of dead, woody stems > three mm in diameter was significantly linked to increased presence of cavity and wood nesting bees, contributing to an increase in overall bee species diversity (Russell et al. 2018).

Blue lupine (*Lupinus perennis*) and associated nectar plants, which are critical habitat for the endangered federally listed Karner blue butterfly (*Lycaeides melissa samuelis*), were associated with low tree and shrub cover on powerline corridors in New York (Smallidge et al. 1996).

Two rare bee species were observed on maleberry shrub (*Lyonia ligustrina*) flowers on operationally-managed powerline corridors in Connecticut (Wagner et al. 2014).

Table 7. "Other Factors" Summary Statements Developed from the Published Literature on Pollinators and Electric Transmission Line ROW VM.

Invasive, Exotic Plants: Higher butterfly species richness on powerline corridors in Manitoba, Canada were associated with greater cover of native plant species and lower cover of invasive exotic plants (Leston and Koper 2016).

Nesting Resources: Percent cover of bare ground was not associated with bee species richness or abundance, though authors reason their method of quantifying bare ground may not have produced an accurate representation for the system, or roadside soil may not have been suitable habitat (Andersson et al. 2017).

Nesting Resources: Percent bare ground was positively associated with ground-nesting bee abundance. Restored roadsides contained significantly more floral species and patches of bare ground, but not floral abundance. Mean bee richness and abundance was significantly greater in restored roadsides in comparison with weedy roadsides across all time periods (Hopwood 2008).

Nesting Resources: Bee and hoverfly abundance, as well as bee species richness, was positive associated with increased availability of nesting habitat, suggesting these taxa are limited by nesting availability near food sources (Moron et al. 2014).

Nesting Resources: Abundance, species richness, and diversity of Lepidoptera species were significantly correlated with larval host presence and abundance (Munguira and Thomas 1992).

Nesting Resources: IVM was associated with increased availability of dead, woody stems and bare ground patches, and correlated to a more even distribution of nesting preferences (cavity/stem vs. ground) among resident bee populations in comparison with episodic mowing (Russell et al. 2018).

Planting: Restoration of roadside verges in an anthropogenic landscape, through planting of native vegetation, was associated with increased bee species richness, appearing to benefit ground nesting bees and increasing floral diversity (Hopwood 2008).

Planting: Blue lupine installations successfully maintained pre-operation presence, germination, and persistence of the Karner blue butterfly larval host plant along a pipeline ROW in Wisconsin, allowing the ROW to continue to support populations of butterfly post-installation (Lowell and Lounsbury 2002).

T**axa-Specific Requirements**: In a comparison of bee, butterfly, and hoverfly abundance and diversity, differing environmental conditions were important for the different groups (i.e., presence of nesting habitat was important for bees; native plant availability for butterflies; and hoverflies were associated with presence of forest within 200 m of the site) (Moron et al. 2014).

Taxa-Specific Requirements: Bee species richness and abundance were closely correlated with percent bare ground (Hopwood 2008; Moron et al. 2014) and floral abundance (Hopwood 2008; Hilll and Bartomeus 2016).

Taxa-Specific Requirements: A difference in the mobility of small bodied bees was observed in relation to other taxa. Due to the central place foraging habits of bees and the shortened flight distance capability of small-bodied bees, they are subject to proximal available resources. Conversely, butterflies and hoverflies can fly long distances throughout their adult life (Moron et al. 2017).

Taxa-Specific Requirements: Diurnal Lepidoptera species richness and abundance was correlated with vegetation height and vegetation richness (Saarien et al. 2005; Valtonen et al. 2006; Valtonen et al. 2007; Berg et al. 2013).

IVM and Environmental Compliance on State, Federal, and Tribal Lands

Christopher N. Watkins
and Lisa L. Young

The well-documented economic and ecological advantages of integrated vegetation management (IVM) have prompted an increasing number of right-of-way (ROW) managers to adopt IVM programs. ROWs in the western U.S. often cross public lands and many IVM control methods require special authorization by land management agencies. Arizona Public Service (APS) recently navigated this regulatory landscape and obtained approval to conduct an IVM program, including chemical, manual, and mechanical control methods on Arizona state, tribal, Bureau of Land Management (BLM), and U.S. Forest Service (USFS) lands. We present this case study as a model for other western U.S. ROW managers who implement IVM programs on public lands. We discuss each agency type individually, and further focus our discussion on three compliance categories: biology, cultural resources, and the National Environmental Policy Act (NEPA). Obtaining these authorizations took varying investments of time and resources, but the benefits of IVM more than justified the cost of compliance.

Keywords: Archaeology, Biology, Herbicide, IVM, National Environmental Policy Act (NEPA), Public Lands.

Environmental Concerns in Rights-of-Way Management
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INTRODUCTION

Arizona Public Service (APS) is Arizona's largest supplier of electricity (Figure 1), serving 2.7 million customers in 11 of the state's 15 counties (APS 2018). The APS Forestry and Special Programs Department (Forestry) manages vegetation along 8,900 kilometers (km) (5,530 miles [mi]) of overhead transmission and sub-transmission lines (69 kilovolts [kV] to 500 kV) and 18,000 km (11,160 mi) of distribution powerline within Arizona and a small portion of New Mexico. Thirty-four percent of APS lines occur on public lands. Of these lines, 47 percent occur on federal lands, 31 percent on state, county, and military lands, and 22 percent on Indian lands (Figure 2). The powerlines cross more than 60 different individual local, state, tribal, and federal land agencies.

Managing right-of-way (ROW) vegetation in Arizona presents multiple challenges. Arizona has high ecological diversity ranging from arid deserts to glaciated peaks (Griffith et al. 2014) (Figure 3 and Figure 4). Access is difficult in much of the state. Growth rates vary from 0.25 centimeter (cm) (0.1 inch [in]) per year for a saguaro cactus (*Carnegiea gigantea*) (National Park Service 2016) to riparian vegetation growing 4.5 m (15 feet [ft]) in a single season. Fire restrictions and wildlife timing restrictions can limit work to only certain times of year. Access to the full range of integrated vegetation management (IVM) control methods is needed to successfully maintain vegetation in these variable conditions.

Description of APS Herbicide Program

APS slowly introduced herbicide into its IVM program in the span of several years. This phased approach has several advantages. Application methods and herbicide blends were adjusted with time to effectively control vegetation while minimizing the amount of herbicide and protecting environmental resources. Herbicide was first applied on private lands, and was later rolled out to agencies with less complex compliance requirements (Arizona state and tribes). By the time federal authorization was sought, APS had an efficient, fully functional herbicide program with several years of success.

APS uses custom herbicide blends (Table 1). Herbicide mixes vary in response to resource-specific concerns (such as an endangered species) and the target vegetation. The mixes in Table 1 are commonly utilized examples, but do not represent the full range of herbicide variation.

Herbicides are applied using targeted spot treatments through three primary methods: foliar, cut-stump, and basal. Foliar application constitutes 75 to 80 percent of APS herbicide treatments. During foliar application, herbicide is sprayed directly to the leaves of target vegetation when the plant is actively growing. Cut-stump application, where herbicide is applied to freshly-cut stumps to prevent re-sprouting, constitutes 15 to 20 percent of herbicide use. During basal treatment, herbicide is sprayed on the lower 30-45 cm (12 to 18 in) of the tree trunk bark along all sides of a standing tree. This method is used on trees less than 15 cm (6 in) in diameter with smooth bark, and

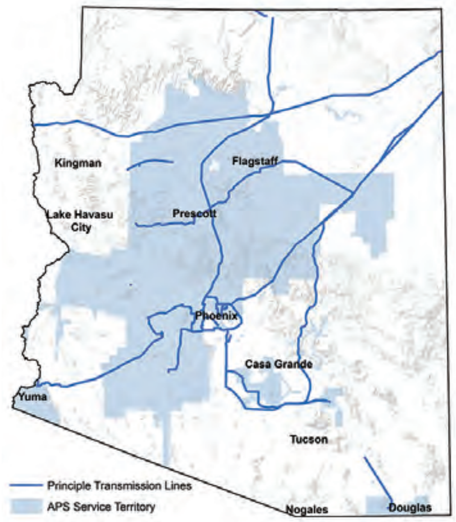

Figure 1. APS Service Territory and Principal Transmission Lines

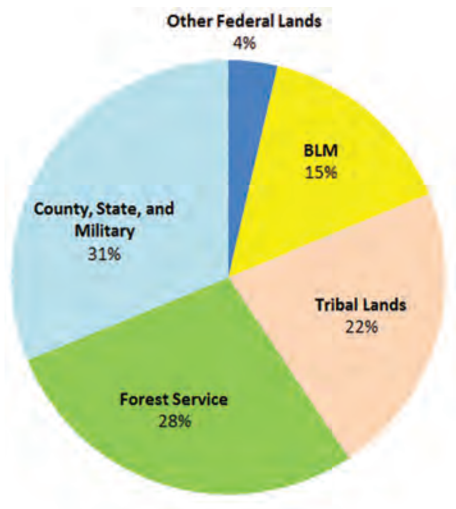

Figure 2. Distribution of APS Powerlines on Public Lands

Figure 3. Saguaro Cacti in APS Transmission ROW (Source: APS)

Figure 4. Mixed Conifer Vegetation in Transmission ROW, Chuska Mountains (Source: APS)

Type	Use Description	Trade Names	Active Ingredient	Carrier	Targeted Volume/ Hectare
Southern Mix	Foliar application in desert vegetation types. Not used in or near riparian, wetland, or aquatic vegetation types.	Garlon 3A	Triclopyr	Thinvert RTU	28-47 liters (3-5 gallons/acre)
		Method 240SL or Milestone	Amincyclopyrachlo r or Aminopyralid		
		Escort XP	Metsulfuron methyl		
Northern Mix	Foliar application in all but desert communities. Not used in or near riparian, wetland, or aquatic vegetation.	Garlon 3A	Triclopyr	Thinvert RTU	28-47 liters (3-5 gallons/ acre)
		Method 240SL or Milestone	Amincyclopyrachlo r or Aminopyralid		
		Arsenal	Imazapyr		
		Escort XP	Metsulfuron methyl		
Wetland Mix	Foliar, cut stump, and basal treatments in riparian, wetland, and aquatic vegetation types.	Rodeo	Glyphosate (aquatic formulation)	Thinvert RTU	28-47 liters (3-5 gallons/ acre)
		Arsenal	Imazapyr (aquatic formulation)		

Table 1. Example Herbicide Blends Used by APS

constitutes less than five percent of herbicide applications. Pre-emergent herbicides are also occasionally used for treatment around distribution poles that include electrical equipment (e.g., transformer, fuse, switch, capacitor bank).

Most herbicide blends used by APS include Thinvert—a combination of paraffinic oil blended with an emulsifier, surfactant, and water to form a thin invert emulsion (fine droplets of water in an outer layer of oil) (Lentz 2014). Herbicide blends including Thinvert are applied at ultra-low volume, reducing transportation costs, and facilitating application in remote areas via all-terrain vehicles (ATVs) (Figure 5) or in backpack sprayers (Figure 6). Thinvert also minimizes spray evaporation and drift, reduces solubility and leaching into groundwater, minimizes runoff, and adheres to the plant, minimizing understory damage (Waldrum Specialties 2002; Odero et al. 2011).

APS uses a closed chain of custody system for shipping, distribution, storage, and mixing of herbicides. Herbicides are mixed at an off-site blending facility and delivered in returnable/reusable product-dedicated storage containers. A closed nozzle system transfers herbicide from storage containers to the ATV and backpack sprayer. Closed chain of custody minimizes spills and ensures the correct concentration is in every container (Goodfellow and Holt 2011).

Environmental Compliance for Herbicide Application on Public Lands

Obtaining authorization to utilize herbicides on some public lands has proved challenging due to varying environmental compliance requirements. APS has been actively seeking herbicide authorization on public lands since 2010. APS can currently apply herbicides within 95 percent of their overhead ROWs on public lands. This case study is specific to public lands in the U.S. We focus our discussion on the State of Arizona;

Figure 5. ATV with Mounted Tanks and Low-Volume Hand-Held Sprayer (Source: Ron Romero, Southwest Ground Control)

Figure 5. Low-Volume Backpack Sprayer (Source: Ron Romero, Southwest Ground Control)

Compliance Type	Agency Category	Compliance Required?	Document Type(s)	Document Length[a]	Time to Complete	Comments
Environmental (NEPA) Compliance	Arizona State	Yes	PGP	3 pages	Few days	Pesticide General Permit required, minimal resource investment
	Tribal Lands	No	-	-	-	NEPA compliance not required
	BLM	Yes	EA	357 pages	3 years	12 resources analyzed
	Forest Service	Yes	EA	326 pages	4 years	12 resources analyzed
Biological Compliance	Arizona State	No	-	-	-	APS has internal review for federally-listed species
	Tribal Lands	Yes & No	BA	Varies	Varies	Biological compliance varies by tribe and from year to year.
	BLM	Yes	BA BO	BA: 225 pages BO: 79 pages	2 years	16 federally-listed species analyzed
	Forest Service	Yes	BA BO BE	BA: 330 pages BO: 139 pages BE: 220 pages	3 years	BA/BO: 21 federally-listed species analyzed BE: 303 species analyzed
Cultural Compliance	Arizona State	No	-	-	-	Herbicide application not an adverse effect
	Tribal Lands	No	-	-	-	Herbicide application not an adverse effect
	BLM	Yes	PA CI MP	PA: 40 pages CI: In prep[b] MP: 10 pages	3 years	Effect of herbicide application unknown, monitoring required.
	Forest Service	Yes	?	Unknown	4 years	Project-specific compliance still in development

[a] Document length listed includes appendices.
[b] A cultural resources overview document was prepared for the project, but the PA requires the BLM to prepare or consult a Class I Overview each time herbicide application is proposed. The page count for these documents will vary based on how extensive herbicide application is during a given cycle and cannot be estimated here.
Key: NEPA = National Environmental Policy Act; EA = Environmental Assessment; BA = Biological Assessment; BO = Biological Opinion; BE: Biological Evaluation; CI = Class I Overview; MIS = Management Indicator Species; MP = Monitoring Plan; PA = Programmatic Agreement; PGP = Pesticide General Permit; TBD = to be determined

Table 2. Environmental Compliance for Herbicide Application by Agency

federally recognized Native American tribes; the Bureau of Land Management (BLM); and the U.S. Forest Service (USFS). Our interactions with Federal agencies will have nationwide relevance. Our experience with state and tribal entities is more localized, but we extrapolate this portion of the case study and provide broadly applicable general expectations.

The herbicide environmental review process on public lands varied by agency. The major resource concerns across all agencies were cultural and biological. The National Environmental Policy Act (NEPA) compliance was required on BLM and USFS lands, and will likely be required for other U.S. Federal agencies. Table 2 provides a summary of the compliance required for herbicide authorization on public lands.

APS manages vegetation along nearly 2,750 km (1,700 mi) of overhead line on Arizona State Land and has been applying herbicide routinely within these ROWs since 2010. The process to obtain approval for herbicide application on Arizona state land was relatively simple. APS submits an operating plan describing the proposed VM activities for annual approval.

The state of Arizona has not required biological, archaeological, or state-level environmental compliance comparable to NEPA for herbicide application. APS conducts an internal review for federally listed species and implements measures to minimize impacts to species. Arizona does have cultural resource laws comparable to the National Historic Preservation Act (NHPA), but the APS herbicide program was determined to not have the potential to adversely affect historic properties and no avoidance or mitigation has been required.

Each U.S. state has varying environmental compliance requirements for herbicide application. Some states have procedures comparable to NEPA, such as the California Environmental Quality Act (CEQA), which would require additional environmental review. Herbicide authorization in states like Arizona without NEPA-comparable legislation will be less time intensive.

Tribal Lands

APS manages vegetation along 1,900 km (1,200 mi) of overhead lines in 14 different Native American communities. Six federally recognized tribes account for the majority of tribal ROWs: Navajo Nation, Hopi Tribe, Salt River Pima-Maricopa Indian Community, Hualapai Tribe, Gila River Indian Community, and Tohono O'Odham Nation.

The process to obtain approval for herbicide application has varied by tribe with a wide range of requirements. Some tribes require telephone or e-mail notifications of upcoming work. Others require a simple form, such as a pesticide use proposal (PUP). Tribes have occasionally required detailed biological compliance. None of the tribes have required NEPA or archaeological compliance.

Even within a given tribe, the herbicide approval process can vary from year to year depending on the designated point of contact. For example, the Navajo Nation required extensive biological compliance in 2013. But in 2018, herbicide application was approved via a phone call after a short conversation. As sovereign nations, federally recognized Native American tribes have a large degree of autonomy in setting environmental standards within their borders (Ranco and Suagee 2007). Utilities seeking herbicide authorization on tribal lands are likely to encounter a wide variety of responses and requirements between tribes and within a tribe from year to year.

BLM

APS manages vegetation along 1,400 km (860 mi) of overhead lines on BLM lands. Herbicide approval was granted in 2017, and application began in 2018. Authorization required a three-year, state-level review addressing NEPA (environmental assessment), biology (ESA), and archaeology (NHPA). This project was completed jointly with another Arizona utility.

BLM decision-making is relatively centralized in state offices (USGAO 1999, 18-20), and analysis including multiple field offices fit well within their organizational structure. The consolidated effort resulted in a project that covered 4,600 hectares (ha) (11,500 acres) of BLM lands in Arizona and analyzed multiple resources. This streamlined effort produced a consistent review of resources and mitigations. In addition to the one-time environmental review for herbicide application, APS continues to coordinate with BLM on a project specific basis including annual PUPs and post-work pesticide application records.

NEPA Compliance

APS contracted with a consulting firm to assist the BLM in preparing an EA for the use of herbicides on BLM lands (BLM 2017a). The No Action Alternative investigated existing VM practices and the Proposed Action included management of vegetation with herbicide. The EA analyzed soils, water resources, water quality, wetlands, riparian areas, noxious and invasive weeds, general vegetation, general fish and wildlife, federally listed species, BLM sensitive species, migratory birds, fire and fuel management, special management areas, and cultural resources. The EA took almost three years to complete and is a little more than 357 pages in length (including appendices).

This EA tiered to two existing Programmatic Environmental Impact Statements (PEISs) (BLM 2007, 2016) that analyzed the impacts of 21 herbicide active ingredients. The APS EA only included herbicides that had been analyzed in these documents. ROW managers attempting to incorporate other active ingredients will likely be required to have an EIS prepared.

The BLM EA resulted in a Finding of No Significant Impact (FONSI) (BLM 2017b). The FONSI was issued pursuant to a number of standard operating procedures and mitigation measures such as: follow all label instructions, use the best blend and application method for the environment and conditions, minimize active ingredient concentration, and employ licensed applicators following closed chain of custody methods.

Biological Compliance

BLM biological compliance analyzed threatened and endangered (T&E) plant and wildlife species through consultation with U.S. Fish and Wildlife Service (USFWS) (BLM 2017c; USFWS 2017), including 12 wildlife species and four plant species. It was determined that the proposed action would adversely affect three species and their critical habitats: the southwestern willow flycatcher (*Empidonax traillii extimus*), yellow-billed cuckoo (*Coccyzus americanus*), and the acuna cactus (*Echinomastus erectocentrus var. acunensis*). No incidental take was issued by the USFWS for these species. The biological compliance was a long and difficult project that included a 225-page biological assessment, 79-page biological opinion, and almost two years of effort.

While the EA only analyzed herbicide application, the biological compliance analyzed all aspects of our IVM program, including vegetation inspections, manual, mechanical, and herbicide control of vegetation, and post-work auditing. Prior to this, when proposed VM could affect federally listed species, BLM consulted with the USFWS on a project-specific basis.

Project-level biological compliance is no longer necessary.

The biological compliance included conservation measures to minimize effects to federally listed species, such as only using low toxicity herbicides within federally listed species habitat; timing restrictions around breeding areas; limiting riparian access to roads open to the public; crew training; pre-work surveys of federally listed plants; and avoidance buffers. The small, federally listed plants are not target species as part of the APS IVM program. The plant conservation measures ensure that the species are not inadvertently exposed to herbicide, which could cause plant stress or even death.

Cultural Compliance

The BLM could not determine whether the proposed herbicide application would have a negative impact on archaeological sites. This uncertainty prompted a programmatic agreement (PA) between the BLM, APS, and the Arizona State Historic Preservation Office (BLM 2017d). Several Native American tribes agreed to participate in the PA as concurring parties. The tribes were consulted on the terms of the PA, received annual reports, and provided feedback through ongoing consultation. The primary agency concern was the periodic driving of all-terrain vehicles (ATVs) overland within the ROW as part of herbicide application. Specifically, ATVs could drive over and damage surface archaeological features or cause erosion that could impact sub-surface deposits or features.

The PA signatories agreed that ATVs would only be used for herbicide application in ROWs that had been previously surveyed for cultural resources. When APS proposes herbicide application, the BLM prepares or consults a Class I Overview, a summary of the previous archaeological research in the target areas (BLM 2004, 2.21.A.1). ATVs can be driven overland to apply herbicides in ROWs that are covered by adequate archaeological survey as documented in the Class I Overview. If no adequate surveys exist, APS will hire a permitted consultant to conduct the survey.

The potential impacts of driving ATVs through sites will be assessed through long-term monitoring. Monitors will document conditions at a sample of sites before and after herbicide application using ATVs within a long period of time. If adverse effects are observed, the agency will take action to avoid or mitigate impacts in consultation with the PA signatories. If no adverse effects are observed, the necessity of the monitoring may be reevaluated. In the interim, APS will be permitted to drive ATVs through archaeological sites without avoidance or mitigation measures. APS will fund the execution of the PA (including monitoring) by paying internal staff, hiring consultants, or reimbursing BLM expenses through cost recovery.

Cultural compliance took three years to complete. A 41-page preliminary cultural resource overview document was prepared as part of this project (Bustoz 2016). The PA is 40 pages long, and the monitoring plan is 10 pages long. Cycle-specific Class I Overviews will be submitted prior to herbicide application. Tribal consultation was initiated with NEPA. None of the tribes expressed concerns about the herbicide program. APS has applied herbicide on tribal lands for several years, and the absence of concerns in consultation is likely attributable to tribal familiarity with the herbicide program. Tribal consultation will continue through the long-term monitoring plan.

USFS

APS manages vegetation along 2,600 km (1,600 mi) of overhead lines on USFS. USFS herbicide approval required a multi-year environmental review that included NEPA, biological, and cultural resource compliance. Herbicide approval was granted in early 2019, and we anticipate beginning application later this year.

APS manages vegetation within five forests in USFS Region 3. APS and the Forests agreed to conduct a single environmental review at the regional level. The USFS is a decentralized organization with decision-making authority focused at the Forest-level (USGAO 1999, 35). Conducting this environmental review at the regional level presented complications, but all parties agreed that it was the best course of action. The consolidated effort resulted in a complex project that covered 5,500 ha (13,500 acres) of USFS lands in Arizona and analyzed multiple resources. This streamlined effort was partially successful in generating consistent review of resources and resource mitigations. In addition to the one-time environmental review, APS continues to coordinate with each forest on a project-specific basis including annual PUPs, updated Corridor Management Plans, and post-work pesticide application records.

NEPA Compliance

Initially, APS, BLM, and USFS considered consolidating the project into a single NEPA effort with BLM as the lead agency. This approach was rejected as the increased complexity would have caused significant delays. The scale of the project was already large, and combining agencies would have included five forests, seven BLM field offices, and almost 10,100 ha (25,000 acres) of federal ROW. Differing interpretations of the same NEPA regulations between agencies would have made project decision-making very difficult.

APS contracted with an environmental consultant to assist the Forest Service in preparing an EA (USFS 2019). The EA also analyzed two alternatives: the No Action Alternative and the Proposed Action. The EA analyzed soils, water resources, water quality, wetlands, riparian areas, floodplains, general vegetation, federally listed species, USFS-sensitive species, migratory birds, eagles, management indicator species (MIS), fire and fuel management, human health and safety, and cultural resources. The EA took four years and the finished product is 326 pages in length (including appendices).

The USFS EA resulted in finding of no significant impact (FONSI) (USFS 2019). The FONSI was issued pursuant to a number of standard operating procedures and mitigation measures such as: follow all label instructions, use the best blend and application method for the environment and conditions, minimize active ingredient concentration, and employ licensed applicators following closed chain-of-custody methods.

Biological Compliance

Biological compliance for threatened and endangered plants and wildlife resulted in a biological assessment (USFS 2018a) and consultation with USFWS (USFWS 2019). Nineteen wildlife species and two plant species were analyzed. It was determined that the proposed action would likely adversely affect five species and their critical habitats: Mexican spotted owl (*Strix occidentalis lucida*), southwestern willow flycatcher (*Epidonax traillii extimus*), yellow-billed cuckoo (*Coccyzus americanus*), narrow-headed gartersnake (*Thamnophis rufipunctatus*), and northern Mexican gartersnake (*Thamnophis eques megalops*). The biological opinion issued incidental take for three of these species: the Mexican spotted owl, narrow-headed gartersnake, and northern Mexican gartersnake. USFS biological compliance was a difficult, three-year project that included lengthy documents (Table 2).

As with BLM, the USFS biological compliance analyzed more than just herbicide application. The proposed action included all aspects of IVM and ongoing line maintenance. This approach eliminates the need for individual project level biological approvals. Similar compliance was completed in 2008 (USFS 2008). This recent biological compliance project renews the previous compliance and authorizes herbicide application. Conservation measures and herbicide design features for USFS biological compliance were very similar to the BLM project. This was by design in an effort to keep conservation efforts consistent regardless of federal agency.

In addition to compliance for federally listed species, biological compliance was completed for Forest Service sensitive species, migratory birds, management indicator species (MIS), and eagles (USFS 2018b). USFS compliance was much more arduous than the BLM, requiring a specialist report separate from the EA that analyzed 26 sensitive wildlife species, 41 sensitive plant species, two eagles (bald and golden eagles), 74 migratory birds, and 17 MIS.

Cultural Compliance

The U.S. government has recommended that federal agencies integrate the NEPA and NHPA compliance processes (Council on Environmental Quality et al. 2013). After pursuing this strategy for four years, the USFS separated the cultural and NEPA compliance processes and required project-specific cultural compliance at the forest level. As cited in the EA, NHPA compliance will proceed under the terms of a previously implemented programmatic agreement. This agreement leaves several compliance options open, some of which include ongoing tribal consultation. We are currently working to implement the first year of cultural compliance, but the details of this process will be specific to each forest and have yet to be determined. Conducting project-specific cultural compliance at the forest level may result in a variety of mitigation requirements.

Tribal consultation was initiated with NEPA. None of the tribes initially expressed concerns about herbicide, but objections were later raised during project-level consultation. Specifically, one tribe has requested that no herbicides be applied within the boundaries of any archaeological site. If the USFS implements this request, herbicide application would be restricted to ROWs that have been surveyed for cultural resources and archaeological sites would be flagged for avoidance prior to application. Consultation is ongoing.

Recent Federal Developments

Recent policy and legislative developments suggest that federal herbicide authorizations are likely to be less resource intensive moving forward. In 2016, the Edison Electric Institute, the Utility Arborist Association (UAA), the Department of the Interior (including the BLM), the USFS, and the Environmental Protection Agency signed a memorandum of understanding (MOU) regarding VM in powerline ROWs (BLM-MOU-WO-301-2016-07). The MOU facilitated cooperation between signatories to implement "cost-effective and environmentally sound VM plans, procedures, and practices… that will reduce adverse environmental and cultural impacts while enhancing the ability of utilities to provide uninterrupted electrical service to customers and address public safety." The MOU encourages submission of annual VM plans, endorsed IVM (including herbicide) as a best management practice (BMP), and suggested that agencies and proponents pursue programmatic environmental analyses when authorizing utility vegetation maintenance projects.

The Consolidated Appropriations Act 2018 (2018 Omnibus) amended the Federal Land Policy and Management Act of 1976 to include several points relevant to utility VM (UVM). The 2016 MOU is referenced in the law, and several aspects of this memorandum have been incorporated into the legislation. Federal land management agencies were directed to "issue and periodically update guidance to ensure that provisions are appropriately developed and implemented for UVM." This guidance is intended to minimize the need for case-by-case approvals and to provide for prompt and timely review of requests to conduct VM activities. The BLM has begun issuing guidance in response to the 2016 MOU and the 2018 Omnibus legislation, including Instruction Memorandum 2018-070. Unlike the MOU, this guidance includes specific details that local BLM officials have been directed to implement. This guidance is so recent that we have yet to see how it will be implemented at the State and Field Office level, but the outlook for herbicide application is promising.

In Instruction Memorandum 2018-070 (issued July 19, 2018), the BLM identifies three possible scenarios for vegetation maintenance activities based on ROW grant details. First, vegetation maintenance activities that are explicitly described and authorized in ROW grants do not require BLM notification unless specified in the ROW grant. Second, vegetation maintenance activities that are authorized in an ROW grant that require BLM notification do not require the BLM to complete additional NEPA analysis, site surveys, or issue a separate decision. Third, vegetation maintenance activities not authorized by ROW grants and require a separate BLM notification may require an associated NEPA analysis and site survey, but these situations are expected to be rare. The memo acknowledges that utility companies will still be required to comply with all applicable laws, regulations, policies, and Executive Orders. It remains to be seen whether NEPA or other environmental compliance will be required ahead of herbicide application with ROW grants that include herbicide provisions. ROW managers interested in applying herbicide on BLM lands are encouraged to review the Instruction Memo, their ROW grants, and follow-up with local BLM representatives.

Though not issued in response to the 2016 MOU or the 2018 Omnibus, a Department of the Interior memorandum dated August 6, 2018 ("Additional Direction for Implementing Secretary's Order 3355 Regarding Environmental Assessments") is relevant to ROW managers seeking authorization for herbicide application. The majority of EAs prepared by Interior should be 10-15 pages long and should be completed within three months. A more detailed EA may occasionally be justified, but these documents should be less than 75 pages (excluding appendices) and the review of these more lengthy documents should be concluded within 180 calendar days of commencement. Exceeding these requires consultation with high-level agency representatives. This memorandum should prevent agencies within the Department of the Interior from requiring lengthy EAs associated with herbicide projects.

CONCLUSIONS

Environmental regulations vary by state. An evaluation of each state's laws is beyond the scope of this case study, but utilities are likely to be familiar with the applicable statutes in their service territories. In states with less restrictive environmental compliance laws, obtaining authorization to apply herbicide on state land will require a minimal investment of time and resources. The Arizona example described in this case study illustrates this level of compliance. Other states, such as California, have more stringent environmental regulations. Obtaining state land authorization in these jurisdictions is likely to be expensive and time consuming.

Federally recognized Native American tribes have significant autonomy in determining environmental policy within reservation boundaries. As with states, utilities are likely to encounter a wide variety of compliance requirements between tribes. We have found variation in herbicide compliance requirements from cycle to cycle within the same tribe. We attribute some of this variation to staff turnover. Overall, the tribal requirements in this case study tended to be less resource-intensive than federal agencies.

Environmental review for herbicide application on federal lands (BLM and USFS) took several years and significant resources. As discussed above, the BLM is a relatively centralized agency. We anticipate that other utilities could apply large portions of the template we created (including the EA) to BLM lands in their service territories. In the relatively decentralized USFS, we anticipate that less of the template will be applicable on other forests. The federal compliance process for herbicide application within utility ROWs will be, at most, comparable to this case study. Recent legislative and policy developments suggest movement towards utility vegetation maintenance compliance processes that are less resource intensive.

We have found that the benefits of incorporating herbicide into IVM programs on public lands outweigh environmental compliance costs. This is particularly true on state and tribal lands, where compliance tends to be less complex. APS is one of the first utilities to seek system-wide herbicide authorization on public lands west of the Mississippi. The benefits of a full IVM program incorporating herbicide application are well documented (Nowak 2002, 2014a, 2014b; Yahner 2004; Nowak and Ballard 2005), and we anticipate that other utilities in the western U.S. will soon follow suit. Our case study provides a model for other interested ROW managers to follow as they navigate their regulatory landscape—particularly with federal agencies such as the BLM and USFS.

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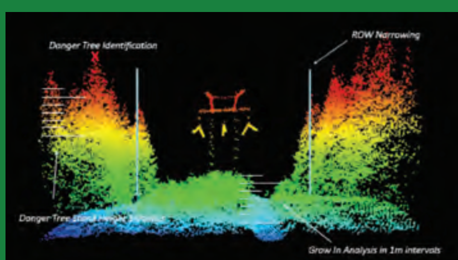
Leveraging Modeling & Predictive Analytics to Optimize VM for ROWs

Mike Hutchinson

Keywords: Data Analytics, Evaluation, Technology.

The Remsoft Spatial Planning System (Woodstock) is a mathematical optimization modeling platform being used globally to forecast and schedule long-term sustainable forest management plans. The same biological and ecological concepts and logic used to model forest dynamics are applicable to vegetation management (VM), and can be used to forecast the impacts of today's VM decisions on the future condition of the ROWs being managed. Remsoft collaborated with John Goodfellow to create a VM model that incorporates industry-accepted VM treatment regimes, treatment costs, and regrowth patterns in northeastern North America to demonstrate the long-term (20+ years) financial impacts of various VM planning approaches. The model is structured as a template, facilitating simple data input and calibration for customized enterprise use throughout the VM industry. The platform utilizes linear programming to produce globally optimal treatment schedules (prescriptive analytics) governed by user-defined constraints (e.g., network reliability thresholds and annual budget limits), and provides scenario generation functionality to facilitate trade-off analysis. User-defined outputs are used to create tabular, graphic, and spatial reports and performance indicators. Although useful for ROW managers using any combination of VM tactics, the VM model is particularly useful for companies interested in exploring the shift toward preventative VM using modern integrated VM (IVM) approaches. With the capability to forecast growth, cost, and reliability metrics into the future, VM managers can create long-term IVM schedules and produce defensible budget requests by demonstrating the ROI of upfront investment into IVM.

We are actively seeking willing utility companies to pilot this model and collaborate to author a subsequent case study. The intention is to co-present the case study with a participating company, or with John Goodfellow.



Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Optimization is the process of making a design, system, or decision as fully effective as possible, and to determine the best "compromise," given multiple objectives and constraints. Some utilities are currently trying to optimize treatment cycles, with mid-cycle hot-spotting, condition-based maintenance, and managing by smaller protected segments instead of circuits. All of this is in an attempt to address different tree growth rates and to reduce costs.

Predictive Analytics is optimization taken several steps further to include mathematics, statistical algorithms, and computer analyses, to arrive at the mathematically optimum solution. Literally, it is performing studies to anticipate a future state using a model to enhance schedule and budget. Software companies have adapted existing analytical tools to assist the utility vegetation management (UVM) planning function. The model uses a utilities' real world asset situation, objectives, constraints, and costs to calculate the optimum schedule and budgets to reach a desired objective or confirm that a utility's budget is insufficient.

Optimization modeling…

- …is an "asset management" strategy with a systematic approach that applies economics, engineering, and business principles.
- …improves decision-making by using factual data as it is performance based, defendable, and transparent.
- …is a "planning exercise" with multiple levels that a utility forester performs in software "external" to geographic information systems (GIS).
- …combined with predictive analytics, is an ideal fit for asset-intensive utilities.

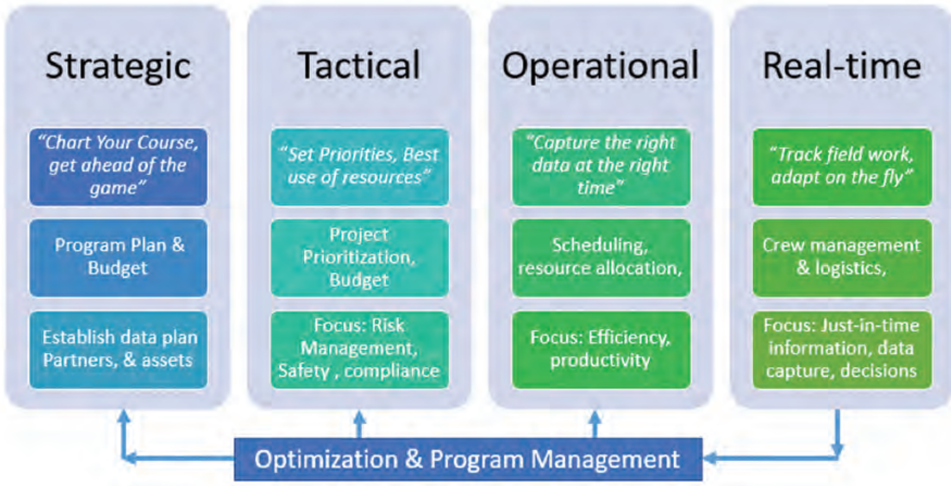


Figure 1. General Topics Within Each Level of Hierarchal Planning.

Optimization modeling has three levels of detail:

1. **Strategic:** Long-term plans (10–30 years), capital forecasting + external issues, objectives, and constraints.
2. **Tactical:** Mid-term plans (one to five years), capital forecasting + contractor capacity.
3. **Operational:** Seasonal production + crew scheduling, and budgeting.

Remsoft uses its modeling software and extensive forestry background to work with partners and utility companies to establish long-term right-of-way (ROW) sustainability plans (Strategic), optimized budget/risk scenarios (Tactical), and establish operational plans to address real life challenges, such as disease tree management (Operational).

Strategic Planning Project

Challenge

In 1999, Nova Scotia Power Inc. (NSPI) initiated a thorough review of its transmission VM program. It was clear, prior to the process, that a full inventory of the system was essential for implementing a preventative program that would allow for an approach leading to "right treatments" being applied to the "right places" at the "right time" for ensuring that vegetation control methods were implemented according to stated thresholds.

A new strategy was adopted to achieve predictive management at the system level. Previous management tended to be implemented on a line cycle, even though it was condition based on a span-by-span basis, and therefore was reactive to what was inventoried the previous year. The decision for a system-level predictive approach led to the development of a vegetation inventory system (VIS) having three main components:

1) Collection of a GIS-based inventory of the entire system
2) Development of a computerized model for predicting growth of the inventory within both untreated and treated regimes
3) Modification of a forest optimization computerized model to reflect the management options of a powerline and developing long-term ROW management strategies.

An optimization model developed by Remsoft and designed for the commercial forestry industry was considered, since modeling forest dynamics at the stand level would be very similar to how the transmission corridors would be categorized—vegetation units would be managed very similar to forest stands and therefore allow for similar scenarios. The Woodstock Optimization Model developed by Remsoft was designed to accommodate forest dynamics and, as such would provide the utility an ability to do three things:

1) Anticipate change in the ROW vegetation with time, both unmanaged and managed, given prescriptive treatments (mow, herbicide application, hand-cutting)
2) Understand the amount of management in accordance with change
3) Alter the change through a sequence of treatments to reach a preferred outcome. NSPI wanted to develop ROWs that were comprised of stable ecosystems, thereby creating a sustainable ROW floor.

The major question that needed to be answered was: "Can I foresee the changes that will occur across the landscape and be there with the right intervention at the right time?" After researching *Woodstock*, NSPI believed the modeling program, with some simple modifications, could give them the answer.

METHODS

Optimization Modeling

The management horizon associated with powerline ROWs is much shorter than that of commercial forest management. On ROWs, a five to 10-year horizon is ideal, whereas in commercial forestry, rotation lengths can be as long as 80 years.

Optimization models provide schedules to demonstrate the comparative advantages of early intervention (vegetation control treatments), versus late intervention. By incorporating growth rates, tree metrics, and productivity data as model inputs, ROW conditions a pathway for the conversion from high-cost vegetation cover to a state of more compatible vegetation species, the impact of limiting herbicide use, the impact of a limited budget, and what ultimately is required on a budgetary and prescriptive treatment basis for the preferred outcome.

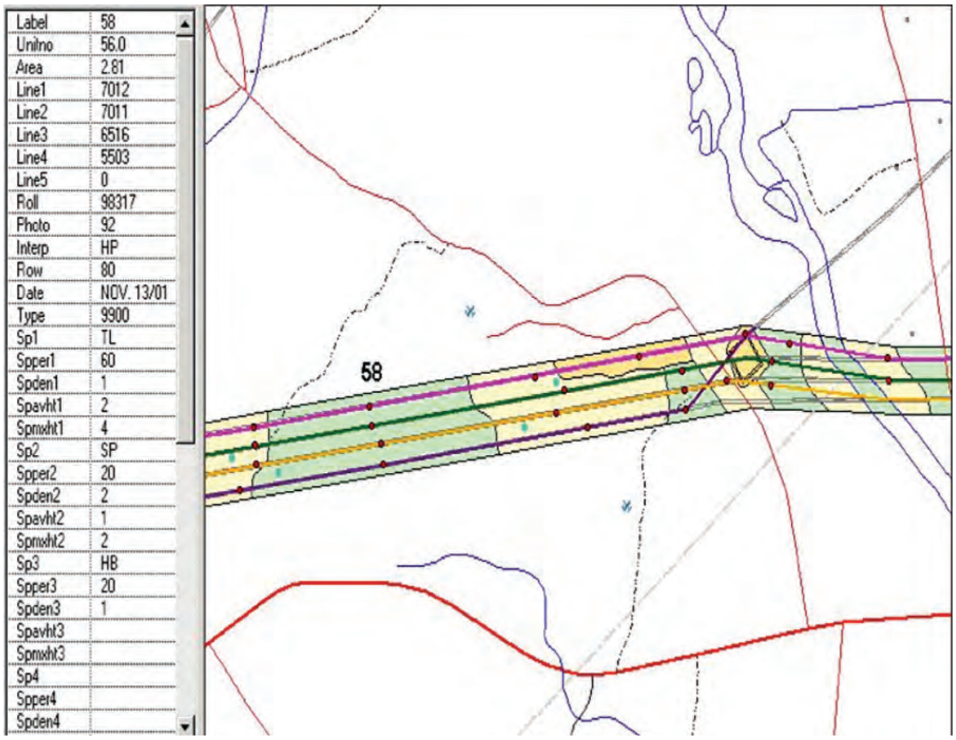


Figure 2. Vegetation units by polygon establish the cover types on a Transmission ROW

NSPI Model Inputs

There are three elements of modeling forest dynamics, whether you are talking about large commercial forestry stands or *vegetation units* along narrow transmission line corridors, that are essential for understanding a cause-effect relationship leading to optimization: **species composition, vegetation development stage**, and **land capability.**

Species Composition

To comply with the species composition component of the model, a "Cover Type" classification system for the entire length of the ROWs was developed. These Cover Types were collected from foot patrols and aerial photos from 1999–2003 and included classifications by: Hardwood (Intolerant vs Tolerant), Softwood, Shrubs, and Herbaceous plants covers.

Developmental Stage

In addition to mapping polygons by Cover Type during the vegetation inspection, NSPI foresters also determined what "Development Stage" each Cover Type was currently in by recording Height, Stocking (density) and Competing Vegetation.

NSPI foresters collected the height of the most dominant tree species and developed a growth model to predict the "Average Height" for dominant species, the "Maximum Height" for the dominant species on the "best" land capability (LC), and the "Worst Height" of the fastest growing tree on "best" LC found on the ROW.

Stocking calculations were based upon a percent cover of the three dominant species including species compatible to ROWs. Stocking was primarily used for changes in cover type when the development pattern is modified as well as to establish sustainability.

Land Capability

For each Cover Type and Developmental Stage, the LC was assessed to determine how the cover type would change with time, providing the predictability vital to the strategy. Foresters recorded the growth increment, topography, and limiting factors (ex. drainage).

Applying the Model to NSPI

Growth modeling software was used to perform the task of predicting growth across the Cover Types to manage the change in the ROW with time regarding: change in height (how the type was changing), change in stocking (when it was eligible for treatment), and change in species composition (what was the response to treatment).

Woodstock uses linear programming to determine the best schedule of management intervention for accomplishing any performance indicator. The constraints used in this model were "Budget," "No Tree More Than 1.82 Meters (m) (Six Feet [ft]) In Height," and to "Maximize Foliar Herbicide Applications."

In the model, treatment thresholds and descriptor tables are used to set treatment eligibility, treatment response, and cost. More than 20 assumptions were utilized to set rules for the growth and optimization models to predict how vegetation is altered and then placed back on the height curve.

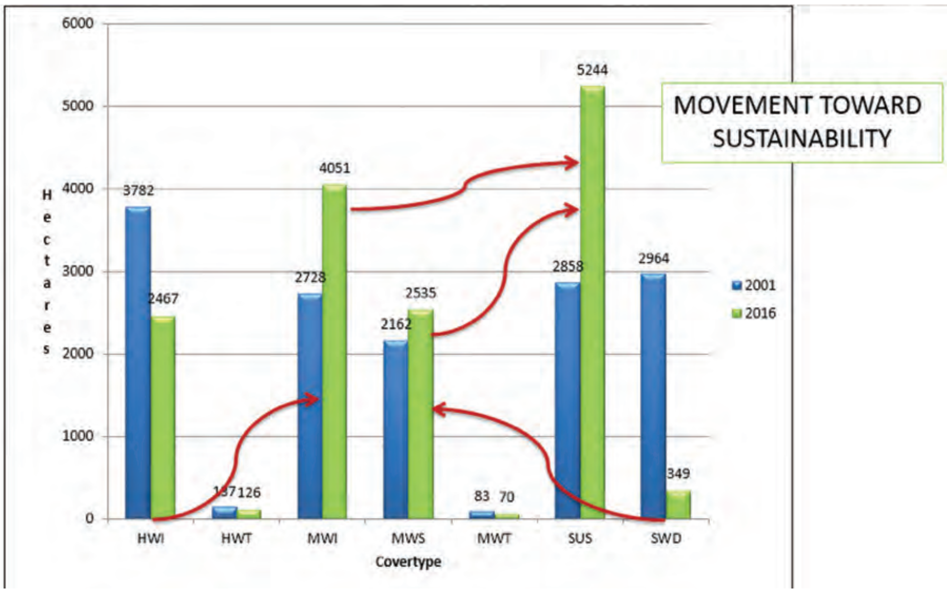


Table 1. Changes in Vegetation Cover Types from 2001 to 2016 showing a large increase in the Sustainable Vegetation Cover Type in 2016.

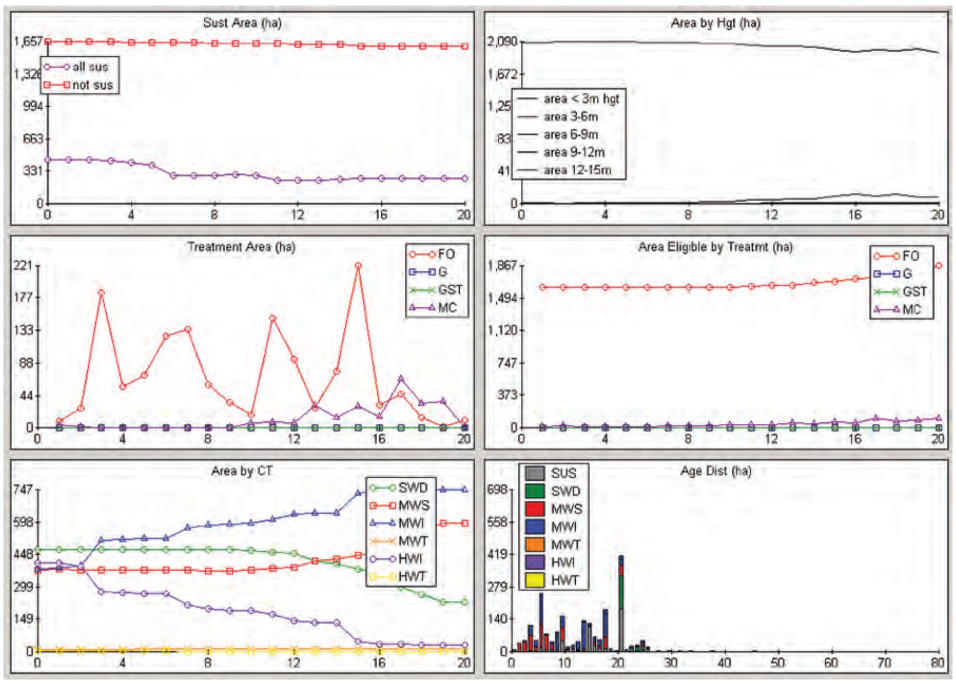


Figure 3. Optimal plan for all trees less than 2.74 m (9 ft) threshold for foliar application of herbicides

RESULTS

Using Woodstock to provide budgets, treatment prescriptions, and the timing of these prescriptions, NSPI was able to convert thousands of hectares (ha) from tall-growing tree species to a "Sustainable" cover type. The table below (Table 3) illustrates the changes with time (2001–2016) in the cover type conversions.

The results of Remsoft's *Woodstock* model led the NSPI Forestry Manager to develop a theory: integrated VM (IVM) leads to greater complexity, and the greater the ecological change, the lower cost with time. Additionally, the model has shown that the absence of trees on a ROW leads to ecological stability and a sustainable vegetation environment, which allows for a decrease in management frequency, which then leads to lower costs.

Since one of the management goals was to reduce the cost of maintaining the ROW as time passes, and his use of IVM could be accurately modeled by *Woodstock*, the timing, cost, and effect of his gradual transition of the ROW from fast-growing species to a sustainable habitat could be accurately predicted (Figure 3) to ensure he had funding and resources available to meet his goal.

LiDAR Data to Fuel Future Vegetation Cover Type Revitalization and Optimization Modeling

Optimization requires an ability to predict change to direct a path to the preferred outcome. A comprehensive inventory is required to maximize the model's full value and provide accurate results. Fortunately, NSPI had collected a detailed inventory from 1999–2003 using foot patrol and aerial photos. For its next optimization model run, NSPI plans to use data from a LiDAR project designed to vitalize the cover types across the transmission system and recalibrate the inventory associated with those cover types. This LiDAR data will be used to reassess the polygon attributes and merge vegetation units from past treatments. It will also be used to assess the prediction strength of growth and treatment response in addition to developing new assumptions and simulations to discover new pathways to sustainability. With the increased focus on maximizing the wildlife benefits through the ROW Stewardship Program, NSPI can add pollinators, birds, and other wildlife species habitat requirements into the optimization model.

Electric utilities are traditionally very conservative in their use of funds, whether they are an investor-owned utility beholden to stockholders, or a member-owned utility owned by the people they serve. Utilities do not want to spend money on management actions that are not essential. While Optimization Modeling is a strategic tool, it offers the utility the advantage of testing predictable outcomes leading to improved decision-making. While modeling does not eliminate the need to inspect transmission ROWs for liability issues, overall management of the system is greatly enhanced to ensure treatment of the ROW is carried out efficiently, and depending on the goal, leading to lower costs with time.

Tactical Planning Project

The primary focus of VM activities at NB Power is on reducing outages caused by the encroachment of vegetation, primarily via cutting, thinning, pruning, and mowing operations. Encroachment is the result of tree fall-in, branches sagging from above, and vegetation growing up from below.

Risk vs. Budget Management—NB Power

During this project, a 10-year model of a subsection of NB Power's bulk transmission lines was developed using available LiDAR data, and treatment scenarios were generated, focusing on reducing the risk of a power outage due to vegetation encroachment. This model enables NB Power to improve the reliability of the power network by reducing the risk of outages both in the near term and in the future. This model also allows NB Power to understand, communicate, and defend the budgetary and capacity requirements necessary to achieve corporate reliability objectives. Further, this model is formulated to be scalable—allowing further transmission lines to be added for management with limited data preparation and model formulation required.

Network risk in the project model includes both the probability of failure (PoF) due to vegetation and the consequence of that failure (CoF). PoF is formulated by leveraging light detection and ranging (LiDAR) data and growth and yield (G&Y) information to define the risk of vegetation grow-in and fall-in on a per-span basis. CoF classifications were defined by NB Power based on line number.

Challenge

Some of the requirement challenges with optimization modeling include:

- A commitment to data sourcing and processing data into what is essential for modeling.
- Ideally capturing changes in annual tree conditions due to cutting or storms, using LIDAR or other means.
- Potentially a full-time analyst to remain familiar with modeling functions, to gather and manage input data, and to perform detailed queries or analyses.

The overall objective of the model is to reduce the risk of power interruption due to vegetation across the entire planning horizon for both ROW and danger tree zones, accounting for budget, risks, business rules, accessibility, etc. while employing growth and yield data for future consideration.

The Optimization Model creates Budget & Schedule for management forecasting and planning:

- Right set of activities at the right time
- Targeting areas of greatest risk (condition-based planning)
- Targeting areas where it can have optimum impact
- Considering budget, resource, and organizational goals

While delivering:

- Spatial & tabular schedules of VM activities
- Trade-off and impact analysis of different scenarios/decisions
- Dashboard visibility into scenario outcomes and data
- Repeatability and transparency of decision-making

Methods

The core elements of Remsoft's model are:

- The transmission network is characterized by polygons that run the length of the lines under review. Each span, which is defined as the distance between structures, contains two types of polygons. The middle polygons of the span represent the ROW zone, and are flanked on either side by polygons that represents danger tree zones (DTZ). By including DTZS within the model, the risk of an interruption due to a potential danger tree falling in and striking the line can be represented and treated according to model objectives and constraints.

- Contains data related to location, cost, probability of failure, consequence of failure, and other important attributes.
- Considers all possible treatment activities and uses mathematical optimization to come up with the right schedule of activities at the right cost.

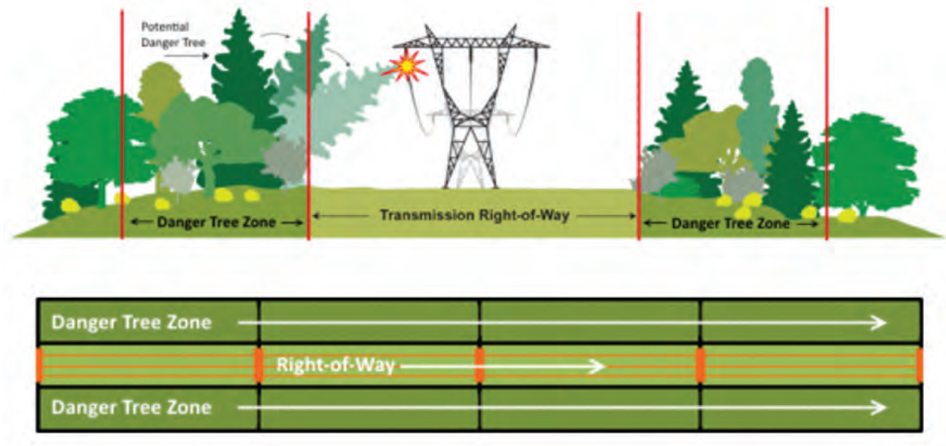


Figure 4. DTZs and the Transmission ROW

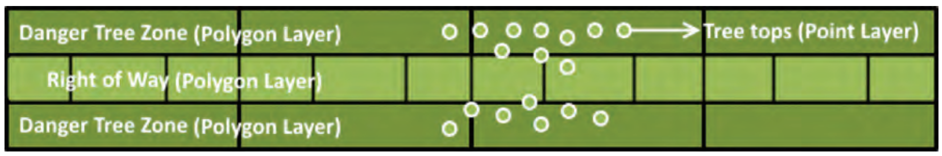


Figure 5. An Example of Top View of Polygon and Point Layers

Classification:

The model (Figure 4) is divided into two zones: ROW and Danger Tree

Each span typically has two DTZ polygons and three ROW polygons. The two DTZ polygons represent the areas to the left and right of the ROW, while the three ROW polygons represent the areas closest to each structure of the span and the area at the midpoint. By dividing the ROW polygons in this manner, the model can more effectively address vegetation in the area closest to the point of maximum sag.

Both polygon types have different widths, lengths, and VM options. DTZ polygons are typically 30 m in width, while the ROW polygons are 45 m in width. All collected data—be it from LiDAR or from NB Power GIS data sources—is assigned to each of these polygons as attribute information. Formulated data is contained in the model structure but can still be view on a per polygon basis.

Vegetation Types

Within the model, vegetation is characterized as either a layer or as an individual tree, where a tree is defined as vegetation more than four m in height. One difference between these two types is that a layer of vegetation can only occur within the ROW zone, while a tree can exist in either zone. Another difference is that a vegetation layer is represented by a height attribute assigned to a ROW polygon, while a tree is represented by a geometric point, and then aggregated into a risk attribute assigned to both the ROW and DTZ polygons.

For example, if LiDAR detects vegetation at a maximum height of 2.3 m within a ROW polygon, this is considered to be a layer of vegetation, and the max height attribute of the polygon (N_MAX) is assigned the value 2.3. However, if LiDAR detects vegetation at a height of 7.6 m within a ROW polygon, this is considered to be a tree, and as such its canopy is removed from the max vegetation height analysis for that polygon and any other overlapping polygons, and its tree top is captured as a single point.

Risk

An overall risk assessment is assigned to each polygon in either the ROW or DTZ. This is formulated from the Criticality of the Line (CoF) and the Probability of Failure (PoF). This risk index is the primary driver for treatment activity within the model.

Probability of Failure

PoF is a calculated value that is determined by the height of vegetation (tree or layer) within a polygon. For vegetation layers in the ROW, it is determined by the distance between the max height of vegetation and the maximum sag of the line. For danger trees in both zones, it is determined by the distance between the top of the tree and the DTZ criticality plane. More information about the DTZ criticality plane is provided below.

There are five categories of PoF:

- *Extreme (5)*: Vegetation is grown into the line or high enough to fall and strike the line
- *Critical (4)*: Vegetation is at a height that presents significant risk
- *High (3)*: Vegetation is close to critical level and could soon pose a threat
- *Medium (2)*: Vegetation is at a safe level

- *Low (1)*: Vegetation is at a safe level and is not expected pose a threat for at least four years

While the category names are the same across all lines in the model, the height ranges for each category varies.

The following illustration demonstrates the categorization of risk posed by vegetation growing in or under the line. In this case, the vegetation is characterized as "medium" risk.

DTZ Criticality Plane

To understand the classification of the risk presented by danger trees, it is important to understand the DTZ Criticality Plane. As the vegetation grows, its classification changes based on the distance to the DTZ criticality plane or the max sag of the line.

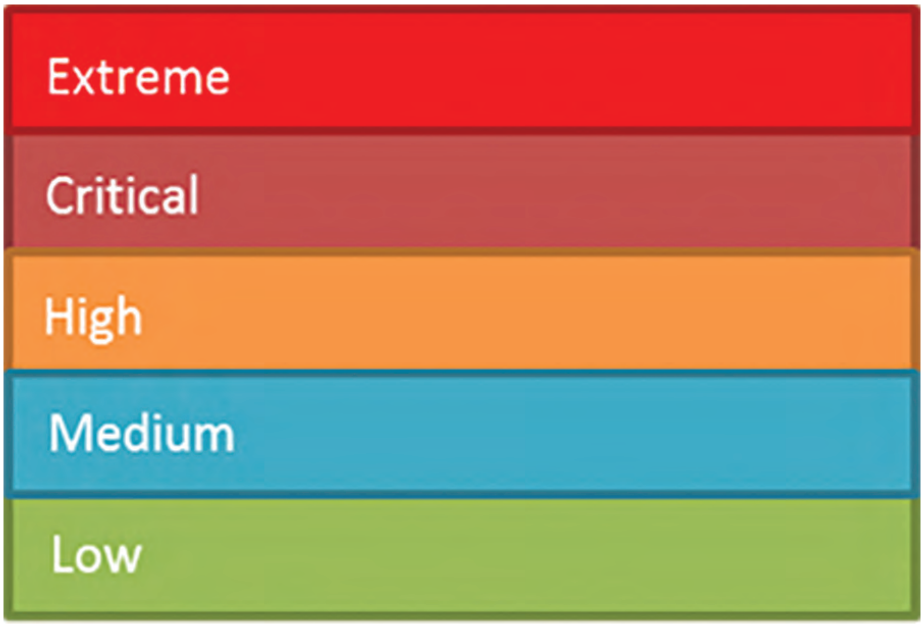


Figure 6. Risk Classifications

Risk Index	345kV	230kV	138kV	69kV
Extreme	>0	>0	>0	>0
Critical	< 0 and ≥ -1.5m	< 0 and ≥ -1.5m	< 0 and ≥ -1m	< 0 and ≥ -0.5m
High	< -1.5 and ≥ -3m	< -1.5 and ≥ -3m	< -1 and ≥ -2m	< -0.5 and ≥ -1m
Medium	< -3 and ≥ -5m	< -3 and ≥ -5m	< -2 and ≥ -3m	< -1 and ≥ -2m
Low	< -5 and ≥ -7m	< -5 and ≥ -7m		

Table 2. Distance between the height of the vegetation and the DTZ Criticality Plane or Max Sag.

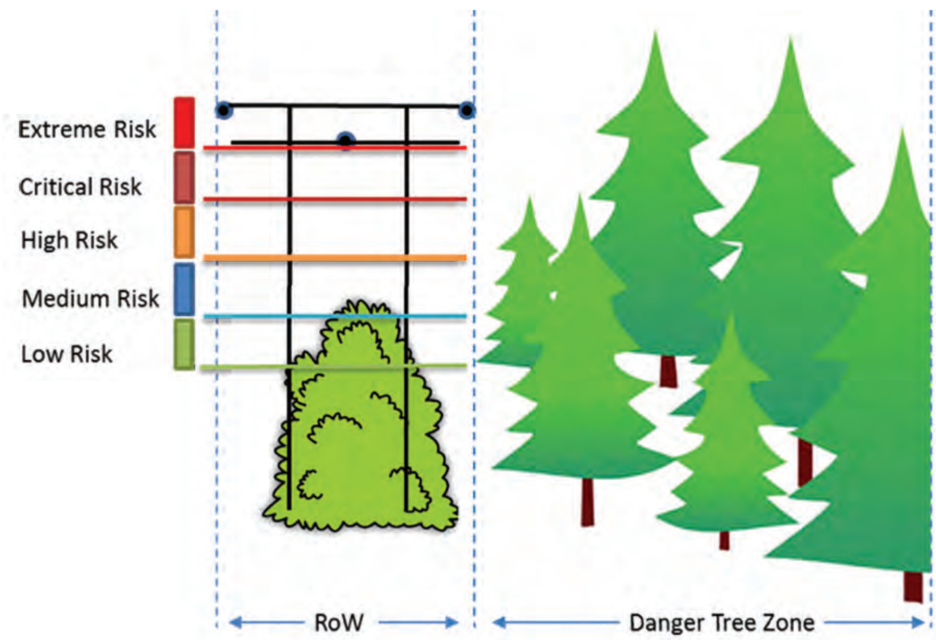


Figure 7. ROW Characterization of Risk

The DTZ Criticality Plane is a 3D surface derived from LiDAR analysis (performed by Leading Edge Geomatics). This plane represents the surface past which vegetation presents a risk to the line. For example, in Figure 8 above, there are three trees that are higher than the criticality plane. Each one of these trees would hit the line if it fell in the right direction.

This plane provides the base for categorizing the risk posed by the fall-in of danger trees in the same way that max sag provides the base for the risk posed by the grow-in of vegetation layers. As trees grow up to and beyond the DTZ criticality plane, the classification of the danger tree and its associated DTZ polygon changes, subject to the distance categories defined in Figure 8 above.

In Figure 9, there are three trees classed as critical; therefore, the PoF for the associated DTZ span polygon would also be "critical."

Overall Risk Assessment

There are two main components to the overall risk assessment for a span: its category and its value. These two components are illustrated in Figure 10 below. A span polygon is assigned a risk category and value dependent on its PoF classification and its CoF ranking. For example, if a ROW polygon is a PoF classification of Critical (4) and a CoF ranking of 5, its overall risk assessment category is "extreme" and its value is 36.

The model requires both the risk category and value to prioritize treatment activity across the network. In general, the model will try to treat spans with the highest risk category first. Then, for all spans within a particular risk category, the model will select the span with the highest value for treatment before a span with a lower. For example, if the model has to choose between two critical spans, one with a value of 26 and the other with a value of 31, it will opt to treat the span with a value of 31 first, despite the fact that the span with a value of 26 is also critical.

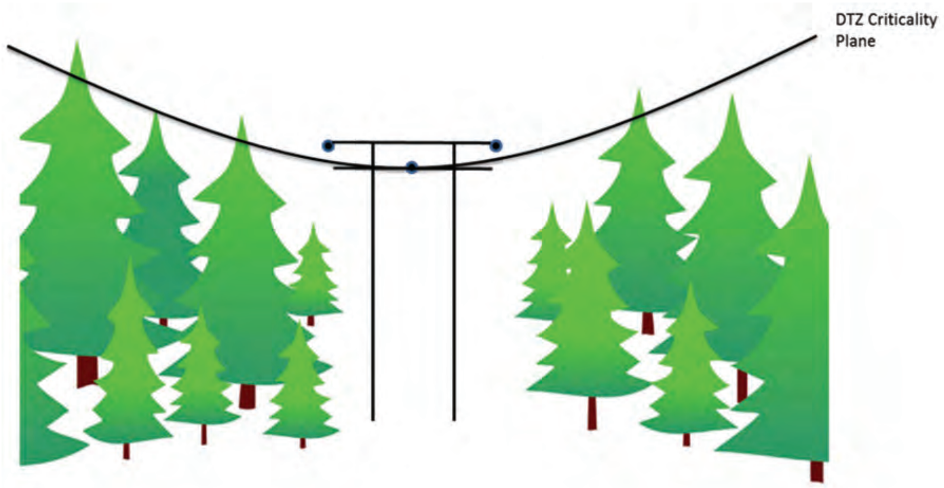


Figure 8. DTZ Criticality Plane

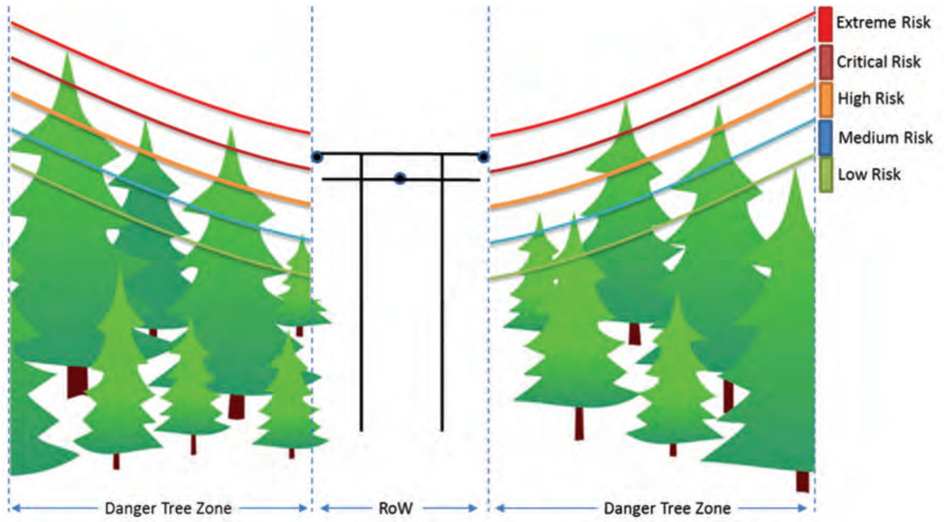


Figure 9.

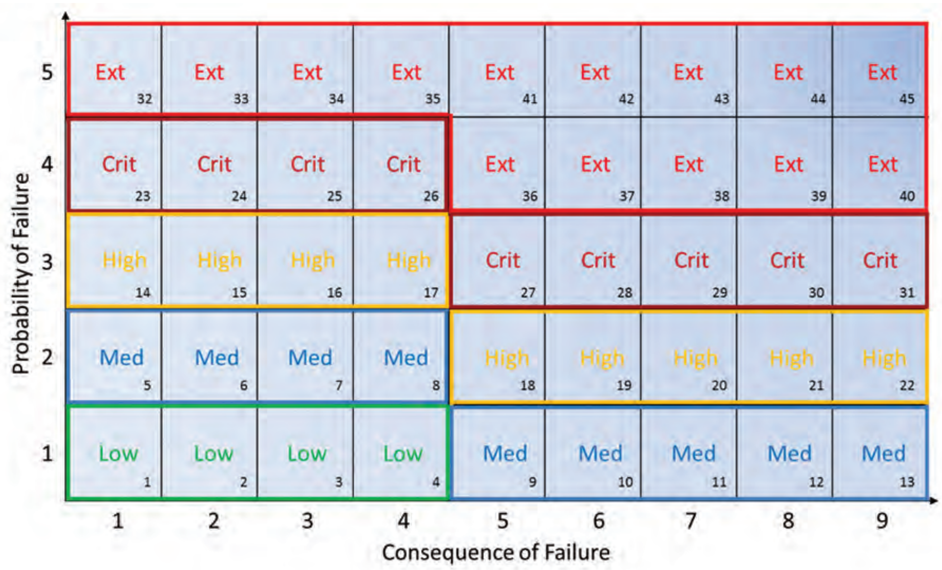


Figure 10. Overall Risk Assessment Categories and Values

The Model contains a series of actions, objectives, and constraints to characterize the data, business rules, and business constraints. Example:

- Contains attribute data from LiDAR, GIS, and other data sources
    - Applies a single treatment (cut) that represents an aggregation of vegetation treatment
    - Mowing ROW, and hand-cutting of danger trees
    - Activity costs are aggregated into a single average price per hectare
- Growth and Yield data
    - A site class index based on numerous environmental parameters was applied to each polygon in the model

Results

The NB Power model was built to run six scenarios.

NBPT

– No constraints

Do_Nothing

– No Actions are allowed to occur

– Spans age and risk grows

Status_Quo

– Even flow of remove vegetation from ROW at ±30 percent

– Goal: let the number of Extreme spans be zero from 2016 onwards

– Goal: let the number of Critical spans be zero from 2016 onwards

– Current budget (at ~10 percent to represent the amount of transmission line within the model).

Unlimited

– Even flow of remove vegetation from ROW at ±30 percent

– Goal: let the number of Extreme spans be zero from 2016 onwards

– Goal: let the number of Critical spans be zero from 2016 onwards

– Unlimited budget

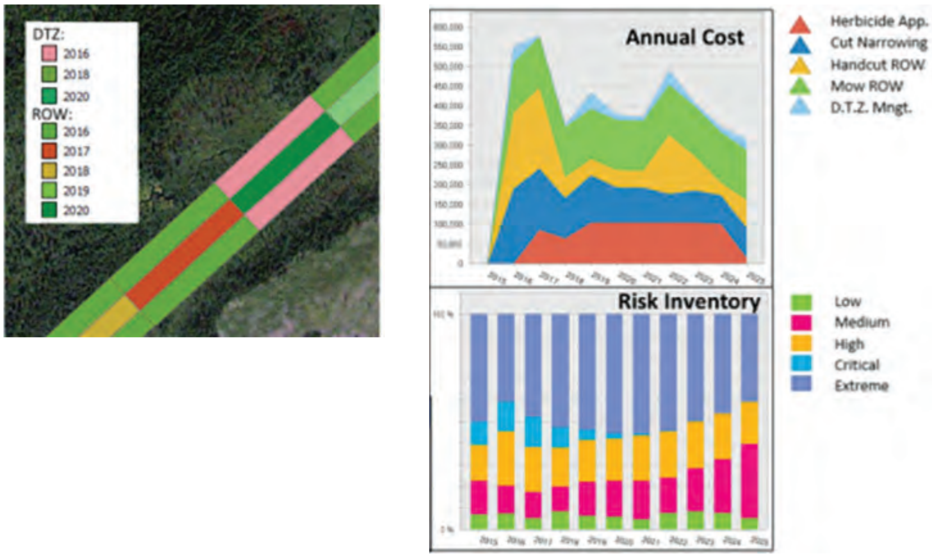


Figure 11 & 12. Status Quo Budget

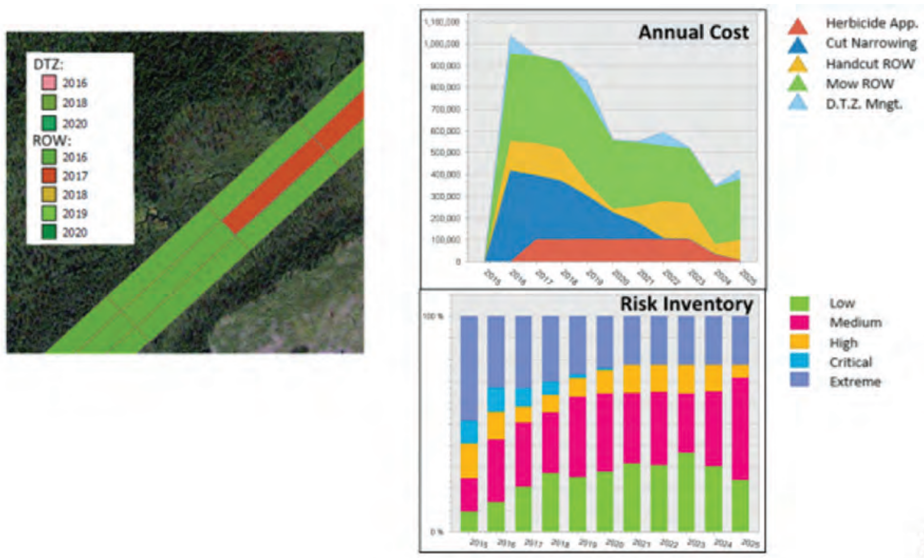


Figure 13. Preferred $XYZ/Year Mowing Program

Preferred_250

– Even flow of remove vegetation from ROW at ±30 percent

– Goal: let the number of Extreme spans be zero from 2016 onwards

– Goal: let the number of Critical spans be zero from 2016 onwards

– Increase the mowing budget (there are many more mowing spans than hand-cut spans) and increase DTZ budget

Preferred_400

– Even flow of remove vegetation from ROW at ±30 percent

– Goal: let the number of Extreme spans be zero from 2016 onwards

– Goal: let the number of Critical spans be zero from 2016 onwards

– Increase the mowing budget (there are many more mowing spans than hand-cut spans) and increase DTZ budget

Preferred_550

– Even flow of remove vegetation from ROW at ±30 percent

– Goal: let the number of Extreme spans be zero from 2016 onwards

– Goal: let the number of Critical

spans be zero from 2016 onwards

- Increase the mowing budget (there are many more mowing spans than hand-cut spans) and increase DTZ budget:

AllActions

- Even flow of remove vegetation from ROW at ±30 percent
- Goal: let the number of Extreme spans be zero from 2016 onwards
- Goal: let the number of Critical spans be zero from 2016 onwards
- Increase the number of actions the model is allowed to complete on the DTZ. There are now combinations such as EEC, where the first and second time the model cuts the DTZ, it removes only the extremes, then from the third time onwards it removes extremes *and* critical trees.
- Budget the same as 4_Preferred_400:

NB Power used the model to assess scenarios and select the optimized plans for implementation Figures 11 and 12).

Summary

In the summary, this project provided an optimized model of a subsection of NB Power's transmission lines that enables:

- Budget planning
    - o determines the right amount of spend.
    - o defensible and transparent
- Treatment scheduling
    - o determines the appropriate treatment activity
    - o considers all treatments and areas to balance activity against risk

This provides a clear and defensible path to help NB Power get on top of network risk and also increases the value of the LiDAR spend by leveraging the investment across multiple planning.

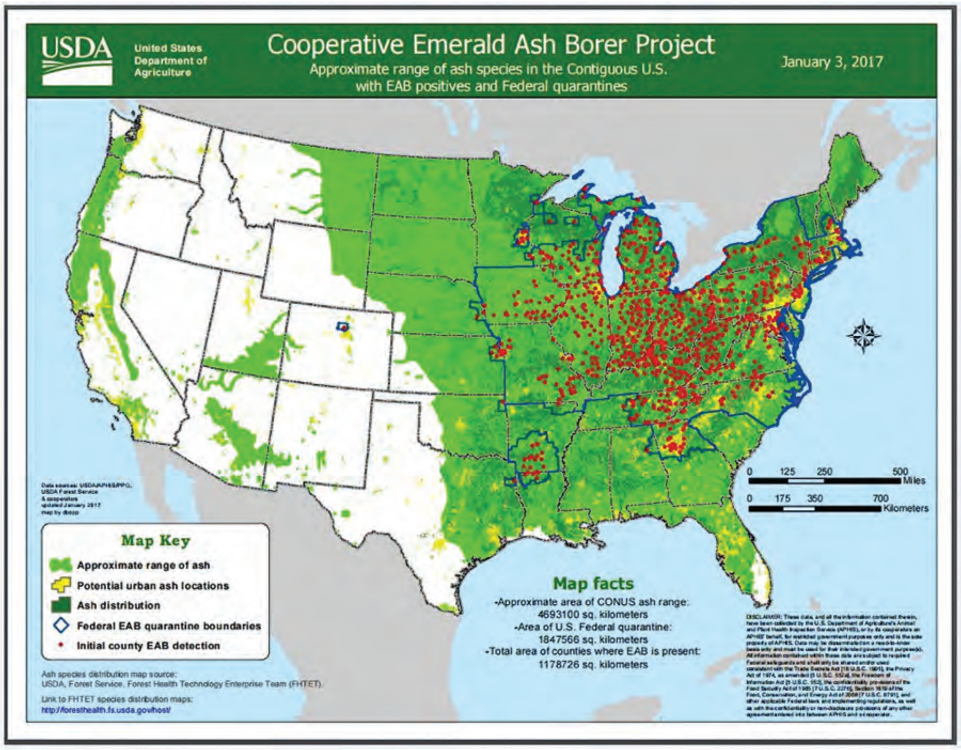


Figure 14. Emerald Ash Borer Map

Key Learnings: Project

1. LiDAR, combined with a modeling platform, can provide the current and future state view of NB Power's network necessary to support strategic planning decisions.
2. The formulated model can be scaled to support the entire NB Power network, and can be adjusted to support sensitivity analysis and to adapt to changing.
3. Millions of danger trees can be modeled and grown across the time horizon to support current and future network risk assessment.

Three Key Learnings: Model

While deeper analysis of the model and results should be performed by NB Power staff, there are some key learnings. Specifically:

1. The current status quo budget does not achieve the network risk goals defined by NB Power over the horizon of the model.
2. An incremental increase in the mowing budget decreases overall network risk, this is highlighted by the fact that, at the status quo budget, the model maximizes the mowing budget every year.
3. Narrowing is an issue (41 percent of spans show some sort of narrowing) that can be addressed with detection of narrowed ROWs and scheduling of the appropriate treatment.

Operational Planning Project

Challenge

Like many areas throughout North America, the Midwest has been hit with the Emerald Ash Borer outbreak, killing ash trees in both forest and urban environments. The increased number of dead and dying ash trees poses a serious threat to the reliability of transmission and distribution (T&D) networks. To manage this new risk, Duke Energy invested in LiDAR and hyperspectral imagery (HSI) to capture a spatial inventory of the trees on and adjacent to their ROWs, identifying more than 20,000 ash trees that need to be removed with a limited time frame and budget. The difficulty they face is scheduling the right equipment and crew to the right tree(s) (at the right time) to maximize budget while minimizing risk, all while trying to organize individual trees into a logical schedule of work packages for their contractors. There is a need to balance operational feasibility, risk, budget, and deadlines.

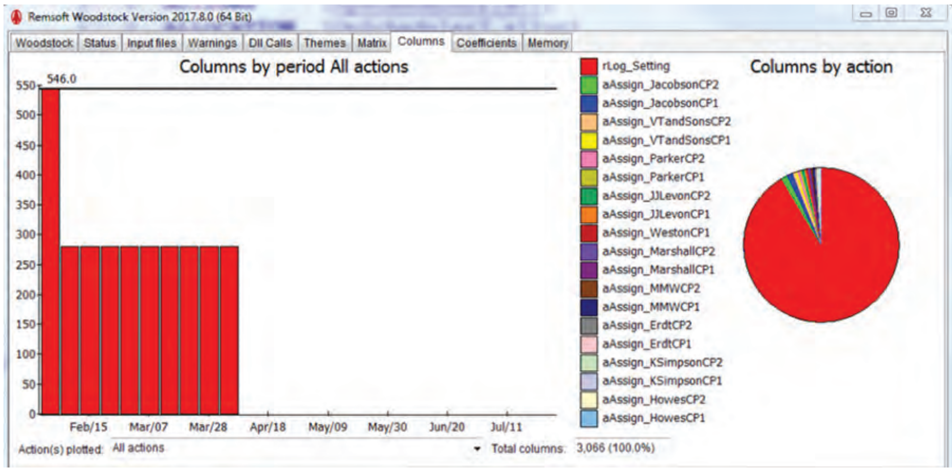


Figure 15. Decision matrix being created during the optimization process

Methods

An optimization model is being designed to consume the LiDAR and HSI data to establish a baseline vegetation inventory. Spatial layers including roads, streams, access points, slope, and pole location will be overlaid to create a complex representation of the network.

The attributes of this spatial data will have operating rules, equipment capability, and productivity rates assigned, and will be used as decision variables by the model to:

a. Define the order trees should be removed in based on their relative risk to network reliability

b. Assign the best equipment for each tree removal

c. Cluster individual trees into logical work packages and assign appropriate crews

d. Prioritize work packages into a mathematically optimized, spatial schedule.

The output schedule will then be run through a heuristics tool to evaluate potential scenarios to re-cluster work packages based on a range of spatial constraints. The range of schedule outcomes will be analyzed for impact on operating cost and total network risk using a comparative analysis tool within the model.

Each model run will output user-defined performance indicators that will include:

- Vegetation Inventory Forecasts
- Crew Utilization Metrics
- Budget Forecasts
- Reliability and Risk Scorecards

Summary

This project is in progress and hopefully delivered by 2018. The delivery of the solution will include user training, output reports, and a defined schedule to remove each of the 20,000+ ash trees by 2023.

CONCLUSIONS

The reality for utility vegetation managers is that trees grow at different rates and are a risk at different times and locations along powerlines. In addition, trees are cut annually and storm damage results in unplanned cutting—all of which are continuous events that undermine the ability to plan and budget. Electric utilities looking for a "better" VM strategy might consider adding optimization modeling to the planning process. The process of modeling starts a utility down the path of gathering appropriate data, defining risks, and setting objectives. It provides a formal framework to gather relevant data and increase data value.

The advantages of optimization modeling include:

- Provides a complete network perspective within a longer planning horizon than one cycle.
- Allows utilities to leverage greater value out of their LIDAR investment.
- Combines simulation and mathematical optimization through predictive models that can generate optimal network management strategies that maximize an objective while meeting business constraints. It does this by generating multi-year treatment schedules.
- Allows utilities to stop annual planning based on "addressing the worst circuits first."
- Takes pole-to-pole span attribute data, adds tree proximity data to define probability of failure, customer data to define consequence of failure, plus all costs, constraints, objectives, and project risks into the future.

- Modeling simulates tree growth and proximity to wires with time so that risk of tree contact can be calculated across the network through time.
- Optimization can plan and schedule at any level of "granularity," from long-term strategy, to multi-year operational, to annual, or site-specific tactical planning of maintenance crews.
- Modeling allows utilities to project outcomes of current strategies and allows budget justification to senior management.
- Automates multi-year scheduling and annual plan updates based on actual cut vs. planned cut.
- Allows utilities to determine budget levels for desired reliability levels, by circuit or network, as time passes.
- Allows utilities to test the impact of cutting a line ahead of schedule for political purposes, demonstrating the long-term negative impact to budget *or* the impact of injecting additional funding to potentially reduce long-term budget trends.
- Allows utilities to compare the value of treatment costs across the system.
- Modeling uses treatment costs to forecast future budgets and can be configured to calculate Net Present Value (NPV) financial comparison of treatment options.
- Allows budget forecasting across any time horizon with automatic updates to future budgets based on imposed changes.
- Potential for reduced costs with time OR increase production with the same budget.
- Provides extensive maps, charts, and data to allow drill-down to data source that helps to understand data significance.

AUTHOR PROFILE

Mike Hutchinson

Mike Hutchinson is the VM Account Manager with Remsoft, an Eastern Canadian software solution company. Based out of New Brunswick, Canada, Hutchinson has an in-depth understanding of Remsoft's optimization technology and works in a project initiation capacity with utility and forestry companies on strategic, tactical, and operational planning projects. Prior to joining Remsoft, Hutchinson had two decades of experience in the forest industry in a variety of operational and planning roles.

Linking Herbicide Dissipation in the Field to Laboratory Toxicity Testing to Improve Soil Ecological Risk Assessment Along Transmission ROWS

Amy Jimmo,
Katherine Stewart, and
Steven Siciliano

Utility companies operating in northern Canada are tasked with finding efficient, effective, and socially acceptable strategies for managing vegetation on transmission rights-of-way (ROWs). At northern latitudes, herbicides have not been widely used as a vegetation management (VM) tool and the dissipation and toxicity of herbicides is poorly understood. Therefore, the dissipation of Garlon™ XRT (triclopyr) and Arsenal® Powerline (imazapyr) in soils was assessed for one year following a low-volume foliar application. Dissipation rates were faster for triclopyr (time to 50 percent of the initial concentration [DT_{50}]; of 1 day after treatment [DAT]) compared with imazapyr (DT_{50} of 16 DAT). Dissipation rates were linked to laboratory toxicity tests on three soil invertebrates (*Enchytreaus crypticus, Folsmia candida*, and *Oppia nitens*) using ROW soils. Maximum application rates (75.5 milligrams [mg] triclopyr kg dw^{-1} and 12 mg imazapyr kg dw-1) were below the effective concentration at 25 percent (EC_{25}) for all soil invertebrates. Weight of evidence (WOE) and toxic exposure ratios (TER) were used to characterize the risks associated with herbicide application. The WOE approach demonstrated that potential environmental concentrations were below the effective concentration at 10 percent (EC_{10}). The TER approach identified no ecological risk to soil organisms through imazapyr application, but identified some risk with triclopyr application.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Utility companies operating in northern Canada are tasked with finding efficient, effective, and socially acceptable strategies for managing woody vegetation on remote transmission rights-of-way (ROWs). Mechanical methods currently used are effective in the short term, but they result in the rapid regeneration of target species, including *Salix* spp. and *Populus* spp., shortening maintenance cycles (Berkowitz et al. 1995). Therefore, vegetation managers have been assessing herbicide application techniques for control of woody vegetation found along utility ROWs in the Yukon Territory. However, herbicides as a vegetation management (VM) tool have not been widely employed in the Yukon Territory, resulting in a data gap surrounding the potential impacts Garlon® XRT (triclopyr) and Arsenal® Powerline (imazapyr) in northern environments.

The dissipation of triclopyr and imazapyr in northern climates typically occurs throughout the growing season, with little to no dissipation occurring in the winter months when the soil is frozen, resulting in longer residence times than observed in more temperate climates. In Alaska, triclopyr residues in soil were detected two years after application via broadcast foliar (Mulkey 1990; Newton et al. 2008; Barnes et al. 2009). Imazapyr is known to have a longer residence time in soils when compared to triclopyr (Senseman 2007; Douglass et al. 2016). In Alaska, imazapyr residues were found 456 days after treatment (DAT) (Newton et al. 2008). While both triclopyr and imazapyr residues persist long after application, it is unknown if the residue concentrations present a risk to the soil ecological community.

Soil invertebrates are fundamental to the functioning of soil ecosystems, providing services such as maintenance of soil structure, decomposition of organic matter, and nutrient cycling. Introduction of chemicals, such as herbicides, may change the abundance and diversity of soil invertebrates, resulting in diminished capacity of the ecosystem (Novais et al. 2010; Römbke 2014). Therefore, it is important to understand the impact of herbicides on soil invertebrates that are representative to areas where herbicides may be applied. Three invertebrates important to ecosystem function in Canada, including enchytraeids (*Enchytreaus crypticus*), collembola (*Folsomia candida*), and Oribatid mites (*Oppia nitens*), are often used as representative species in standardized toxicity assessments (Römbke et al. 2006; Princz et al. 2010, 2012). To protect soils in the Yukon Territory and the ecosystem services that they provide, the invertebrate species mentioned above should be included in an assessment of the risks prior to herbicide applications along northern utility rights-of-way (ROWs).

This study assessed the dissipation of triclopyr and imazapyr from soils along transmission ROWs, linking it to soil toxicity studies using three ecologically relevant species to assess the risk associated with adding herbicides to the VM scheme in the Yukon Territory. It was hypothesized that herbicides would be present in soils longer than 365 DAT, but at concentrations that would not affect more than 25 percent of the soil invertebrate community when sprayed at concentrations at or below the maximum recommended application rates (Jimmo 2018; Jimmo et al. 2018).

METHODS

Herbicide Dissipation

In the summer of 2014 and 2015, five sites (CAR, DAW, HJ1, HJ2, LS) were selected along Yukon Territory utility ROWs. Sites were selected for the study based on vegetation generally representative of Yukon Territory ROWs and the appropriate age for treatment. Soils at each site were of silt loam texture and classified as eutric brunisols (Jimmo 2018; Jimmo et al. 2018). Site details are provided in Jimmo (2018).

Two herbicides, Garlon XRT (755 grams (g) liters $(L)^{-1}$ triclopyr butoxyethyl ester; Dow AgroSciences Canada Inc, Calgary, AB) and Arsenal Powerline (240 g L^{-1} imazapyr isopropylamine salt; BASF Canada Inc., Mississauga, ON) were selected for the study based on the results of a pilot study conducted in 2013 (EDI 2013). At each of the five sites, triclopyr and imazapyr were applied to separate six-meter (m)2 treatment plots. Herbicides were applied with a Stanley 61804 Poly 4 Gallon Professional Backpack Sprayer at rates of 4.5 kilograms (kg) of active ingredient per hectare (ha) (kg a.i. ha^{-1}) and 0.72 kg a.i. ha^{-1} for triclopyr and imazapyr, respectively (Jimmo 2018; Jimmo et al. 2018). Complete study details are presented in Jimmo (2018).

Soils were sampled using a trowel with a depth gauge from the upper soil horizon that consisted primarily of organic soil. Samples were collected at three random locations within the treatment plots. Sample areas were approximately eight centimeters (cm) in diameter and an approximate depth of three cm, resulting in varied amounts of organic matter, to ensure adequate representation of the treatment plot (Figure 1). Samples from CAR, DAW, HJ1 and HJ2 were collected one, 30, and 365 DAT. Increased sampling intervals were introduced at LS to ensure an appropriate dissipation rate could be calculated. Soil samples were analyzed for herbicide residues at the University of Guelph's Food and Agriculture Laboratory (Jimmo 2018).

Laboratory Toxicity Tests

Approximately 20 kg of clean organic soils located outside of the treatment were collected at each of five sites. Garlon™ XRT (triclopyr) and Arsenal® Powerline (imazapyr) were also used for the laboratory toxicity tests. Field application rates, soil bulk density, and an assumed sampling depth of three cm were used to determine a series of eight increasing concentrations (as mg of active ingredient per kg of soil dry weight [mg a.i. kg $d.w.^{-1}$]) plus a negative control (where no herbicide is added).

Five replicates were used for each dose interval. A standard toxicity test was conducted for *Enchytreaus crypticus, Folsomia candida*, and *Oppia nitens*. Species specific protocols were followed for each species (OECD 2004; Princz et al. 2010; Environment Canada 2014; Jimmo 2018).

Risk Characterization

In this study, soil ecological risk was characterized using two approaches: weight of evidence (WOE) and toxic exposure ratios (TER). Using Environment Canada procedures, the WOE approach integrates the two lines of evidence (LOE) generated as part of this study: soil dissipation and soil toxicity (Environment Canada 2007). TERs, on the other hand, are a quantitative measure that is used to extrapolate standardized test results and potential environmental concentrations in the soil (PEC_{soil}). Here, the TER calculation used a 28-d EC10, and divided it by the PEC_{soil} from the field dissipation study (EC directive No 91/414 Annex VI (1991); EC Regulation No 1107/2009 2009; Christl et al. 2016; Ernst et al. 2016). The calculated TER values are then compared to critical trigger values. When TERs are below the critical trigger value, unacceptable risk is present and additional studies should be conducted (Christl et al. 2016; Ernst et al. 2016; Jimmo et al. 2018). Full details on the risk characterization methods are included in Jimmo (2018) and Jimmo et al. (2018).

RESULTS

Herbicide Dissipation

In the LS soil, triclopyr followed a three-parameter biphasic distribution, with rapid initial loss within the first three DAT, followed by a slower persistent phase measured at 60 DAT (0.52 mg a.i. kg^{-1} [SE ± 0.18, p=0.01]). Within the mobile phase, 50 percent of the herbicide residues dissipated by one DAT (k=0.76, SE ± 0.58, p<0.20) and 90

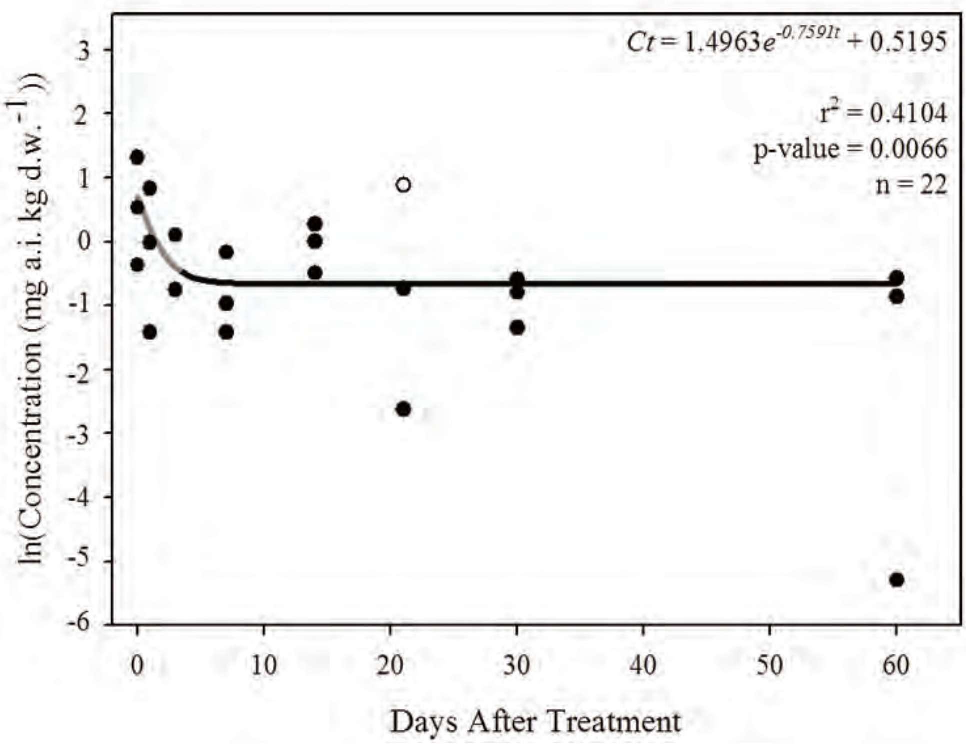


Figure 1. Three-Parameter Biphasic Dissipation Model For Triclopyr Residues

Three-parameter biphasic dissipation model for Triclopyr residues in the upper soil horizon at the LS site (r^2=0.4104). Calculated $DT_{50\ BIPHASIC}$ and $DT_{90\ BIPHASIC}$ values are one DAT and three DAT, respectively.

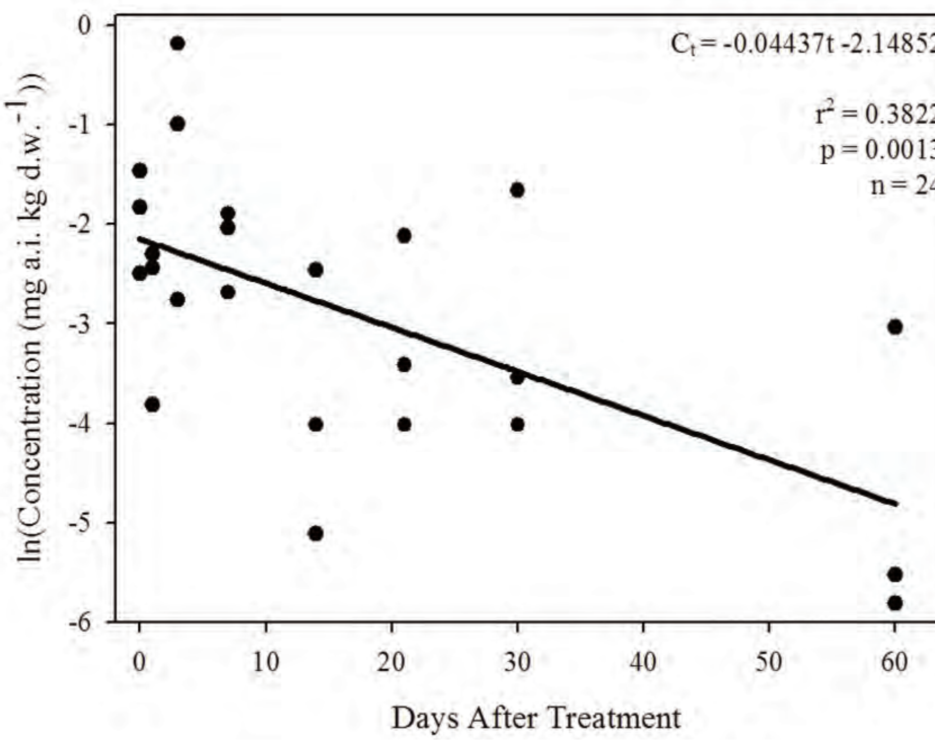


Figure 2. First Order Dissipation Model for Imazapyr Residues

First order dissipation model for imazapyr residues from the backpack spray treatment at the LS site (r^2=0.3822) from soils collected from the upper soil horizon (0-3 cm). The DT_{50} and DT_{90} were calculated as 16 and 52 DAT, respectively (Jimmo et al. 2018).

percent of the herbicide residues by three DAT when the pattern transitions to a persistent phase (Figure 1).

The concentration in the persistent phase is 0.52 mg a.i. kg^{-1}. Grey line and circles represent the first phase modeled with first order kinetics, while the black dots and line represent the persistent phase. The white circle indicates data point that was removed to obtain optimal model fit, but was not statistically identified as an outlier. (Jimmo et al. 2018).

In contrast, imazapyr dissipated slower than triclopyr following a first-order model (Figure 2). The degradation constant from the linear regression equation determined reduction of 50 percent of the herbicide residues (DT50) and 90 percent of the herbicide residues (DT90) of 16 and 52 DAT, respectively (Jimmo 2018; Jimmo et al. 2018).

Site comparison of herbicide residues for the backpack spray treatment indicated that the dissipation of triclopyr and imazapyr varied among the sites at different time intervals. No significant site differences were observed at one DAT, but HJ2 (6.60 ± 2.51 mg a.i. kg^{-1}) and LS (0.42 ± 0.08 mg a.i. kg^{-1}) were significantly different (ANOVA, TukeyHSD <0.05) at 30 DAT. Samples collected at 365 DAT were not analyzed for triclopyr residue since there was no qualitative evidence of triclopyr at 365 DAT (Isbister 2016). Imazapyr residues for backpack spray were analyzed at one, 30, and 365 DAT, with a significant difference in residues observed at 365 DAT for all sites. However, imazapyr residues at 365 DAT identified no statistically significant differences between sites when the herbicide was applied via backpack spraying (Jimmo 2018; Jimmo et al. 2018). While not statistically significant, the LS soil, appeared to have a faster dissipation rate for both herbicides when compared to the other four site soils tested.

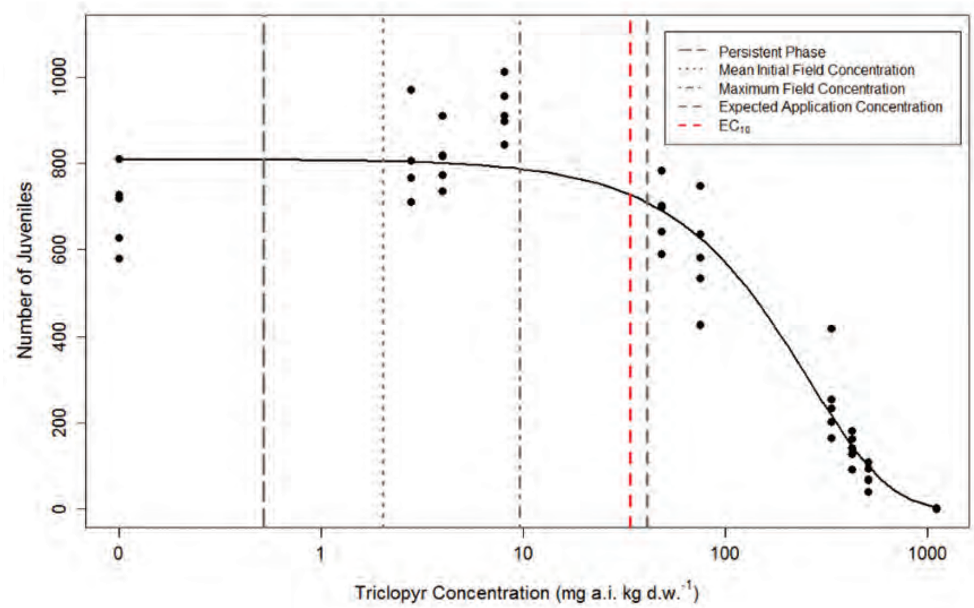


Figure 3. Dose-Response Curve for F. Candida Reproduction from the Toxicity Test Conducted with LS Soil Linked with Field Dissipation Data from the LS Site for Triclopyr

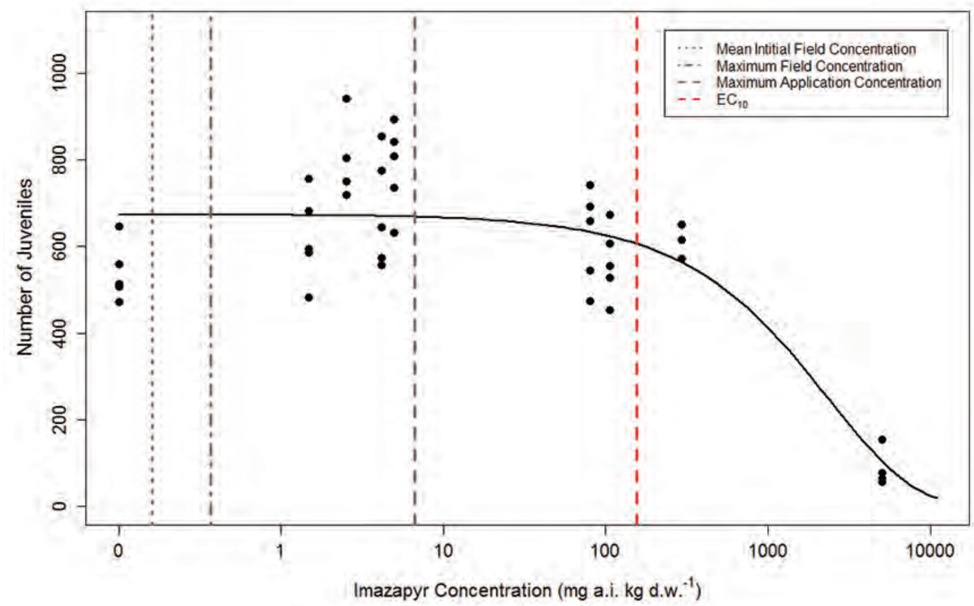


Figure 4. Dose-Response Curve for F. candida Reproduction in LS Soil Linked with Field Dissipation Data from the LS Site for Imazapyr

Laboratory Toxicity Results

To determine the risk associated with the application of triclopyr and imazapyr along ROWs in the Yukon Territory, 28-day (28-d) laboratory toxicity tests were conducted on three ecologically relevant soil organisms (*E. crypticus, F. candida, O. nitens*). The 28-d lethal concentrations causing 25 percent mortality (28-d LC_{25}) and the 28-d effective concentration causing a 25 percent decrease in juvenile production (28-d EC_{25}) values were above concentrations expected when herbicides are applied at manufacturer-recommended rates. The lowest 28-d LC_{25} was observed for *E. crypticus* in the DAW soil with the lowest 28-d EC_{25} observed for *F. candida* reproduction in the LS soil. For imazapyr, *E. crypticus* was the most sensitive of the species tested with the lowest LC_{25} and 28-d EC_{25} observed in the CAR and DAW soils, respectively.

Risk Characterization

Two lines of evidence (field dissipation and laboratory toxicity tests) were used to characterize the risk associated with adding herbicide application to the management regime along transmission ROWs in the Yukon Territory. The WOE approach was conducted using the field dissipation and laboratory toxicity data. Specifically, data from the LS soil was used due to the detailed soil sampling, which allowed for the modelling of dissipation kinetics (Jimmo 2018). For triclopyr, the 28-d EC_{10} for *F. candida* in the LS soil was 34 ± 9.97 mg a.i. kg $d.w.^{-1}$, which was lower than modelled residues from the persistent phase (0.52 mg a.i. kg $d.w.^{-1}$) (Figure 3). The EC_{10} was also lower than the mean initial residue concentration (2.03 mg a.i. kg $d.w.^{-1}$) and the highest residue concentration (9.6 mg a.i. kg $d.w.^{-1}$) quantified for the backpack spray treatment (Figure 3) (Jimmo et al. 2018).

The black dots represent individual data points, with the black line representing the dose-response curve. The vertical grey lines represent environmental concentrations quantified from the dissipation study. The long-dashed line represents the concentration of the persistent phase obtained from the biphasic distribution (0.52 mg a.i. kg $d.w.^{-1}$), the dotted line represents the mean initial concentration from the LS site (2.03 mg a.i. kg $d.w.^{-1}$), and the dot-dash line represents the maximum residue concentration quantified from the backpack spray treatment at the LS site (9.6 mg a.i. kg $d.w.^{-1}$), and the small dash line represents the expected application concentration (41.3 mg a.i. kg $d.w.^{-1}$). The red dashed line represents the F. candida 28-d EC_{10} value (34.0 mg a.i. kg $d.w.^{-1}$) (Jimmo et al. 2018).

For imazapyr, the lowest 28-d EC_{10} (*F. candida*) in the LS soil was above the maximum observed residue concentration (0.37 mg a.i. kg $d.w.^{-1}$) for the backpack spray application and the expected application concentration (6.56 mg a.i. kg $d.w.^{-1}$) at the LS site (Figure 4) (Jimmo et al. 2018).

The black dots represent individual data points, with the black line representing the dose response curve. The vertical grey lines represent environmental concentrations quantified from the dissipation study. The dot-dash line represents highest overall concentration (1.34 mg a.i. kg $d.w.^{-1}$), the dotted line represents the mean initial concentration (0.16 mg a.i. kg $d.w.^{-1}$), and the small dash line represents the expected application rate (6.56 mg a.i. kg $d.w.^{-1}$). The red dashed line represents the *F. candida* 28-d EC_{10} endpoint value (156 mg a.i. kg $d.w.^{-1}$) (Jimmo et al. 2018).

The TER approach was used as a quantitative approach to characterize the risks associated with the foliar application of herbicides in the Yukon Territory. In this study, TERs were calculated for both herbicides using PEC_{soil} concentrations. We collected one, 30, and 365 DAT from each site, where data was available, and the most sensitive 28-d EC_{10} value for each site soil (Table 1). TERs calculated using the triclopyr data identified that acute exposure (1 DAT) in the CAR and HJ1 soil and chronic exposure (30 DAT) were below the critical trigger values of 10 and 5, respectively. No TERs were

Herbicide	Site	28-d EC10† (mg a.i. kg $d.w.^{-1}$)		1 DAT‡		30 DAT‡		365 DAT‡	
		Species	Value	PECsoil (mg a.i. kg $d.w.^{-1}$)	TER	PEC_{soil} (mg a.i. kg $d.w.^{-1}$)	TER	PEC_{soil} (mg a.i. kg $d.w.^{-1}$)	TER
Triclopyr	CAR	*E. crypticus*	18 ± 21.3	11	1.64	4.1	4.39	NA	NC
	DAW	*E. crypticus*	76 ± 17.8	2.9	26.2	16	4.75	NA	NC
	HJ1	*F. candida*	188 ± 74.3	35	5.37	4	47	NA	NC
	HJ2	*F. candida*	161 ± 135	11	14.6	10	16.1	NA	NC
	LS	*F. candida*	34 ± 9.91	2.3	14.8	0.55	61.8	NA	NC
Imazapyr	CAR	*E. crypticus*	392 ± 264	0.2	1960	0.16	2450	0.005	78400
	DAW	*E. crypticus*	23.3 ± 21.3	0.078	299	0.3	77.7	0.03	777
	HJ1	*E. crypticus*	176 ± 116	0.67	263	0.15	1173	0.027	6519
	HJ2	*F. candida*	213 ± 108	0.67	318	0.28	761	0.008	26625
	LS	*F. candida*	156 ± 129	0.1	1560	0.19	821	0.032	4875

Table 1. TER for tricopyr and imazapyr calculated using the lowest 28-d EC_{10} endpoint generated for each site soil, and the potential environmental concentration (PECsoil) from the soil at one, 30, and 365 days after backpack spray treatment.

28-d EC_{10} values were used to determine the TERs because all TERs calculated with 28-d EC_{25} values were above the critical trigger values. The acute TER values used PEC_{soil} values from one DAT and a critical trigger value of 10. The chronic TER values used PEC_{soil} values from 30 and 365 days after treatment and have a critical trigger value of five. Bold and underlined font indicates TER values below the critical trigger value.

below critical trigger values for imazapyr, indicating no unacceptable risk for imazapyr (Jimmo et al. 2018).

DISCUSSION

Herbicide Dissipation

Field dissipation of Garlon XRT (triclopyr) and Arsenal Powerline (imazapyr) was assessed at five sites in the Yukon Territory, each with varying soil properties. Detailed analysis of dissipation kinetics from the backpack spray application at the LS site identified that triclopyr dissipated rapidly until three DAT, when it entered a persistent dissipation stage at a residue concentration of 0.52 mg a.i. kg^{-1} (SE ± 0.18, p=0.01). The rapid initial dissipation of triclopyr was likely controlled by the photo degradation and volatilization processes, whereas the persistent phase was likely controlled more by sorption (Hill and Schaalje 1985). In comparison, imazapyr dissipated slower following first order kinetics and was likely controlled by rapid sorption to soil colloids and microbial degradation (Wang et al. 2005; Gianelli et al. 2014). Half-lives (50 percent dissipation of the initial concentration) from the field dissipation study were calculated as one DAT in the initial phase and 16 DAT for triclopyr and imazapyr, respectively (Jimmo et al. 2018). In comparison to the LS sites, the other soils tested had slower dissipation. The LS residue concentrations should be interpreted with caution as 9.6 mm of precipitation was documented within 48 hours of application (Environment Canada 2015), which may have resulted in some leeching of herbicides.

In comparison to the LS sites, the other soils tested had slower dissipation. However, it is believed that the LS residue concentrations should be interpreted with caution as 9.6 millimeters (mm) of precipitation was documented within 48 hours of application (Environment Canada 2015). Slower dissipation rates in the other soils is also likely associated with higher total organic and clay contents. For example, HJ2, the site with the highest soil residues, also had the highest amount of soil organic carbon and clay contents. The organic matter and fine-grained nature of the HJ2 likely increased absorption of the herbicides to the soil colloids, reducing dissipation rates (Jimmo 2018; Jimmo et al. 2018).

Soil Toxicology

Based on the results of the laboratory toxicity testing, it is unlikely that the soil invertebrate community will be impacted by the addition of foliar herbicide applications. The most sensitive endpoints calculated (28-d LC_{10} and 28-d EC_{10}) did not identify significant risks to the invertebrates tested when compared to the expected application concentrations. The results presented above identified that the threshold is well above both PEC_{soil} and expected application concentrations, indicating no unacceptable risks to the soil invertebrates tested though the application of triclopyr and imazapyr.

Risk Characterization

WOE and TER were used in this study to both qualitatively and quantitatively characterize the risks associated with herbicide application along utility ROWs in the Yukon Territory. The WOE approach used here combines professional judgment and graphical presentations of the data to identify that there are no unacceptable risks associated with the low-volume foliar application of either triclopyr or imazapyr. However, the TER approach identified some risk associated with triclopyr applications at CAR, DAW, and HJ1 (Table 4), where the calculated TERs were above the critical trigger values, indicating that further high-level studies should be conducted. However, the chronic TER values were generally close to the trigger values indicating that the populations may recover within 365 DAT.

CONCLUSIONS

Northern vegetation managers need a more effective and efficient method than the mechanical methods currently used for managing woody vegetation along utility ROWs. While the foliar application appears to have limited impact on the soil invertebrates tested, the soil community is just one component of a functioning ecosystem. High value is placed on non-target vegetation in northern communities and as such, the impact of the herbicides on culturally important, non-target vegetation needs to be considered. Damage assessments conducted at the same five sites in this study identified that non-target forbs in triclopyr plots recovered within 365 DAT, but the damage associated with imazapyr was still evident two years post-application (Isbister et al. 2018). The addition of vegetation damage data identifies that triclopyr may be the better option for use along Yukon Territory transmission ROWs due to relatively rapid dissipation, minimal chronic effects on soil invertebrates, and recovery of non-target species within 365 DAT (Jimmo et al. 2018).

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Bamboo is a fast-growing, woody monocot, which is often planted as a privacy screen along residential properties. Plant placement in rights-of-way (ROWs) often result in conflicts between vegetation and powerlines. The fast growth habit necessitates frequent trimming, which adds to vegetation management (VM) costs and creates scheduling difficulties when planning a normal three-year trim cycle. A 27-month study was conducted to evaluate the use of plant growth regulators (PGRs) and mechanical methods to manage the growth of Hedge bamboo (*Bambusa glaucescens*) growing in proximity to powerlines in southwest Florida. The PGR paclobutrazol (PBZ) was tested in two formulations: a foliar treatment and a soil drench. Mechanical method (trimming) was evaluated either alone or combined with PGR soil drench. After 27 months, both PGR application methods provided acceptable plant height and resulted in comparable cost. When compared to other treatments, mechanical trimming resulted in the lowest cost; however, plant height was not acceptable after 27 months. The combination of mechanical trimming and PGR soil drench provided acceptable results during the first 12 months, but not during the second half of the study.

Management of Hedge Bamboo Growing Near Powerlines

A.D. Ali

Keywords: *Bambusa*, Paclobutrazol (PBZ), Cost Analysis.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

One of the popular ornamental plants in Florida is Hedge bamboo, *Bambusa glaucescens*. While other bamboo species spread rapidly and may require root system confinement (Halfacre and Shawcroft 1989), Hedge bamboo remains in a relatively confined area due to its clump growth habit. In south Florida, Hedge bamboo is often planted as a privacy screen, which may be under or in close proximity to powerlines. In order to reduce plant height and potential line interference, frequent trimming is required. The trimming cycle may be necessary on an annual basis in some instances.

Power interruptions and customer inconveniences often result from vegetation conflicts with powerlines. Trees, both hardwoods and conifers, are the usual culprits; however, palms may also cause power interruptions (Tamsberg 1990). Mechanical methods or chemical (herbicide) applications are the two most commonly employed methods for vegetation management (VM). Total acreage treated mechanically for VM along transmission lines exceeded the acreage treated chemically by 2.7:1 (Sulak and Kielbaso 2000). The cost of various management methods in a utility ROW was compared by Abrahamson et al. (1991a). They reported a trend for lower cost associated with selective or clear cutting and no chemical treatments. In another study, Abrahamson et al. (1991b) compared the cost effectiveness of various herbicide treatment methods. They concluded that basal treatments are less cost effective than stem-foliar treatments. Weather-related power outages result in an estimated $20 billion to $55 billion annual loss to the U.S. economy (Campbell 2012). Improvement of tree trimming schedules to maintain powerlines clear of vegetation is one of the suggested solutions presented by Campbell (2012).

Another group of chemicals, which has been investigated as a tool for VM, are the PGRs (Bowles 1985; Tamsberg, 1990). PGRs are useful in potentially prolonging the interval between trim cycles by slowing the rate of plant growth. Australian pine (*Casuarina equisetifolia*), hedgerow treated with PGRs, resulted in a re-trim cost saving of $96.14 per 100 feet (ft) compared to an untreated section (Tamsberg 1990).

A commonly used PGR that has been available for decades is paclobutrazol (PBZ) (Barrett and Nell 1983; Ruter 1994). Growth is reduced by the inhibition of gibberellin synthesis in the meristem of woody plants (Blaedow 2003; Bai et al. 2004). Several studies demonstrated the activity of PBZ on specific palms (Hensley and Yogi 1996; Carvajal et al. 1998; El-Hodairi et al., 1998). On the other hand, Ali and Bernick (2010) reported a lack of significant growth reduction of the Royal Palm (*Roystonea regia*). As for other woody monocots, Han et al. (2005) demonstrated reduced bamboo growth upon treatment with PBZ.

The objective of this study was to evaluate cost effectiveness of several bamboo growth management methods, such as mechanical control (trimming) and/or treatment with PGRs. The goal is to maintain a reliable power supply while reducing overall trimming and VM costs.

METHODS

For this study, a mature planting of Hedge bamboo growing in a maintained landscape in Ft. Myers, Florida was selected. The row of individual clumps was located within one meter (m) (three ft) of the overhead powerline easement. Average clump height was 4.5 m (15 ft) and an average basal circumference of 7.6 m (25 ft). Two PBZ formulations (Trimtect and Cambistat; Rainbow Tree Care, Minnetonka, Minnesota) were evaluated. Trimtect was delivered as a foliar treatment at the rate of 192 milliliters (ml)/3.785 liters (L) (6.4 fluid ounces/gallons) with a 95-L (25-gallon) sprayer and an electric pump. Cambistat was delivered as a basal soil drench at the rate of 10 ml a.i./0.1 sq. m (0.3 fluid ounces a.i./sq. feet) basal clump area. Mechanical trimming for height reduction was conducted with an aerial lift (Genie, Redmond, Washington). Treatments included: 1) Trimtect foliar spray; 2) Cambistat basal soil drench; 3) Cambistat basal soil drench and mechanical trimming; 4) Mechanical trimming only. All treatments were applied on October 5, 2011. Trimtect was re-applied on December 7, 2012, and mechanical trimming was conducted a second time on December 14, 2012.

A clinometer (Brunton Classic Clinomaster CM66LA, Sweden) was used to determine clump height. In addition, the length of four stems per clump (one in each Cardinal direction) were also recorded every three months for the first 12 months. Height evaluations were made 0, 3, 6, 9, 12, 15, 18, 21, 24 and 27 months after treatment (MAT). In the absence of precipitation, irrigation was applied twice per week. The study began in October 2011 and ended in December 2013. A Randomized Complete Block design was used with three replications (clumps) per treatment. Data analysis was with ANOVA and mean separation via Student-Newman-Keuls test at p=0.05 (ARM6, Gylling Data Management, Brookings, S.Dak.).

RESULTS & DISCUSSION

Bamboo growth response to the chemical treatments is shown in Figure 1. PBZ applied either as a foliar spray or a basal soil drench resulted in arrested growth within 3-6 MAT. At 18 MAT, there was a slight increase in height for plants subjected to the second foliar application, but growth arrest was again accomplished through 27 MAT. During the first 12 months, there was a slight—but consistent—height increase in plants receiving both the basal soil drench and trimming (Figure 2). After the second mechanical trimming at 15 MAT, plants continued to grow and PBZ basal soil drench did not appear to reduce clump height. PBZ acts on developing cells in meristems (Bai et al., 2004). Thus, removal of growing tips through mechanical trimming may explain the lack of growth suppression in those plants. Plants subjected to trimming only continued to increase in height at a steady rate during the first 12 months; their growth rate accelerated at 21 MAT.

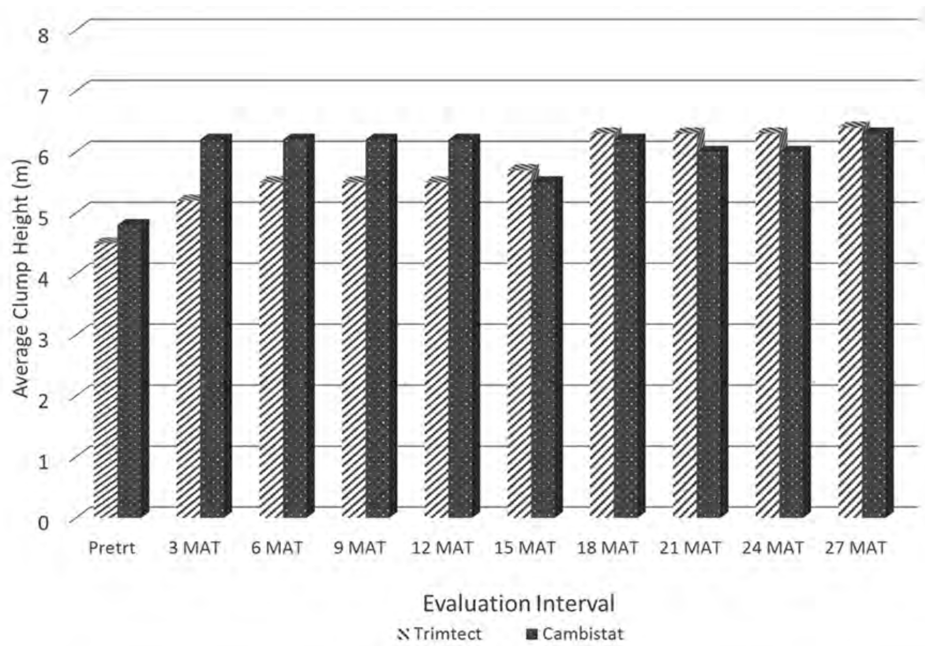

Figure 1. Hedge Bamboo Growth Response to the Plant Growth Regulator PBZ Applied as a Foliar Spray or a Basal Soil Drench. Ft. Myers, Florida.

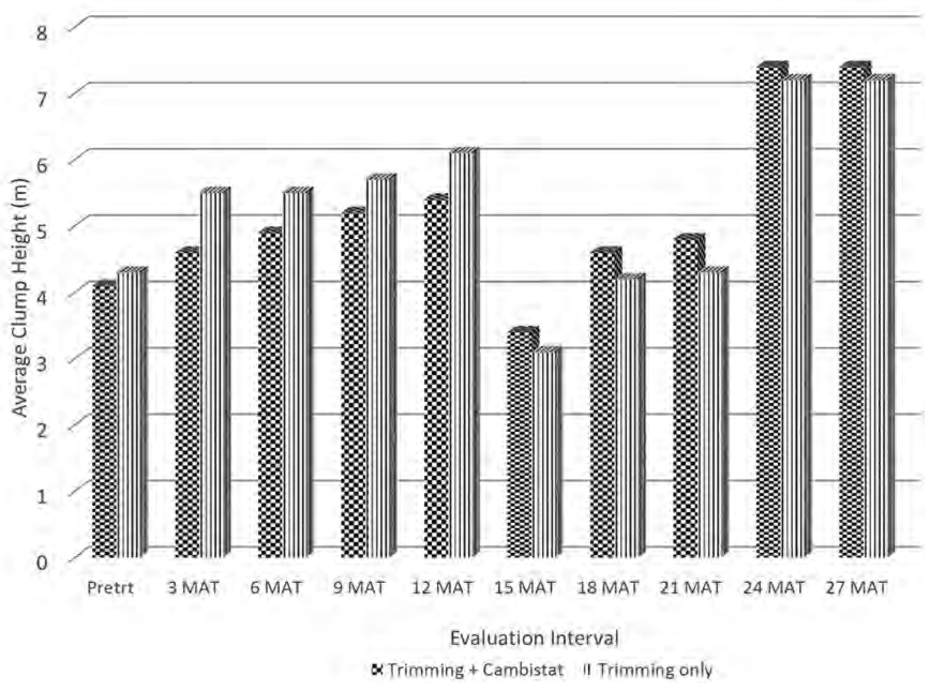

Figure 2. Hedge Bamboo Growth Response After Mechanical Trimming Alone or in Combination With a Basal Soil Drench of the Plant Growth Regulator PBZ. Ft. Myers, Florida.

Table 1 shows the relative costs associated with the various treatments. No cost differences were noted for either of the PBZ alone chemical treatments. The lowest cost during the study was associated with mechanical trimming only; however, plant height in that treatment was not acceptable at 27 MAT. Costs shown were estimated from current year (2013) contractor pricing.

Average stem length data were not used due to unreliability caused by wide data variability. Individual stem growth rates did not reflect overall clump response. Thus, clump height was deemed the more consistent parameter.

Treatment	Labor, Material Cost / Hour	Labor Hours / Clump	Cost / Clump
Trimtect Foliar	$60, $82	2.6	$238*
Cambistat Drench	$60, $165	1	$225
Cambistat Drench + Trimming	$60, $165	4**	$405***
Trimming Only	$60	3	$180

* Includes labor at $60/hour x 2.6 hours, plus material cost
** Includes 1 hour, labor, and 3 hours trimming
*** Includes Cambistat drench labor at $60/hour x 1 hour, plus trimming labor at $60/hour x 3 hours, plus material cost

Table 1. Expected Labor and Material Costs Associated with Various Treatments to Reduce Hedge Bamboo Growth in a 27-Month Period in South Florida

CONCLUSIONS

PBZ applied either as a foliar treatment or a basal soil drench seems to provide acceptable growth rate suppression of Hedge bamboo. Mechanical trimming alone, or when combined with PBZ basal soil drench, did not provide acceptable plant height management in a 27-month period. Long-term cost benefits of PGR use may be illustrated by additional multi-year studies.

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Outcomes of ROW Vegetation Plot Monitoring along the TMX Anchor Loop Project 2010 2017

Kristen Beechey

Keywords: Jasper National Park (JNP), Mount Robson Provincial Park (MRPP), Management Objectives/Desired End Results (MO/DER), Post-Construction Monitoring, Right-of-Way (ROW) Vegetation Cover, ROW Vegetation Density, Species Overlap, Vegetation Plots.

Kinder Morgan Canada, Inc. constructed the Trans Mountain Expansion (TMX) Anchor Loop Project between the summer of 2007 and the fall of 2008. This project area encompasses federal, provincial, and private lands, including Jasper National Park (JNP) in Alberta and Mount Robson Provincial Park (MRPP) in British Columbia (BC). During consultation with JNP and MRPP, Management Objectives/Desired End Results (MO/DERs) were developed. These included MO/DERs related to right-of-way (ROW) species composition and similarity compared to off-ROW areas. Vegetation plots along the length of the ROW were sampled in 2010, 2011, and 2012 for cover of live plants and plant litter as well as for species composition and overlap with undisturbed off-ROW plots. These results were included in the Post-Construction Monitoring (PCM) program reports that were submitted to the National Energy Board (NEB) in January 2010, 2011, 2012, and 2013 (TERA 2009b; 2011a; 2012b; 2013).

In fall 2012, following review of the 2012 PCM reporting, Parks Canada and BC Parks recommended sign off of most MO/DERs. Both Parks Canada and BC Parks requested that monitoring of detailed vegetation plots be implemented in the tenth year (2017) following the commencement of Project PCM. In July 2017, the 50 vegetation plots were resampled.

At the end of five years of PCM in 2012, the average combined cover of plant litter and all live plants was 75 percent, and the average combined cover of plant litter and all live *native* plants was 43 percent. In 2017, these numbers were 90 percent and 57 percent, respectively. Average species similarity of on-ROW plots compared to off-ROW plots increased from 13 percent in 2012 to 16 percent in 2017. Similarity between on- and off-ROW communities has increased within the monitoring period, but remains below the level originally laid out in the MO/DERs. MO/DERs or other measurable reclamation goals help inform post-construction monitoring programs and determine the success of reclamation. Reclamation goals should acknowledge baseline conditions and focus on positive trends.

Environmental Concerns in Rights-of-Way Management
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INTRODUCTION

Kinder Morgan Canada, Inc. commenced construction of the Trans Mountain Expansion (TMX) Anchor Loop Project, a National Energy Board (NEB)-regulated oil pipeline system, in the summer of 2007 and completed construction in the fall of 2008. Restoration commenced in June 2008. The project entailed the construction of 158 kilometers (km) of 76.2 centimeter (cm) (30-inch [in]) and 91.4 cm (36-in) outer diameter pipeline between a location west of Hinton, Alberta, and a location near Rearguard, British Columbia (BC). This unique project area straddling the continental divide encompasses federal, provincial, and private lands, including Jasper National Park (JNP) in Alberta and Mount Robson Provincial Park (MRPP) in BC, both of which are part of the United Nations Environmental, Scientific, and Cultural Organization (UNESCO) Canadian Rocky Mountain Parks World Heritage Site.

Prior to construction of the TMX Anchor Loop Project, extensive consultation occurred with stakeholders from JNP and MRPP. During consultation with JNP and MRPP, Management Objectives/Desired End Results (MO/DERs) to be implemented in JNP and MRPP were developed. These included MO/DERs related to on-right-of-way (ROW) species composition and similarity compared to off-ROW areas.

The following MO/DERs are addressed in this paper:

- MO/DER A3.1.2. Vegetation Success. Mitigation measures achieve the following accepted Line Leaseholders Working Group (AXYS and David Walker & Associates 1998) standard for revegetation success on the ROW and temporary work areas:
  - The ground cover of native herbaceous vegetation meets the density requirement of 10 plants (native) per meters $(m)^2$ in 90 percent of the m^2 in any area measuring 10 m by 10 m, or—alternatively—to a density that emulates the surrounding natural undisturbed vegetation, of the same or equivalent ecosite (to avoid artificial enhancement, but not to avoid restoration of ecological integrity in appropriate situations).
  - The combined cover of mulch (plant litter) and live native plants is greater than or equal to 80 percent ground cover of the ROW and temporary work areas, or—alternatively—to a percentage cover that emulates the surrounding natural undisturbed vegetation, of the same or equivalent ecosite (to avoid artificial enhancement, but not to avoid restoration of ecological integrity in appropriate situations).
- MOD/ER A3.1.6 Vegetation Processes. Within the constraints of accomplishing specific restoration targets, native plant species establish (either by active measures by Trans Mountain or by natural encroachment/invasion) such that there is at least a 50 percent overlap in total plant species composition between the ROW and temporary work areas and the adjacent plant communities within five years (commencing with the first partial or full growing season as year 0) following pipeline construction.

Throughout this paper, these will be referred to as the Density MO/DER, Native Cover MO/DER, and the Species Overlap MO/DER.

Baseline vegetation surveys were conducted in April, June, July, and August of 2005, and May, June, July, and August of 2006 (TERA and Westland 2005, 2006). Additional surveys relating to re-routes were conducted in May 2007 (TERA and Westland 2007). Based on vegetation composition prior to construction, five construction/reclamation (con/rec) units were mapped: cedar forest, closed coniferous forest, deciduous forest, grassland, and open coniferous forest. There, con/rec units were used to specify particular mitigation measures, such as seed mixes and plantings. Certain locations (such as the Athabasca River) with unique vegetation communities were not included in the con/rec units.

To monitor progress towards achieving the MO/DERs, an extensive post-construction monitoring (PCM) program was developed. One component of this program was data collection at vegetation plots. Vegetation plots along the length of the ROW were sampled in 2010, 2011, and 2012 for cover of live plants and plant litter, and for species composition and overlap with undisturbed off-ROW plots. These results were included in the PCM program reports that were submitted in January 2010, 2011, 2012, and 2013 (TERA 2009b, 2011a, 2012b, 2013).

In fall 2012, following review of the 2012 PCM reporting, Parks Canada and BC Parks replied to Kinder Morgan and recommended sign-off of most MO/DERs. Both Parks Canada and BC Parks requested that monitoring of detailed vegetation plots be implemented in the 10th year (2017) following the commencement of Project PCM. In July 2017, the 50 vegetation plots sampled during the PCM program were resampled.

METHODS

In 2010, 45 plots were established to monitor vegetation MO/DERs. Plot locations were randomly generated prior to fieldwork and pre-programed into a handheld global positioning system (GPS). In 2011, the 45 original plots were resampled, and five additional plots were added, targeting specific areas, for a total of 50 plots. All 50 plots were resampled in 2012 and 2017. Each plot location consisted of three 5 m by 5 m on-ROW subplots and one off-ROW 5 m by 5 m comparison plot, for a total of 150 on-ROW subplots and 50 comparison plots equalling 200 total subplots. The comparison plot was used to determine species composition overlap with adjacent off-ROW plant communities.

To address the plant density requirement in the Density MO/DER, the plants in a 1 m by 1 m area in the corner of each on-ROW subplot were counted (up to 10 plants), and it was noted if plants were native or non-native.

To address the combined cover requirement in the Native Cover MO/DER, the cover of functional groups in the three on-ROW subplots was recorded. The functional groups measured were native grasses, native herbs, native shrubs and trees, non-native grass, other non-native species, and litter. Cover of bare ground was also recorded. In 2017, the cover of bryophytes and lichens was recorded (this value was negligible in 2012 and earlier).

To address the Species Overlap MO/DER, all vascular plant species present in the on- and off-ROW subplots were recorded. Overlap was defined as the total number of native vascular plant species in common, divided by the total number of native vascular plant species present in the off-ROW comparison plot.

During analysis of sampling data in 2010, a trend emerged that identified an increase in both the number and the percent cover of native plants (and decrease in non-native grasses) the further the sites were located from Highway 16 and railway ROW (for the

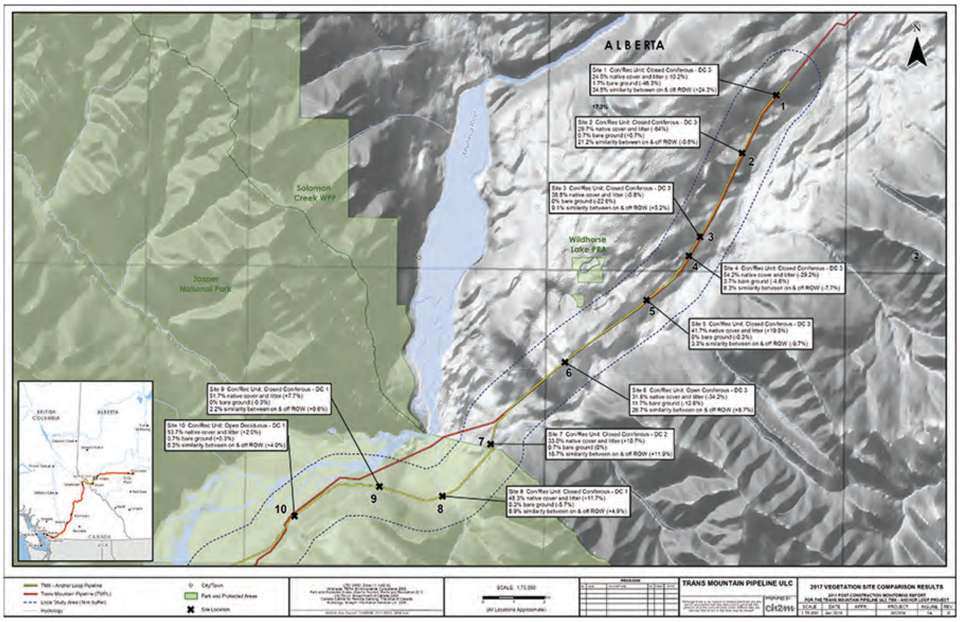


Figure 1a. 2017 Vegetation Site Comparison Results

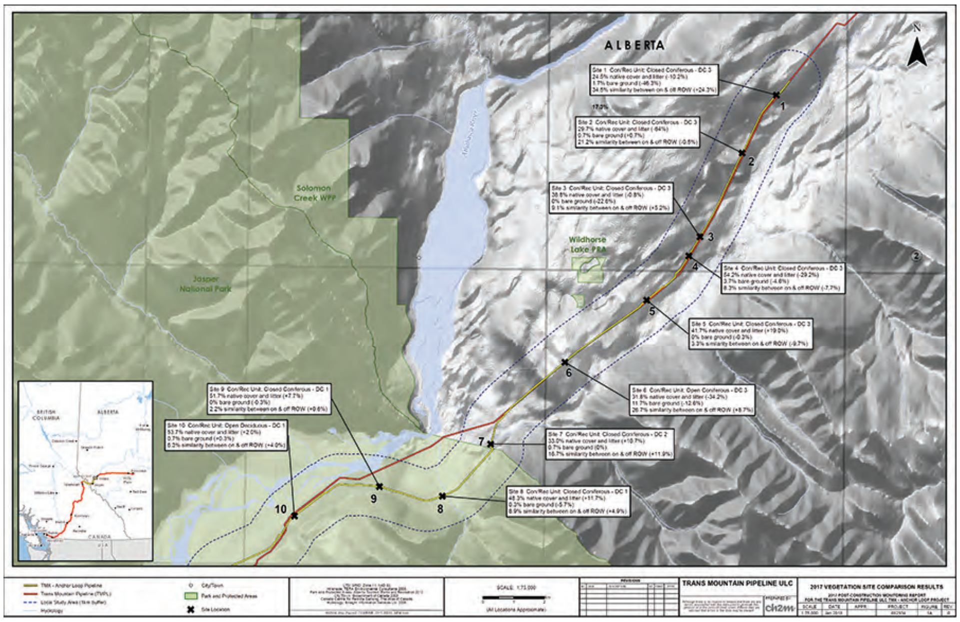


Figure 1b. 2017 Vegetation Site Comparison Results

on-ROW subplots only). In 2011, four distinct classifications were identified based on their proximity to disturbance and were classified into disturbance classes as follows: adjacent to Highway 16 or railway ROWs (Disturbance Class 1); within 100 m of Highway 16 or railway ROWs (Disturbance Class 2); in proximity to a smaller disturbance, such as the Celestine Road, the Wynd Road, or a powerline ROW (Disturbance Class 3); and not in proximity to any frequently used location (Disturbance Class 4).

The locations of the 50 plots, their con/rec unit and disturbance class, as well as the results of the 2017 sampling are shown in Figure 1.

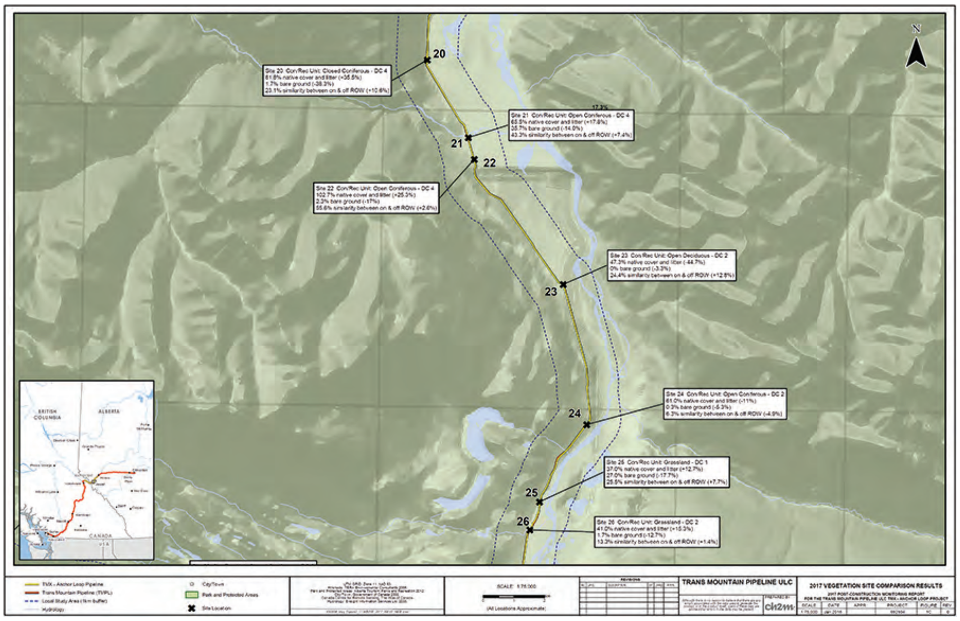


Figure 1c. 2017 Vegetation Site Comparison Results

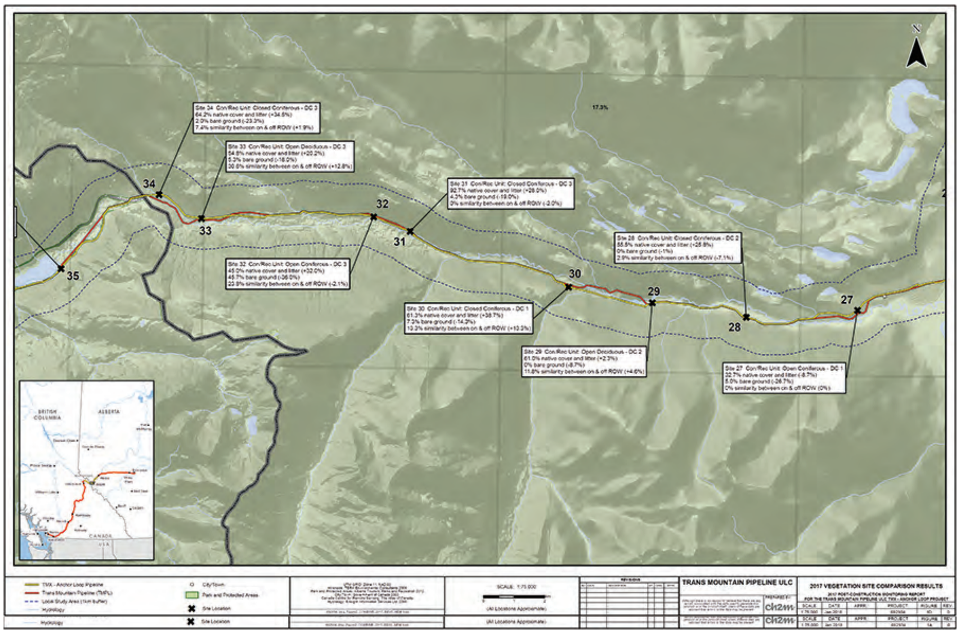


Figure 1d. 2017 Vegetation Site Comparison Results

RESULTS

Density MO/DER

Data collected in 2012 showed that 122 of 150 subplots sampled (81.3 percent) had achieved the 10 native plants per m^2 target.

Data on the number of native plants per m^2 were collected again in 2017. In 2017, vegetation cover was higher, plants were larger, and fewer plants occurred in each m^2 than in 2012. Between 2010 and 2012, it was reasonable to count the number of plants per m^2. In 2017, it was difficult to distinguish individual plants because many plants were large and close together. The density data collected in 2017 showed that 77 of the 150 subplots sampled (51.3 percent) met the 10 native plants per m^2 target.

Native Cover MO/DER

Cover of mulch and all live plants (total cover) was quantitatively assessed at the on-ROW vegetation subplots. The average measured values at each of the 50 plot locations are shown on Figure 1 (values in brackets are the change at that location since 2012).

In 2017, the average combined cover of plant litter and all live plants (total cover) was 95.4 percent, higher than the 80 percent target set in MO/DER A3.1.2. However, MO/DER A3.1.2 specifies combined cover of plant litter and live native plants (native cover). This value was measured in 2011, 2012, and 2017. The average measured values of total cover and native cover are shown on Figure 2.

In 2017, there were 34 on-ROW sub-plots (23 percent) that had native plant cover equivalent to or greater than 80 percent (up from 10 sub-plots in 2012). There were 110 on-ROW sub-plots (73 percent) that had native cover equivalent to or greater than 40 percent, half of the value specified in MO/DER A3.1.2 (up from 75 sub-plots in 2012). The average combined cover of plant litter and live native plants was 55.5 percent in 2017, up from 43.1 percent in 2012.

Cover of native grasses decreased between 2012 and 2017 (down 6.5 percent), while cover of non-native grasses increased (up 10.8 percent).

Cover of weeds (all non-native species except grasses) decreased to 1.8 percent between 2012 and 2017 (down 3.1 percent).

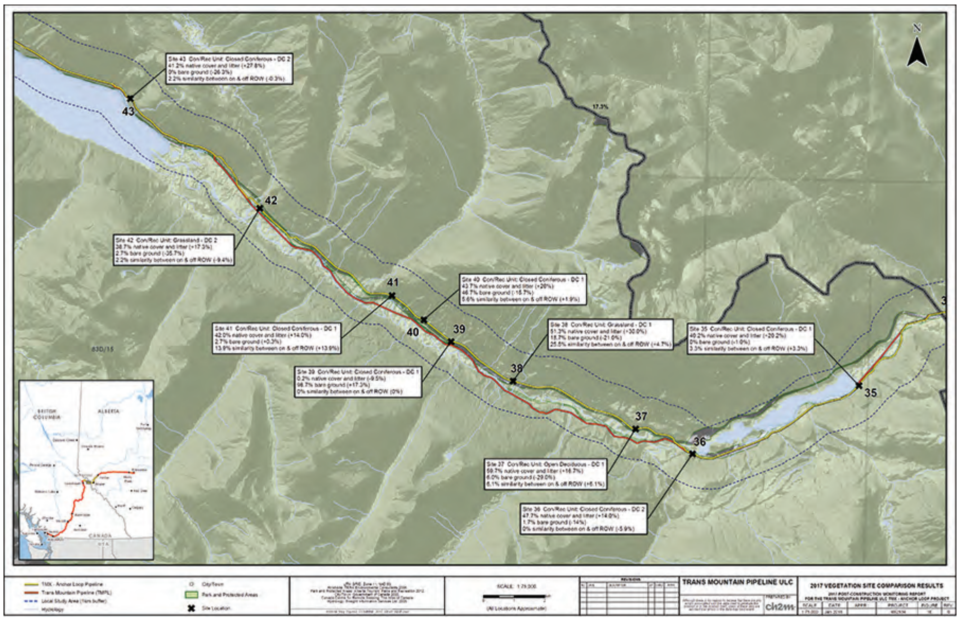


Figure 1e. 2017 Vegetation Site Comparison Results

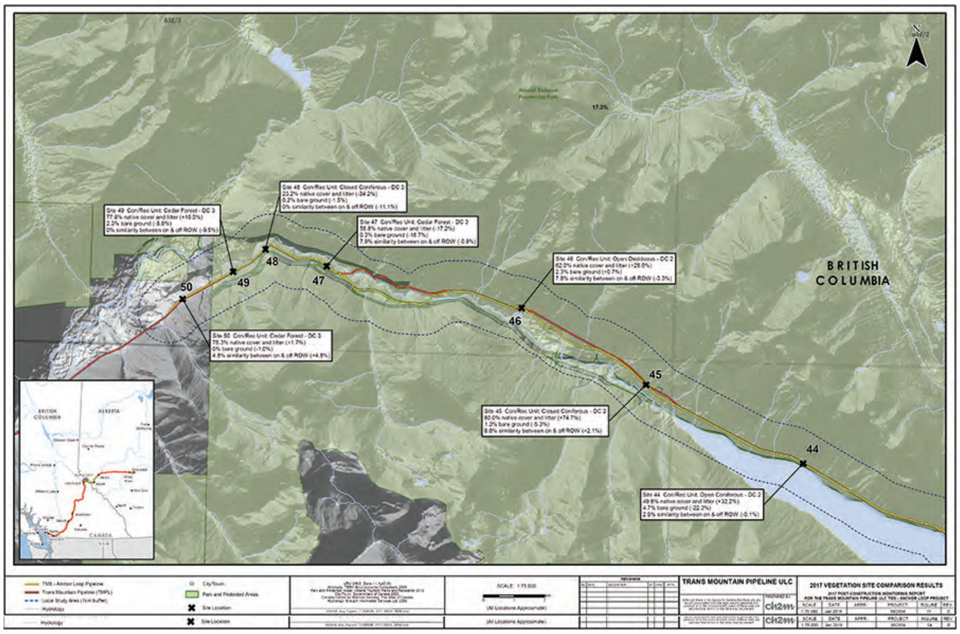


Figure 1f. 2017 Vegetation Site Comparison Results

Currently, litter (26.1 percent) and native grasses (22 percent) are the largest contributors to combined cover of plant litter and all native plants. Herbs (2.8 percent), shrubs (2 percent), and bryophytes and lichens (2.6 percent) are smaller contributors. Litter from non-native grasses is included in the combined cover of plant litter and all native plants. Litter cover was not measured separately in 2010. Litter cover was 3.4 percent in 2011, 12.2 percent in 2012, and 26.1 percent in 2017.

The con/rec unit was not observed to affect native cover. Disturbance class appeared to be related to native cover. These results are shown in Figure 3. Figure 3 shows native cover increasing across all disturbance classes with time. However, average sites in Disturbance Classes 1 and 2 have lower native cover than those in Disturbance Classes 3 and 4.

Species Overlap MO/DER

Species overlap was quantitatively assessed at every plot in 2010, 2011, 2012, and 2017. Figure 1 shows the similarity measured in 2017, and the change since 2012.

The average similarity recorded in 2010 was 9.2 percent (this value is slightly different from other years because only 45 plots were sampled and only one on-ROW subplot was completed). In 2011, the average similarity was 13.1 percent. In 2012, the average similarity was 13.3 percent. In 2017, the average similarity was 16.2 percent. Figure 1 shows the similarity measured at each plot in 2017, and the change at that location since 2012.

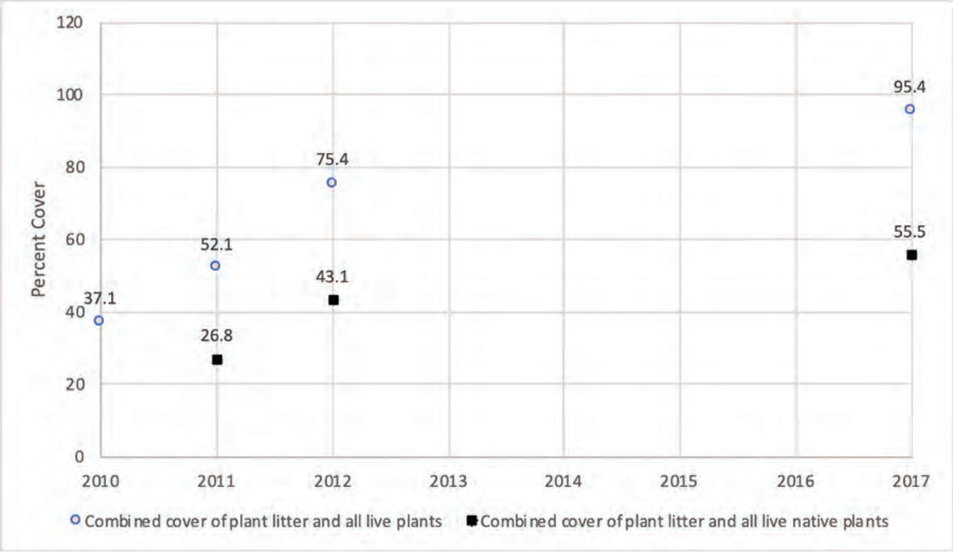
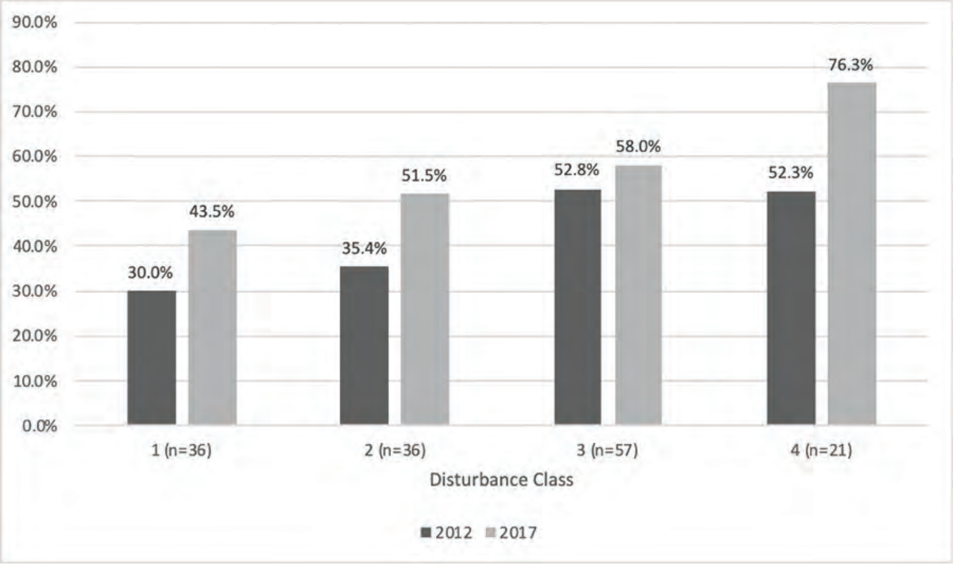


Figure 2. Change in Combined Cover from 2010 to 2017



Notes:
Percent similarity between on- and off-ROW locations in four disturbance class categories:
1 – adjacent to Highway 16 or railway ROWs
2 – within 100 m of Highway 16 or railway ROWs
3 – in proximity to a smaller disturbance such as the Celestine Road, the Wynd Road, or a powerline ROW
4 – not in proximity to any frequently used location
n= number of pair-wise comparisons on- and off-ROW within each of the disturbance classes

Figure 3. Combined Cover of Plant Litter and Live Native Plants (Native Cover) per Disturbance Class

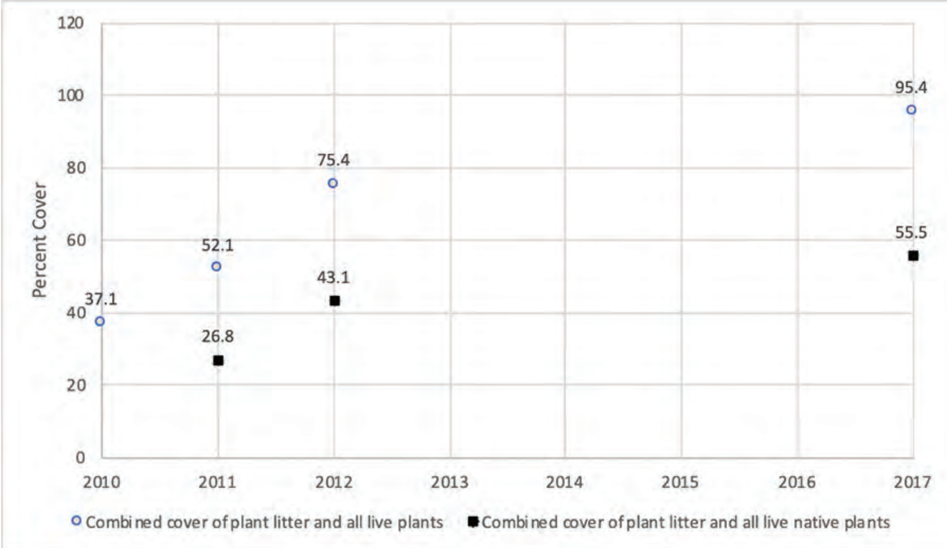
Average similarity varied widely (between 0 and 50 percent in 2010, and between 0 and 76 percent in 2017). While not analysed statistically, every year there were variances in similarity between different con/rec units and different disturbance classes. Similarity by con/rec unit and disturbance class in 2017 is shown on Figures 4 and 5.

DISCUSSION

The 50 vegetation plots sampled for this Project represent a wide range of conditions, from Site 12 in the open grasslands southwest of the Athabasca River, where combined cover of litter and native vegetation is 85 percent and species overlap with off-ROW is 64.7 percent, to Site 48, near the west end of the project in BC, adjacent to a dark cedar forest, where combined cover of litter and native vegetation is 23.2 percent and there is no overlap between the on- and off-ROW subplots. Reclamation has progressed differently at different sites depending on the specifics of the site, surrounding land cover, and construction.

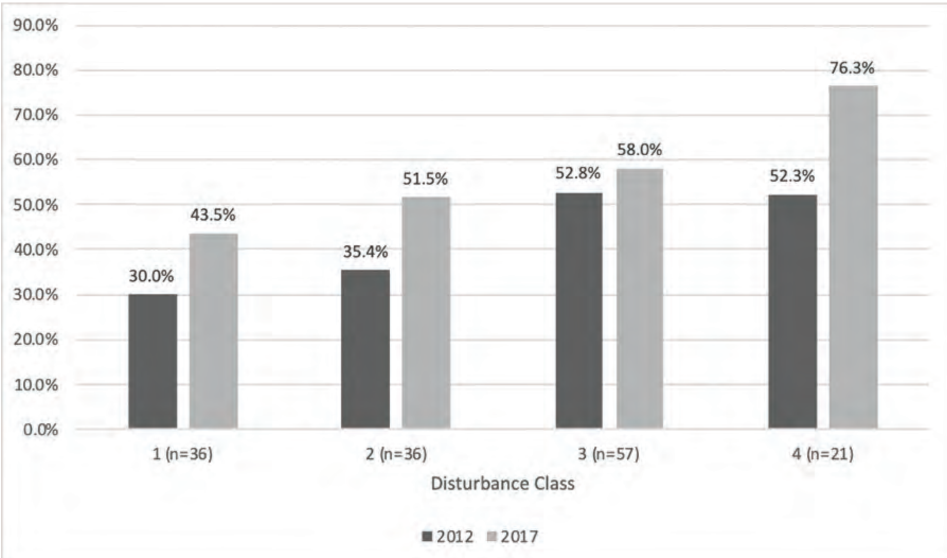
Density MO/DER and Native Cover MO/DER

Overall, ground cover 10 years following construction is high. During restoration and environmental protection planning, measures were developed and later implemented to establish native plant communities to the extent feasible. Salvage and replacement of root zone material during construction were important measures that allowed for the germination of native (and non-native) grass and forb seed and the preservation and re-establishment of plant vegetative propagules. These measures were followed by seeding of native grass



Note:
n= number of pair-wise comparisons on- and off-ROW within each of the disturbance classes

Figure 4. Percent Similarity by Con/Rec Unit



Notes:
Percent similarity between on- and off-ROW locations in four disturbance class categories:
1 – adjacent to Highway 16 or railway ROWs
2 – within 100 m of Highway 16 or railway ROWs
3 – in proximity to a smaller disturbance such as the Celestine Road, the Wynd Road, or a powerline ROW
4 – not in proximity to any frequently used location
n= number of pair-wise comparisons on- and off-ROW within each of the disturbance classes

Figure 5. Percent Similarity by Disturbance Class

species. Average total cover recorded in 2017 was 95.4 percent; as a result, erosion concerns throughout most of the project area are now low.

During the early successional period, plant establishment was supported by favorable conditions on-ROW (low competition and full sun). These conditions have been especially favorable for grasses. The large increase in plant litter from 2012 to 2017 (up more than 100 percent) is indicative of perennial grasses maturing and producing plant litter.

Between 2012 and 2017, the portion of plots that met the 10 plants (native) per m^2 portion of MO/DER A3.1.2 has decreased. In 2012, competition remained sufficiently low that many sites dominated by non-native grasses often still had 10 small native plants in the 1 m by 1 m quadrat sampled. In 2017, far fewer of these small native plants were observed, and the fraction of subplots meeting the 10 plants (native) per m^2 criteria fell from 81.3 percent to 51.3 percent. Measurements of density are most useful in early reclamation; in time, cover becomes more relevant.

During the 2012 to 2017 time period, the average cover of native grasses also decreased from 28.5 percent in 2012 to 22 percent in 2017.

These decreases are driven by an increase in perennial, non-native grasses and their litter. Seeding with native grasses gave those native species an advantage in early succession (in 2012, cover of native grasses was 28.5 percent and cover of non-native grasses was 27.3 percent). Non-native grasses were not seeded on the Project during reclamation (seed certificates were included with the 2009 Post-Construction Environmental As-Built-Report [TERA 2009a]). Since 2012, however, non-native grasses have begun to outcompete native grasses in many parts of the ROW. This suggests that the non-native grasses were present in the seed bank prior to construction, which is supported by the finding that total native cover is lower in proximity to other disturbances like Highway 16, where non-native grasses were likely seeded in the past, or along which non-native grasses have spread. Non-native grasses are frequently found to outcompete native grasses (Corbin and D'Antonio 2010; McClay et al. 2004; Nernberg and Dale 1997).

Between 2012 and 2017, the average cover of native forbs and shrubs increased slightly (up to 4.8 percent from 2.4 percent). With time, as conditions change and native species continue to encroach from forb islands and the edges of the ROW, it is anticipated that cover of native forbs and shrubs will continue to increase. Where native woody vegetation is permitted to grow, it is anticipated that it will eventually outcompete the non-native grasses.

Weeds (all non-native species other than grasses) were observed to have decreased from 2012 to 2017. This decrease is likely a result of ongoing successional shift, where annual weeds are being outcompeted by grasses, in addition to the ongoing control of priority perennial weed species.

In certain areas (mostly in Disturbance Classes 1 and 2), the presence of non-native grasses is a potential barrier to meeting the Native Cover MO/DER (where in-growth of native woody vegetation is not feasible because of operation of the pipeline). In areas where competition with non-native grasses is not limiting, this MO/DER has already been met or is likely to be met in the future.

Species Overlap MO/DER

Species overlap was analysed by con/rec unit and disturbance class. Similar to 2012 results, the data analysis indicates that the survey sites located in grassland and open coniferous con/rec units have higher similarity than the other con/rec units sampled. Some of this pattern can be attributed to similarities of growing conditions (light, moisture, and fertility regimes) between grassland and open coniferous con/rec units and the adjacent off-ROW areas. However, the distribution of con/rec units is not independent of disturbance class and geography, and these factors appear to strongly influence observed similarity throughout the Project route as follows:

- Most Disturbance Class 1 sites are located within closed coniferous con/rec units.
- All cedar forest con/rec units occur at the west end of the route within Disturbance Class 3.
- Most open coniferous con/rec units occur within the vicinity of Celestine Lake Road (Disturbance Class 3 or 4) where similarity is generally high.
- Most open deciduous con/rec units occur in areas in proximity to disturbance (Disturbance Class 1 or 2).

The strongest pattern in similarity between on- and off-ROW sample sites across the Project in all years of monitoring was the relationship between the sample site and its proximity to pre-existing disturbance. In both 2012 and 2017, on-ROW sample sites located away from disturbance (Disturbance Class 4) were much more similar to adjacent off-ROW locations than sample sites located adjacent to Highway 16 or railway ROWs (Disturbance Class 1). This trend is shown on Figure 5. Although the increase in similarity between on- and off-ROW locations has progressed slowly between 2012 and 2017, it is expected that most locations will support a diverse assemblage of native plants over time where competition with invasive grasses is not a limiting factor.

CONCLUSIONS

Significant effort was put into reclamation along this project (Novak and Fryer 2009), including seeding with reclamation unit-specific native species, establishing forb islands along the ROW to aid seed dispersion and support biodiversity, and implementing intensive post-planting irrigation and plant protection programs to promote survival and preserve quality of plants. In 2017, *total* ground cover surpassed the 80 percent *native* vegetation target in the

Native Cover MO/DER and vegetation was controlling erosion throughout the vast majority of the project. Nevertheless, 10 years following construction, the three quantitative MO/DERS discussed in this paper have not been achieved, suggesting that the targets laid out in these MO/DERS were not realistic short-term objectives.

More recent projects have addressed this issue by focusing more on comparison to pre-construction conditions (including pre-disturbance non-native grass cover) and on the overall trends observed. For example, the Grassland Survey and Mitigation Plan for the Trans Mountain Expansion Project (Trans Mountain 2017) includes a goal to "revegetate areas of native grassland disturbed by Project activities with native grassland species." This goal includes the following measurable targets:

- Percent cover of native bunchgrass species, both individually and together similar to baseline using the thresholds in Delesalle et al. 2009.
- Relative percent cover of each plant functional group (i.e., layer) within the community, in total, similar to baseline using thresholds in Delesalle et al. 2009.
- Native species diversity and percent cover within each functional group is increasing with time since disturbance.

These targets focus on similarity to baseline—rather than a uniform target—and they measure success in achieving native species diversity as "increasing with time since disturbance," rather than reaching a specific overlap with off-ROW. Also, the timeframe to achieve these goals is 10 years, rather than the original five-year timeframe of the TMX MO/DERS. These changes mean that the goals are more likely to be met than the Density, Native Cover, and Species Overlap MO/DERS discussed in this paper.

Collecting sufficiently detailed baseline data to measure success, and monitoring at 10 years, are both substantial commitments. This level of effort is only appropriate in specific areas of concern, such as JNP and the native grasslands along the TMX Project.

Ten years after the construction of the TMX Anchor Loop Project, total vegetation cover is high, and total native cover is increasing where competition with non-native grasses is not limiting. After 10 years, cover on-ROW is predominantly grasses; trees, shrubs, and forbs still make up a small fraction of total cover. Similarity between on- and off-ROW communities has increased in the monitoring period, but remains below the level originally laid out in the MO/DERs. MO/DERs or other measurable reclamation goals help inform post-construction monitoring programs and determine the success of reclamation. Reclamation goals should acknowledge baseline conditions and focus on positive trends.

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AUTHOR PROFILE

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Kristen Beechey is a biologist with Jacobs. Beechey holds a Bachelor of Science degree from the University of British Columbia. Her areas of expertise include vegetation inventory, rare plant mitigation, and vegetation assessment. Beechey has experience leading fieldwork and reporting on the vegetation components of NEB-regulated projects in Alberta and BC.

ROW VM Using Web and Mobile-Based GIS

Dane Pehrman, John Hurd, and Jeremy Drake

Keywords: Control, Geographic Information System (GIS), Mobile, Natural Gas, Right-of-Way (ROW), Vegetation Management (VM).

Vegetation management (VM) along thousands of miles of rights-of-way (ROW) is a dynamic challenge requiring a continual effort to monitor and maintain. In 2017, TransCanada (TC) contracted Jacobs to assess the condition of existing vegetation within more than 16,093 kilometers (km) (10,000 miles [mi]) of their pipeline ROW. To contract VM services for the existing ROW, TC needed to understand the current state of vegetation along their ROW and classify it into four different grades based on pipeline access requirements and patrol needs. In addition to this classification, TC also wanted an economical method to assist them in prioritizing areas along their ROW based on geographic concentration of areas requiring more vegetation clearing. In partnership with TC, we developed a web and mobile geographic information system (GIS)-based solution to identify vegetation grades within the ROW. This solution primarily utilized existing georeferenced aerial imagery supplemented with verification data collected in the field by biologists. This solution provided TC with a geospatial database of vegetation grades within their ROW, alignment sheets, easy access to geo-referenced photographs to support maintenance planning, prioritizing, and clearing activities. Vegetation maintenance contractors were given access to the alignment sheets and photographs to help them more accurately estimate and plan vegetation maintenance activities.

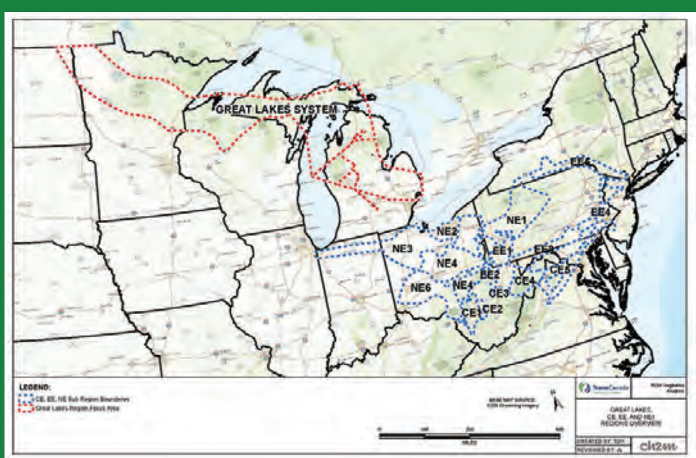

Figure 1. Areas of assessment for natural gas pipeline ROW

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

In 2016, the Columbia Pipeline Group (CPG) was acquired by TransCanada (TC), forming one of the largest energy infrastructure companies in North America. This acquisition included 24,140 kilometers (km) (more than 15,000 miles [mi]) of natural gas pipelines extending from New York to the Gulf of Mexico, with a significant presence in the Appalachia shale-gas basins. After this acquisition, the vegetation management (VM) team at TC, who formerly oversaw the legacy CPG right-of-way (ROW) system, needed an economical and fast method to collect and access data about the status of ROW vegetation control requirements for the legacy TC system to help them set aside the necessary budget for 2018 and 2019 vegetation control activities. To do this, TC employed a time-intensive method of developing hand-drawn ROW schematics based on physical inspection of the ROW by VM contractors. Once completed, the value of such information was immediately recognized, and the decision was made to pursue a similar survey of the legacy CPG system. While this original method was economical (at approximately $70/ROW mile) for a small ROW section, this method was schedule intensive, unmanageable over a very large system, and could not meet TC's budget and schedule requirements for acquiring the legacy CPG data.

In 2017, TC contacted Jacobs to develop and execute a method to accomplish this task for 16,093 km (10,000 ROW miles) of the legacy CPG system. In general, the methodology would include:

- Establishment of the criteria for defining four separate VM grades.
- Creation of a web-based geographic information system (GIS) that would provide access to publicly-available infrastructure, environmental, and aerial imagery data and would also be used to create and store data created by biologists both in the office and in the field.
- Desktop review of aerial imagery data to classify all 16,093 km (10,000 miles) of ROW into one of the four VM grades.
- Field verification by biologists to confirm the desktop review with actual conditions and near real-time upload of data collected on mobile devices.
- Automated generation of alignment sheets, photo logs, and summary reports to support planning and management decisions and for contractor use in the field.

We initially considered and priced three different methodologies to conduct the preliminary desktop assessment of vegetation within the ROW, followed by a similar field verification step. The first option proposed performing a remote sensing land classification algorithm on multi-spectral satellite imagery specifically obtained for this project. The second option proposed the use of newly obtained aerial imagery (2017) at a resolution of 0.5 meters (m) and then performing a remote sensing land classification algorithm on that imagery. The third option proposed a manual interpretation on publicly available aerial and satellite imagery between 2013 and 2017 such as Google Earth, Environmental Systems Research Institute (ESRI), NAIP, and Bing.

The costs for these approaches ranged from $416/ROW mile for the newly acquired satellite imagery to $107/ROW mile when using free public aerial imagery sources, primarily due to the costs of purchasing or acquiring the multi-spectral satellite imagery across such a large geographic area. When piloting the ability to interpret the vegetation grades resolution of these varying approaches and considering the rate of new growth that might have occurred when using older imagery, we concluded that we could accomplish the objective of classifying the ROW into the four vegetation grades with reasonable accuracy using the free public data. To meet the aggressive schedule with this manual approach, Jacobs internally conducted the interpretation and

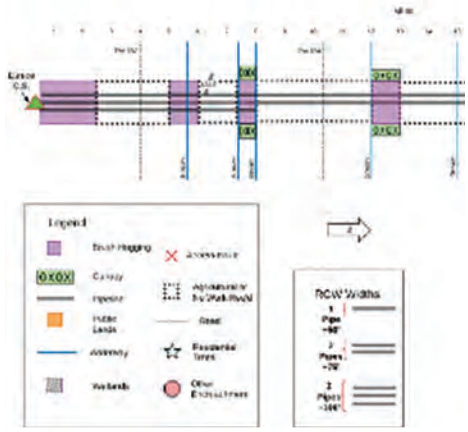

Figure 2. Schematic Depiction of Vegetation Assesment Outcome Using Initial Methodology

classification using a web-based GIS system and a widely dispersed team of experienced analysts familiar with aerial imagery interpretation ("crowd-sourcing"). Based on this value comparison, TC concurred and selected the more economical approach.

Work began in mid-2017 and continued through early 2018, when Jacobs completed the 16,093 km (10,000 mi) of classification, with interim deliverables of data, summary reports, geodatabases, and alignment sheets at the completion of each major pipeline system ROW. This data has been utilized in multi-year planning, as well as assessment of existing ROW projects for their benefit to the overall system.

METHODS

The geographic scale of the ROW and project schedule required a process that allowed for standardization, automation, and collaboration amongst a large and geographically diverse team of biologists. To achieve this schedule Jacobs developed an approach utilizing a commercial off-the-shelf (COTS) web-based GIS solution that allowed for offline mobile GIS data collection workflows. ESRI's ArcGIS Online and Collector for ArcGIS were utilized in addition to ArcGIS desktop client's ArcMap and ArcGIS Pro. In addition to the COTS software, some python scripts were developed to help automate the creation of the photo logs during the reporting phase.

To develop a scalable solution that would enable multiple teams to be working concurrently and meet the project schedule Jacobs and TC developed the solution by first focusing on a 2,414-km (1,500-mi) region to refine the process. This allowed the development of aerial interpretation of the imagery as well as understand the field data review process before deploying many more teams for the remaining regions.

After the first region was completed, the ROW was organized geographically to help group work into distinct areas for planning and executing the work. Seventeen areas, each including approximately 804 km (500 mi) of ROW on average were evaluated. Dividing the work into these areas allowed multiple teams to be working online and in the field without duplication of effort. The workflow followed for these 17 geographic areas was:

1. Preparation and training
2. Desktop review
3. Field prioritization
4. Field verification
5. Final review
6. Reporting

The preparation step of the workflow included gathering relevant existing GIS data related to the existing infrastructure and major geographic features and publishing those to a web application. An additional key step in the preparation step included the establishment and definition of the vegetation grades, done in conjunction with TC. This resulted in the following four vegetation grades:

- Grade 1—Difficult to patrol, requires clearing due to heavy growth (denser shrub/trees)
- Grade 2—Restricted foot patrol (sparser shrub, saplings)
- Grade 3—Compliant and accessible, may require regular mowing and limited clearing
- Grade 4—Clear ROW with minimal/no maintenance required, including agricultural/developed land

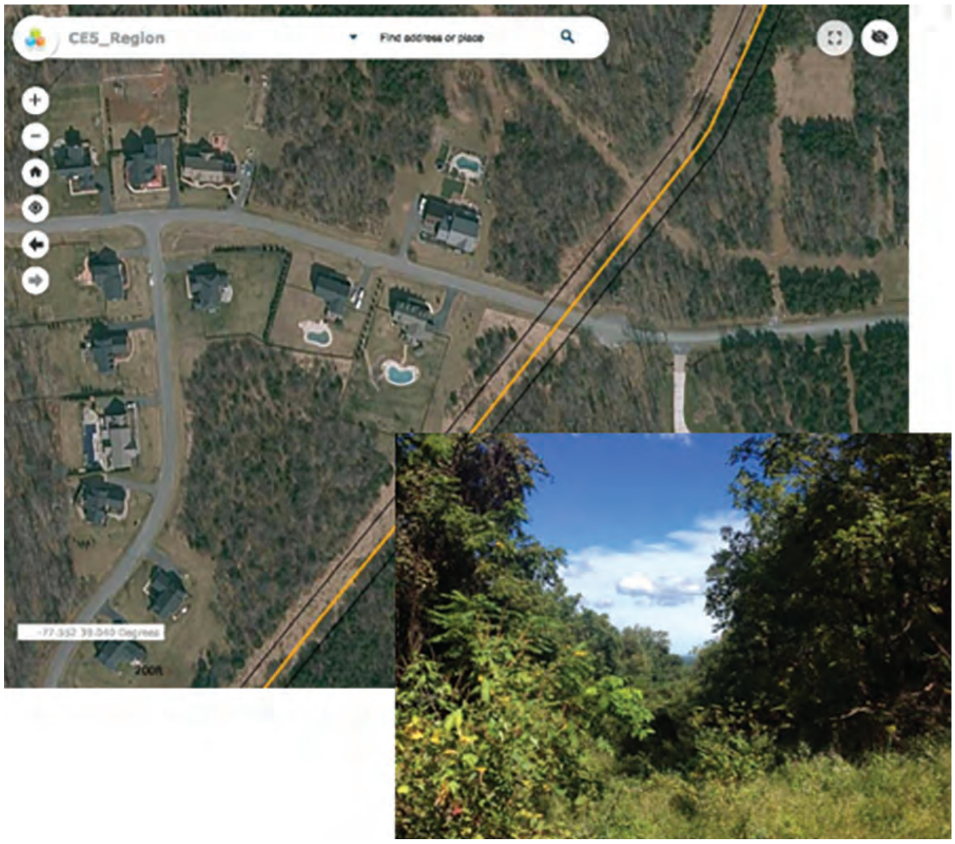

Figure 3. Example of Grade 2 ROW Conditions

Once the web mapping application was set up for each area, a training session with the biologists was completed to demonstrate how the application worked as well as a standardized approach to interpret the imagery. Each team created a draft vegetation grade dataset for each area. This dataset included the vegetation grades 1-4 described above, but also allowed for the identification of areas between grades 1-2 and 2-3 that were challenging to interpret from the online imagery alone.

After the draft datasets were created, areas were then prioritized for the field verification. This prioritization visually identified areas that were challenging to determine in the desktop imagery review and that were also within 304 m (1,000 feet [ft]) of a road. This prioritization was necessary so that field work could be focused on areas that were easily accessible increasing the number of sites that could be visited in a day and meet the aggressive project schedule. Once the field verification priority areas were identified, the biologists went into the field equipped with iPads and a Trimble R1 Bluetooth GNSS receiver to verify and correct the vegetation grade dataset. To streamline the process, the entire draft dataset was loaded onto the tablet by using the Collector for ArcGIS mobile application. This application allowed for work outside of cellular coverage, which was the case for much of this project. Additionally, the application allowed for collecting georeferenced photographs for documentation of the ROW condition.

After the field verification was complete, the biologists synced their data with the online web mapping applications, which was then subsequently reviewed by a senior biologist, and then incorporated into a final master GIS dataset for reporting and delivery.

After the datasets were reviewed and completed a final report was generated giving metrics on km of ROW in each vegetation grade and a description of geographic concentrations of areas requiring more significant vegetation clearing activities. This report was accompanied with detailed alignment sheets and photo logs for each region that were created utilizing data driven pages and some python scripts to help automate.

RESULTS & DISCUSSION

The result of utilizing the workflow described above allowed for each area to be completed from start to finish in approximately two months. Because there were 17 areas to be complete in the short span of about four months during the latter portion of 2017, many areas were completed concurrently to each other by utilizing multiple teams of biologists located near each geographic project area.

Approximately 20 different biologists were utilized to complete this work with a peak of about 15 working concurrently, either online or in the field. To complete this work about 200 field days were required, averaging around 80 km (50 mi) of ROW review a day. More than 50,000 individual polygons representing the vegetation grades along the ROW were created, verified, and reviewed as part of this assessment with thousands of georeferenced photographs being collected. Approximately 1,000 alignment sheets were generated as well.

This approach has saved TC hundreds of thousands of dollars annually, compared to the previous method, has significantly improved the accuracy of vegetation control estimates, and has improved TC's ability to meet regulatory requirements for vegetation control on their natural gas pipeline system.

CONCLUSIONS

As outlined in the introduction, we were asked by TC to develop a methodology for assessing the vegetation conditions along a very large distance and area of pipeline ROW that could be conducted economically and quickly meet a very

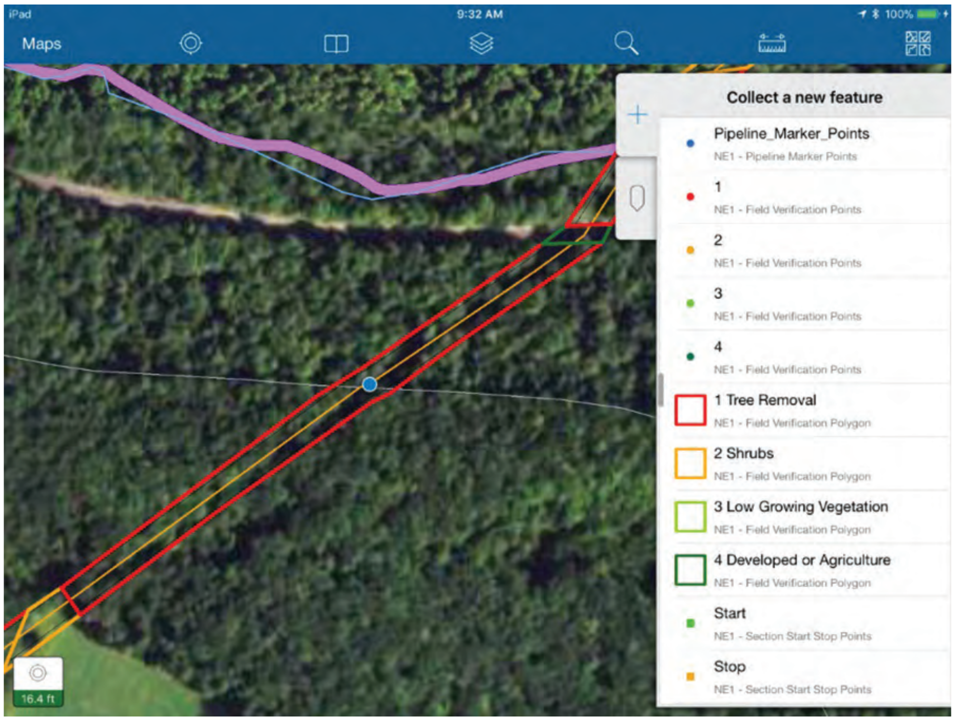

Figure 4. Field review of initial grades using iPad and Collector

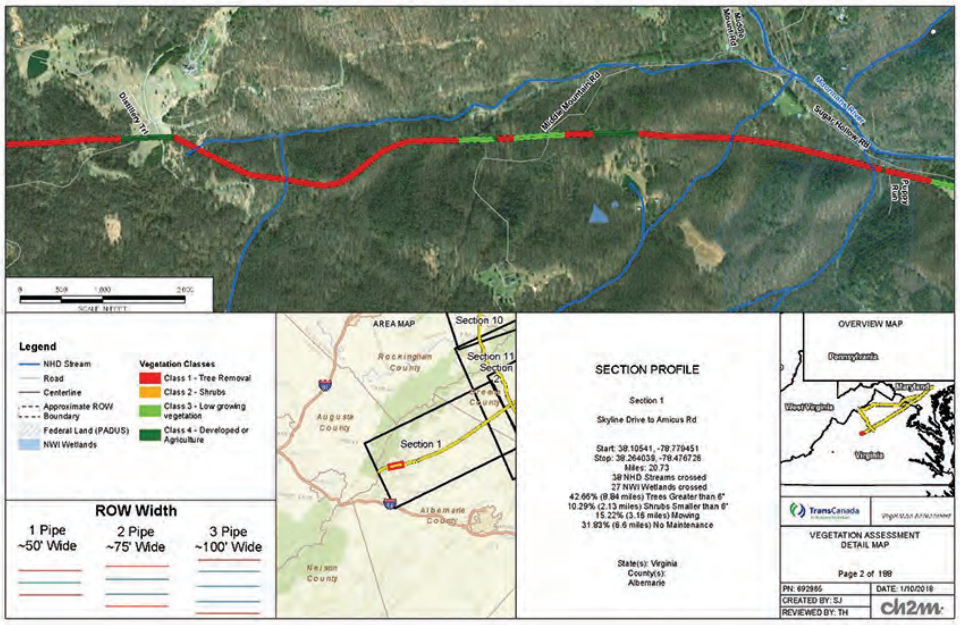

Figure 5. Example alignment sheet generated through customized web application

aggressive schedule. We developed three potential approaches that would achieve the schedule at varying costs for the data collection and analysis.

The scale and schedule of the project required a process that was as streamlined as possible to allow for quick turnarounds and to foster collaboration. The ESRI-based COTS GIS solution enabled the work to be completed by the subject matter experts regardless of location. Given that the biologists were spread out geographically across multiple office locations, having a web-based GIS platform allowed crowd-sourcing of the data creation and collaboration across offices to prioritize and review the work being completed.

Based on this process, we conducted the selected option (in this case, the most economical) to compete an assessment of vegetation conditions along these ROW which was to serve as a basis for later determination of VM requirements.

The mobile GIS solution of Collector for ArcGIS met all the project requirements and allowed for a streamlined field workflow. The data collection required polygons to be created with minimal attribute information along with photographs in a disconnected environment.

The integration of the mobile, web, and desktop GIS workflows allowed one central location for all the project GIS data that could be accessed by people in multiple locations. This central repository empowered the team to seamlessly move from one phase of the project to the next. An example of this was that as soon as the field review was completed for the day, it would be synced with an internet connection, and then the senior biologists and GIS staff could review the data the following day, back in the office, keeping the schedule moving.

Since completion of the work, TC and Jacobs have begun working together to provide access and training in using the GIS dashboard and mobile GIS for TC staff. The web-based GIS dashboard allows all staff and contractors immediate access to a wide variety of management information and allows real-time addition of observation data and will continue to develop as a geospatial database for TC's VM program.

ACKNOWLEDGMENTS

This work was funded and supported by TC. The development and selection of the technical approach pilot and subsequent modifications that supported production were aided significantly by Karen Stephenson and Almeda Tincher as TC. Refinement of the aerial and field interpretation approaches were made by Scott McBurney and Jody Lima at Jacobs. This work would not have been possible without these key contributors to the project.

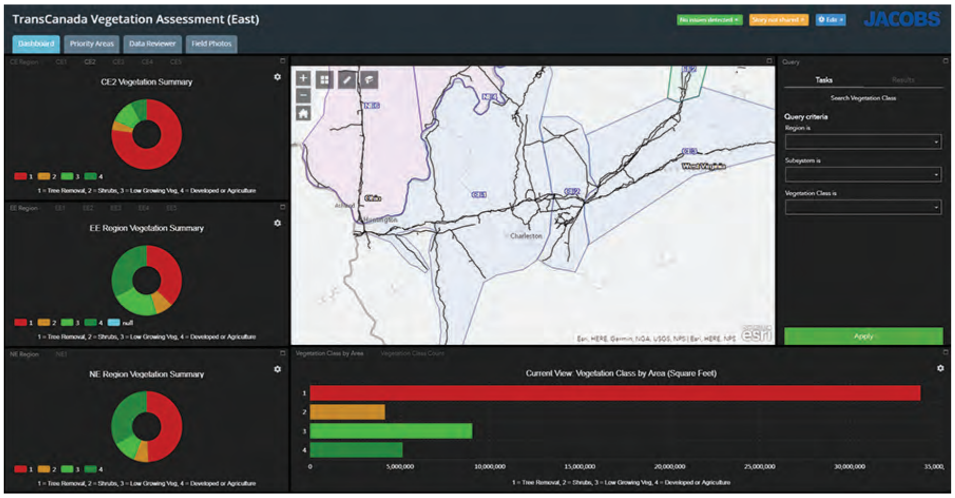

Figure 6. Screenshot of a portion of the web-based GIS dashboard developed for VM Group

AUTHOR PROFILES

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Pehrman is the vice president and resource manager for the Environmental Planning Practice in Jacobs' Global Environmental Services Business Unit. He received a Bachelor's of science degree in Biology from Stockton University and has more than 35 years' experience in successfully delivering international and U.S.-domestic projects involving expertise environmental and social impact assessment, routing, planning & permitting, and site remediation & restoration. Project types have included gas/oil pipelines, terminals, regional high-voltage transmission lines and substations, renewable energy generating facilities (geothermal, hydropower, solar, wind, biomass, and biogas), transportation (highways, bridges, and tunnels), water reservoirs, flood control facilities, residential/commercial projects.

John Hurd

John Hurd is currently a Senior Transmission Siting Specialist for Duke Energy. Prior to joining Duke Energy in 2018, Hurd spent 13 years in the environmental consulting field focused on GIS and siting and permitting energy-related projects—most recently at Jacobs in the Global Environmental Services Business where the work of this paper was performed. He has a strong background in project management, GIS, public engagement, route selection, and site selection. Hurd has been a project manager for more than 10 years and a GIS technology leader. John's GIS technical skills include GIS system architecture, database design, analysis, remote sensing, siting, and environmental modeling.

Jeremy Drake

Drake works for the U.S. Operations Strategy and Planning for TC. He previously worked with Chesapeake Energy and joined the TC ROW department in 2015. He brings seven years of industry experience in land rights and records management and has applied that experience in cataloguing TransCanada's Eastern pipeline systems and maintaining that information in the GIS system. He currently serves as manager of the TC ROW Departments research program and is responsible for metric tracking for all projects across the U.S. footprint. He also serves as Project Manager for various small dollar projects, including hazardous trees, residential encroachment removal, and brushing work for the northeast region.

12th International Symposium

Environmental Concerns in Rights-of-Way Management

PART VII

Wildlife Habitat

A Comparison of Pollinator Communities in ROWs and Unmanaged Lands: Understanding Habitat Opportunities in California Electric Transmission ROWs

Kerry Wininger, Victoria Wojcik, and Chris Halle

Keywords: Electric Transmission, Floral, Habitat, Integrated Vegetation Management (IVM), Oak Resources, Pollinator, Rights-of-Way (ROWs), Utility, Woodland.

Historic and recent evidence indicates that managed rights-of-way (ROWs) provide habitat for native pollinators. However, research and technical guideline gaps exist in western landscapes where studies on this are limited. We conducted a three-year investigation with the objective of assessing and comparing pollinator communities associated with managed ROWs crossing conservation lands at Fairfield Osborn Preserve in Sonoma County, California and the adjacent conservation lands to gauge the value of each landscape to pollinators. ROW management, primarily the removal of taller vegetation in preference of low-growing species, may create a landscape with more flowering plants and more foraging opportunities for pollinators. Three landscape types were compared in this study: managed ROWs, adjacent closed-canopy oak woodland, and adjacent open oak woodland meadow. Results of our three-year study show trends of higher occurrence and abundance of pollinators on the managed ROW and adjacent open meadow when compared to adjacent closed-canopy, including highest pollinator richness in ROWs. Multiple years of data collection have produced a database of plant-pollinator relationships that can be used to quantify the biodiversity benefits of managed ROWs to pollinators in these systems. Comparative data further support the value of targeted ROW management to pollinators in western oak woodland landscapes.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Plant-pollinator interactions are critical to the sustainability of plant and animal life, yet pollinators are in decline (Kevan and Viana 2003). Pollinators are essential not just for conservation, but also for agriculture and the direct and indirect ecosystem services that natural living organisms provide. Although many factors are contributing to decline in pollinator populations, habitat loss has been singled out as the largest threat (Aizen and Feinsinger 2003; Brown and Paxton 2009).

Vegetation in habitats managed for the thousands of miles of overhead powerlines that exist in the U.S. and worldwide provide unique opportunities for potential pollinator conservation areas (Wojcik and Buchmann 2012). ROWs also intersect multiple habitats, connecting prime agricultural areas and home gardens, and reinforcing key pollinator migration routes. When correctly managed, research has shown that green spaces within developed systems can act as important refuges for pollinators (Angold et al. 2006; McFrederick & LeBuhn 2006). Electric transmission rights-of-way (ROWs) must provide safe and reliable power while ensuring public safety, and are managed with these responsibilities in mind. Additional achievable goals often include supporting ecosystem sustainability and wildlife habitat (Bramble and Byrnes 1983). Pollinators are documented to occur in higher richness and abundance on early successional lands, which are often maintained by the moderate level of disturbance that ROW management activities themselves create (Russell et al. 2018). Thus, we are interested in the overall effect of ROW activities, including integrated vegetation management (IVM), on maintaining pollinator habitat.

However, much of this research and the resulting technical guidelines, such as those on the timing of mowing, have been developed from studies of eastern landscapes. This limits the ability of western utilities to quantify the value of their lands to conservation and to make science-based management decisions. Pollinator-friendly habitat in northern California is often utility-line-friendly habitat: low-growing, typically herbaceous, self-seeding, often native plant species that are adapted to a Mediterranean climate and are not particularly flammable. Aside from different climate and species composition, challenges in the west include the role of fire and topographical variability. Western ROWs are not as often cut through large tracts of forest, but instead create a highly variable patchwork with more edges.

Oak woodlands are the dominant plant community at Fairfield Osborn Preserve in Sonoma County, which is owned and managed by Sonoma State University's (SSU) Center for Environmental Inquiry (CEI). A novel partnership was formed between CEI, the non-profit Pollinator Partnership (P2), and Pacific Gas & Electric Company (PG&E), who manages the electric transmission ROW that crosses conservation lands on the preserve. CEI envisions an environmentally ready generation. It develops innovative programs at three preserves, creating teams of faculty, students from all disciplines, and community partners to find solutions to key regional issues, including water shortage, loss of biodiversity, climate change, and more. CEI supplied student interns for this project, who gained valuable experience tackling a real-world challenge in an outdoor environment. P2 connects all stakeholders—agriculture, business, government, gardeners, and consumers—in order to increase sustainable best practices for pollinators through development of conservation tools, educational materials for schools and the public, regional habitat planning guides, original research and consulting, and via public policy advocating. A founder of the Right-of-Way Stewardship Council, PG&E has invested in IVM research projects and field studies investigating best practices for supporting multiple resource management goals encompassing both energy service and ecological resources, such as pollinators and wildlife.

Figure 1. One of two managed ROW plots at Fairfield Osborn Preserve, May 2017

Figure 1. A leafcutter bee (*Megachile spp.*) on Italian thistle

In this study, we aim to collect new data to help describe the plant-pollinator relationships common to managed ROWs in California oak woodlands. We are also interested in assessing the impact of ROW management, and aim to compare the pollinator support value of managed ROWs to non-managed natural areas in and around oak woodlands. We hope to help inform evidence-based management decisions for western ROWs, with the potential to transform 150,000 miles of habitat for pollinators in California.

METHODS

Site Description

In 2015, a Fairfield Osborn Preserve ROW Vegetation Treatment Plan was developed in consultation with SSU Facility arborists, the Director of CEI, PG&E, and PG&E Consultants, and in compliance with existing easements governing preserve ROWs. This stipulated that vegetation clearing and trimming be kept to a minimum, no wood be removed from the preserve, and that dead trees and cut trunks be left in place for use by wildlife. Selective cut-stump and low-volume foliar spray herbicide treatments were used in 2014, with subsequent IVM in 2015, 2016, and 2017 that included spraying for noxious weeds and treatment of incompatible plants that were re-growing, newly growing, or re-sprouting. The Osborn Preserve is home to many ongoing and short-term research projects by students, faculty, and other researchers, so ROW management has also aimed to minimize impacts on these studies.

Two locations on the preserve near the ROW were chosen for establishment of research plots. Each location contained three plots of different habitat types: managed ROW, adjacent closed-canopy oak woodland, and adjacent open oak woodland meadow. In both locations, the managed ROW was previously part of the oak woodland habitat, and the meadow was several hundred yards beyond the current woodland.

Pollinator Sampling

In order to assess level of habitat value for pollinators, we measured their active use of flowers on the landscape. Five-minute observations of pollinator bloom visitation were conducted within standard square meter quadrats. Before data was collected each day, floral resources were examined across each of the six plots for five to 10 minutes to select sampling quadrats. Three or more quadrats were selected in each plot and sampled in the morning, then these same quadrats were sampled again in the afternoon. Each year, counts were conducted during periods of bloom, on a bi-weekly basis during high bloom, and reducing to once every three to four weeks when bloom levels diminished near the end of the year. Data was collected from June to October in 2015, March to October in 2016, and May to July in 2017.

Pollinators observed were categorized by functional groups instead of species, which is a common method that allows more data to be collected when assessing pollinator community dynamics (Wojcik et al. 2015). Assessing to functional groups minimizes error in visual identifications of pollinators in motion and allows for a wider range of participants, such as student interns, to collect accurate data. We assessed the following functional groups:

- Green bees (*Agapostemon spp.*)
- Mining/spring bees (*Andrena spp.*)
- Honey bees (*Apis mellifera*)
- Bumble bees (*Bombus spp.*)
- Small carpenter bees (*Ceratina spp.*)
- Large and small sweat bees (*Halictus spp.*)
- Tiny sweat bees (*Lassioglossum spp.*)
- Leafcutter bees (*Megachile spp.*)
- Long-horned bees, (*Melisodes spp.*)
- Mason bees (*Osmia spp.*)
- Large carpenter bees (*Xylocopa spp.*)
- Bombyliid flies (family Bombyliidae)
- Hover flies (family Syrphididae)
- Other pollinating insects that include taxa such as beetles, ants, and butterflies

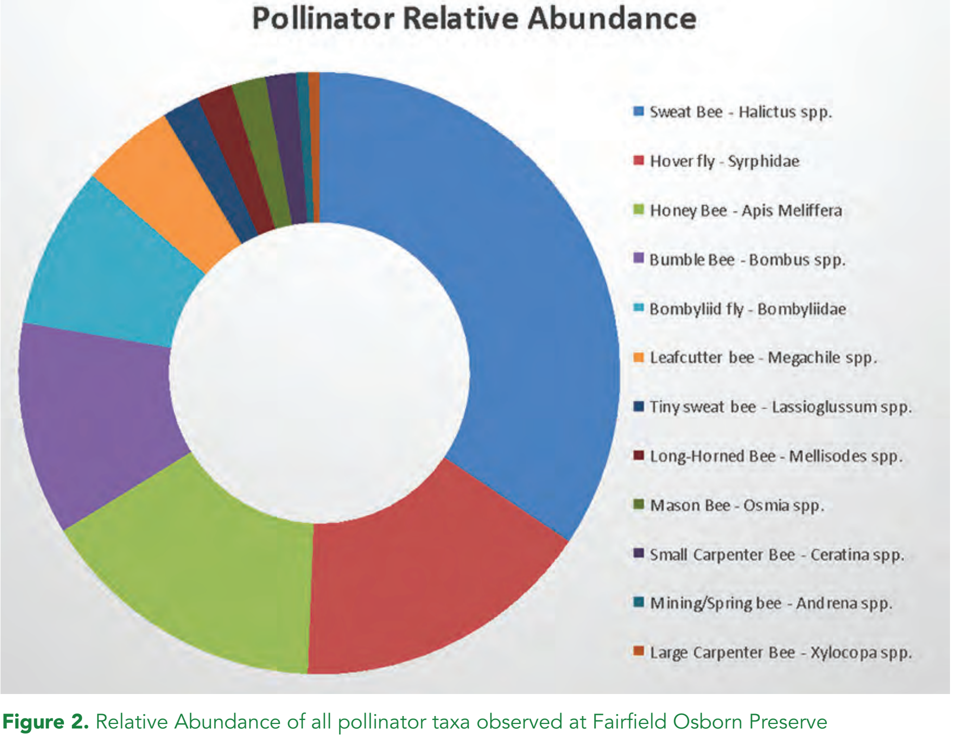

Figure 2. Relative Abundance of all pollinator taxa observed at Fairfield Osborn Preserve

Data Management and Analysis

A dataset was created in Microsoft Excel from pollinator visitation observations across all plots in both locations. This data was analyzed using the web-based StatCrunch statistical software application from Pearson Education. Measures from ROW, woodland, and meadow sites were compared using analysis of variance (ANOVA) with Tukey HSD.

RESULTS

Nine native bee genera (mining/spring bees, bumble bees, small carpenter bees, sweat bees, tiny sweat bees, leafcutter bees, long-horned bees, mason bees, and large carpenter bees), honey bees, and two families of pollinating flies (Bombyliidae and Syrphidae) were observed visiting flowers in plots at Osborn Preserve (Figure 3). The most common pollinators recorded were sweat bees, followed by hover flies, then honey bees, then bumble bees.

Honey bees were found in much larger numbers in ROW plots than meadow or oak woodland plots (Figure 4). Occurrence rates of most native bee types were higher in ROWs than meadows or woodlands, but not significantly. Exceptions to this were sweat bees and mining bees, which were seen in larger numbers in meadow habitat. Pollinating flies preferred meadow to woodland or ROW plots. For every pollinator group, oak woodlands showed the lowest pollinator occurrence rate.

In both 2015 and 2017, overall pollinator occurrence rates were higher in ROWs than meadows or woodlands, but the only significant relationship was between ROWs and woodlands in 2015 ($p = 0.039$, Figure 5). In 2016, larger numbers of pollinators were found in meadows than ROWs, though this result

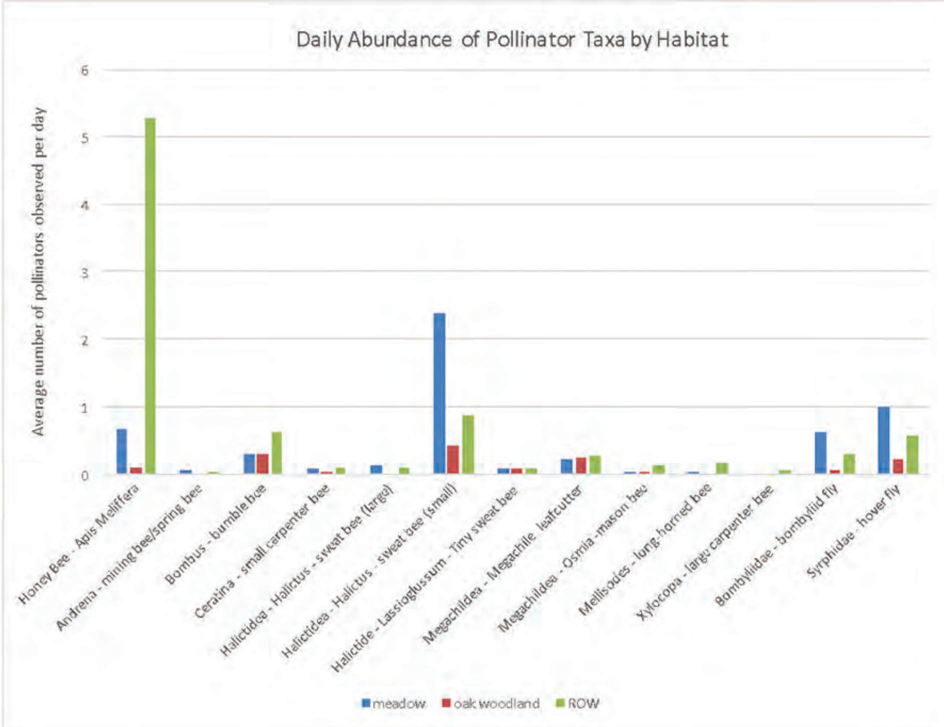

Figure 4. Pollinator visitation to floral resources in meadow, oak woodland, and ROW plots at Fairfield Osborn Preserve across all three study years.

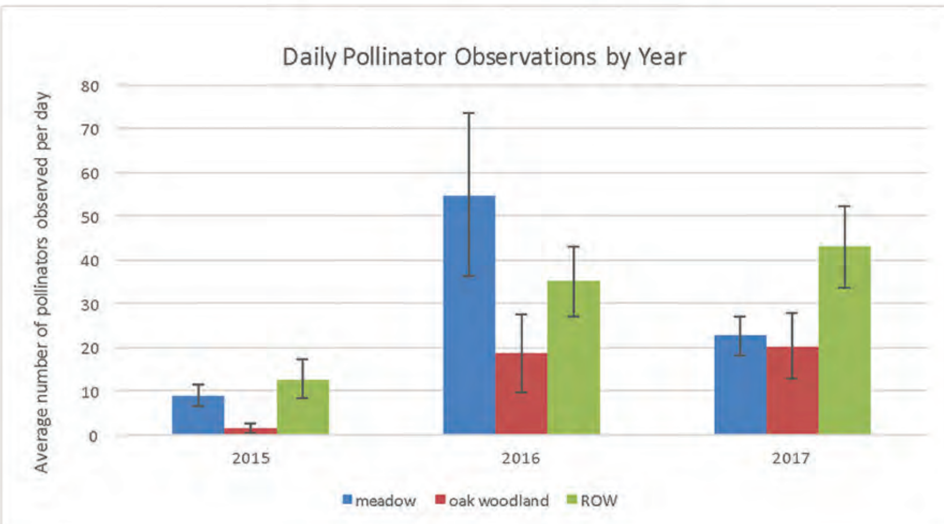

Figure 5. Pollinator visitation to floral resources in meadow, oak woodland, and ROW habitats at Fairfield Osborn Preserve during each year of our study. The error bars represent standard error.

was not significant (p = 0.150), and both habitats showed larger occurrence rates than oak woodlands. The average number of pollinators in both ROW plots and adjacent oak woodland plots increased across the three years of our study.

Looking across the season, pollinator observations peak for all habitat types in May, and to a lesser extent in August for meadows and ROWs (Figure 6). Throughout the year, the number of pollinator observations in ROWs varies less than in meadow or oak woodland habitats.

ROW plots also contained more plant taxa than meadow and oak woodland plots (Figure 7). However, out of 25 plant families represented in the data, ROW plots had only 16 families present, while unmanaged meadow and oak woodland plots both had 19 families present.

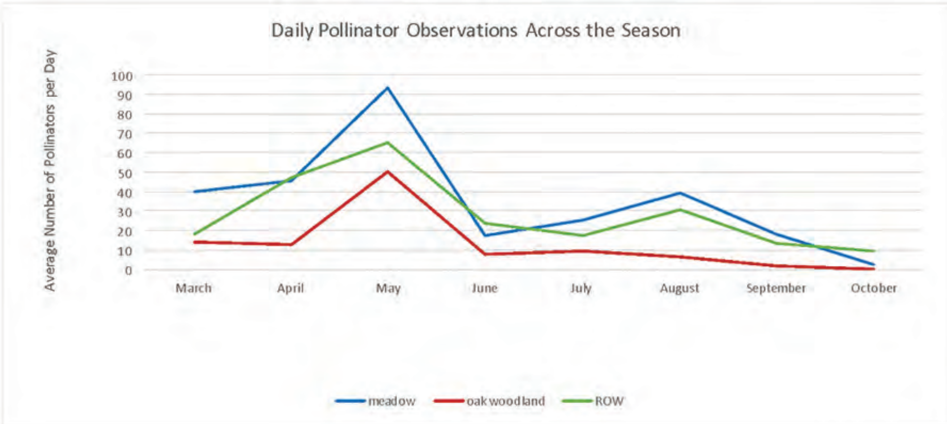

Figure 6. Seasonal trends in observations of pollinators utilizing floral resources at Fairfield Osborn Preserve across all study years

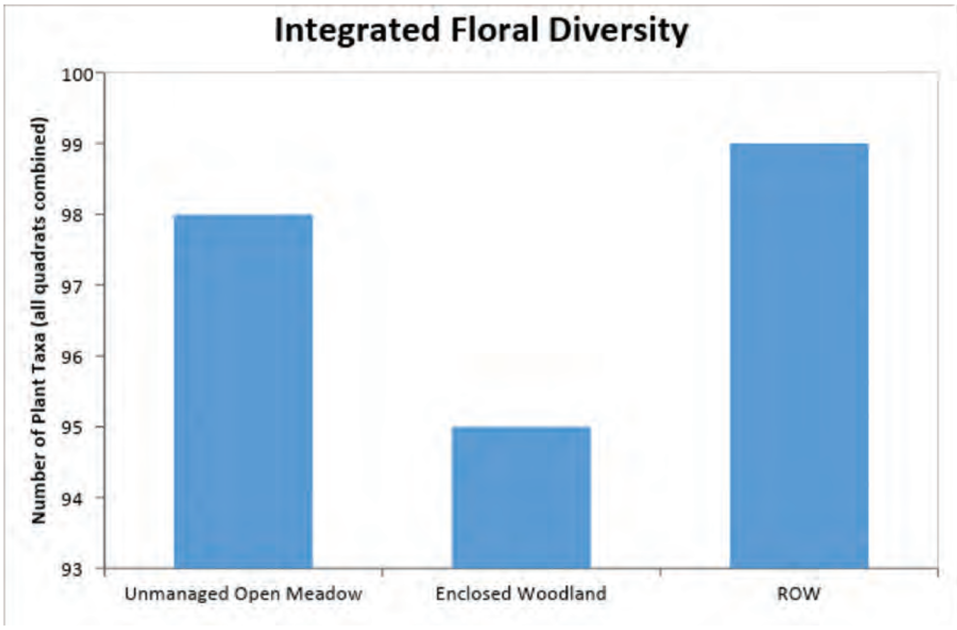

Figure 7. Number of plant taxa observed at Fairfield Osborn Preserve across in each habitat type.

DISCUSSION

Many pollinators utilize floral resources in and near ROWs at Osborn Preserve. Almost every pollinator type was found in every habitat, though some patterns were observed. In our study, we consistently saw more native bees, and more pollinators in general, in ROWs and meadows than in adjacent oak woodlands, though this is not always statistically significant. Other studies have shown that transmission corridors can provide valuable habitat for native bees when compared to surrounding areas that are less actively managed (Russell et al. 2005; Wagner et al. 2015). Disturbance from ROW management that increased floral diversity and lack of floral resources due to shade were factors indicated as possible explanations for this trend (Hill and Bartomeus 2015). Remembering that ROW plots were naturally part of the oak woodland habitat, we can infer that more pollinators are supported now in those area than when they were unmanaged.

The inclination of honey bees to utilize ROW habitat moreso than other habitats was remarkable. One clue may lie in the types of plants found in each habitat. More than a third of all plant taxa in ROW sites were from the family *Asteraceae*, containing many species that prefer disturbed areas, whereas less than a quarter of plants observed in meadow and oak woodland sites were from this family. Many native members of *Asteraceae* are ideal components of ROW habitat, providing foraging resources for a diversity of pollinators and adding minimally flammable, low-growing, herbaceous material to utility-line corridors. However, some of the most noxious species for both ROWs and native California habitats also belong to *Asteraceae*, such as yellow star thistle (*Centaurea solstitialis*) and Italian thistle (*Carduus pycnocephalus*). Previous research on pollinator use of managed ROWs in the American River Parkway about 97 kilometers (km) (60 miles [mi]) inland from Osborn Preserve asserted that honey bee preference for weedy plant species, such as thistles, contributed to their higher occurrence in ROW plots (Wojcik et al. 2015). This could be at play here as well, though without singling out plant species within *Asteraceae*, we're unable to fully understand finer scale patterns in pollinator floral visitation such as this. Interestingly, members of *Xylocopa*, which are known to prefer flowers from *Asteraceae*, were only observed in ROW sites. Additionally, bees within *Melisodes*, another bee genus that prefers to forage on flowers that grow in disturbed areas in full sunlight, were found 24 times in ROWs throughout the three-year study, but only once in meadows and not at all in woodlands.

In addition to an abundance of plant taxa within *Asteraceae*, we found more total plant taxa in ROW sites, but these taxa represented fewer plant families than in meadows and woodlands. Similarly, ROW sites show the highest richness of bee families. When comparing the presence of at least one individual pollinator from a bee family, ROW sites contained all eight bee families observed, while meadows had seven out of eight, and woodland had only six out of eight.

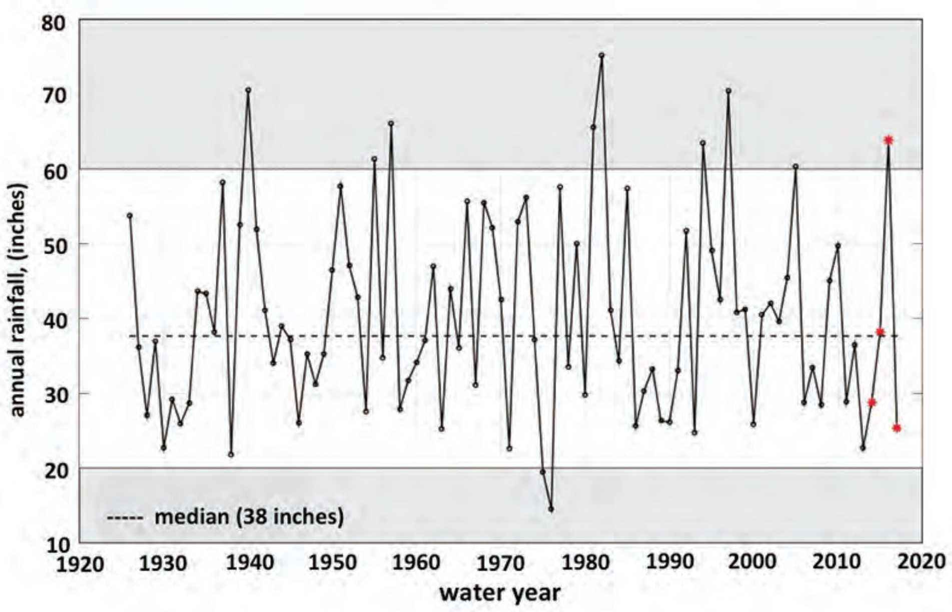

Figure 8. (Title): Annual Rainfall at Graton, California from the 1926 Water Year Through the Present. A water year is defined as beginning on October 1st. The last four years are indicated in red, and correspond to the study years at Fairfield Osborn Preserve. "Wet Years" ("Dry Years"), indicated by the upper (lower) gray bars, are defined here as the "approximate median" of 40 inches, plus (minus) 20 in.

One interesting finding was the lack of consistency in regards to whether flowers in meadow or ROW sites provided for more pollinator activity across the three years of the study. Though visual trends can be seen graphically, there was no statistically significant difference between pollinator observations in these two habitat types both when broken down by year and with all years pooled. In 2016, meadows visually appear to provide better habitat value than ROWs, whereas the opposite appears to be true in 2017.

One potential explanation for this stems from the high variability of rainfall in the region, with the longest observational record in the region showing an annual rainfall that varies between 15 and 75 inches (Figure 8). In 2015, following four years of drought, and one year after the original IVM work, pollinator observations were low in all habitats. One year later, the drought had begun to subside, likely encouraging plant growth, which in turn appears to have encouraged pollinator activity in all habitats, but especially in meadow plots. This could be due to a larger seed bank or dormant individuals lying in wait in meadows when compared to ROW habitats that had recently resembled a closed-canopy woodland. The 2016 water year, corresponding to the pollinator observations made in 2017, was extreme in the context of the 92-year observational record. Three years after the original treatment, ROW habitat may have been given sufficient time, when combined with sufficient rainfall, for early successional species to grow large enough in numbers to attract more pollinators, though it is difficult to explain the drop in pollinator observations that year in meadows.

Another possible explanation for the variation between years relates to changes seen throughout each season. The number of pollinator observations fluctuates monthly, with peaks in May and August. 2015 sampling did not start until after the first peak, and 2017 sampling ended before the second peak. Only 2016 captured the full length of time when pollinators are most active. Also interesting is that activity levels of pollinators remain most consistent throughout the year in ROW habitats, perhaps providing more stable year-round sources of floral resources.

It is also possible that outliers may be skewing the data. Of note is one particular sample day in 2016 that may be driving the higher number of observations recorded that year in meadow plots relative to ROW plots when compared to the two surrounding years. On May 11, 2016, there were 277 observations in the meadow habitat—more than 11 times more than the average for meadow plots with that day excluded. That day, plants of just one species (poison oak, *Toxicodendron diversilobum*) in one individual quadrat showed 102 pollinator visitations during one five-minute observation. This species is less common in ROW habitats as it tends to be treated near towers and access routes. Overall, poison oak accounted for 151 of that day's meadow pollinator observations, while a second species (California buttercup, *Ranunculus californicus*) accounted for 104, leaving just 22 observations for all other plant species combined. Also notable is that the majority of pollinators observed in meadow plots on that day were not bees. On August 22, 2016, a similar situation occurred. If data from both days were excluded, average daily pollinator observations between meadow and ROW habitat in 2016 would be nearly equal (meadow=34.3 average observations, ROW=33.9 average observations).

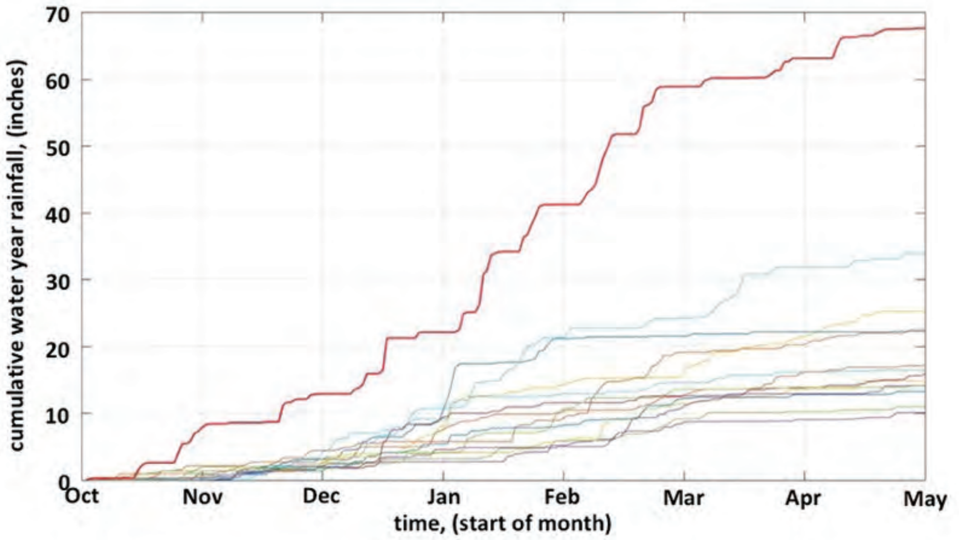

Figure 9. Cumulative Rainfall at Fairfield Osborn Preserve for the Years 1996-2007, 2015, and 2016. The totals are measured from the beginning of each water year on October 1st. Total rainfall during the 2016 water year (the bold red line) reached nearly 70 in by May.

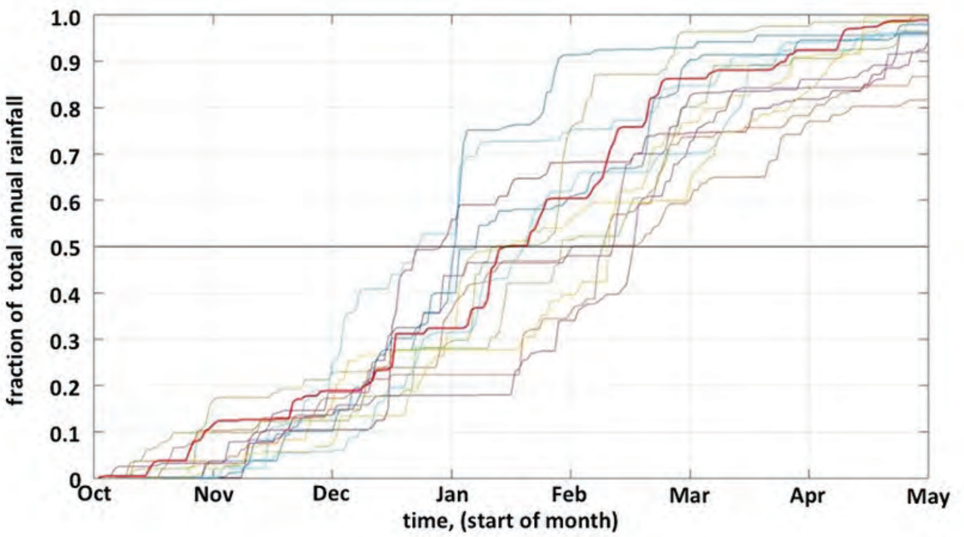

Figure 10. Normalized cumulative rainfall at Fairfield Osborn Preserve for the water years 1996-2007, 2015, and 2016. Rainfall is measured from the beginning of each water year on October 1st, and is normalized so that it reaches a value of 1 by the end of the water year. The time at which half of the rainfall is recorded each year varies between mid-December and mid-February. (The year 2016, in bold red, received half of its total rainfall by mid-January).

Future Directions

Further monitoring of these sites is necessary in order to better investigate how successional patterns in managed ROWs affect pollinator activity. It is difficult to make sense of anomalies that could be short-term cycles or related to environmental conditions with only three years of data. The TREE Fund and PG&E have provided funding to SSU to continue this project into the future. We plan to expand the research in a few meaningful ways.

Firstly, as noted, the pollinator observations need to be placed in the correct long-term environmental context. The more limited rainfall observational record at the Fairfield Osborn Preserve (Figure 9) may provide insight. As shown in the regional data, the 2016 water year was also an extremely wet year at the Preserve, with the annual rainfall reaching nearly 70 in, double that of the next highest rainfall total. The rainfall timing was also fairly typical, with half the rainfall being recorded before January 15, and half afterward (Figure 10). However, other years are more variable, with half of the rainfall in any water year occurring anywhere from mid-December to mid-February. We plan to investigate the rainfall timing and temperature fluctuations more closely to provide a clearer understanding between climate variability, plant bloom, and pollinator abundance. We hope to explain some of the late plant blooms seen in this most recent water year (S. Benson, *personal communication*, August 2018; Halle, *personal communication*, October 2018), as well as the effects of the varying bloom on local pollinator abundance. Local outdoor enthusiasts report getting stung some years by hornets, some years by honeybees, and some years not at all.

Secondly, we have established field sites at Pepperwood Preserve in Santa Rosa, California and Eldorado National Forest outside of Placerville, California. These two sites provide the opportunity to examine ROW management techniques across a variety of western ecosystems, including oak woodlands and a mixed conifer forest. In addition, both of these sites have burned since 2014, allowing us to integrate the role of fire in western ecosystems into our study.

Thirdly, an investigation into the impact of two different approaches to ROW management has been added. The 2015 American River Parkway study found variation in bee richness and abundance according to ROW management type. Drawing on this, newly established sites at all three locations will contrast untreated sites, sites that are treated mechanically, and sites that are treated both mechanically and chemically. This will allow us to get a deeper understanding of the dynamics affecting the impact of ROW management strategies across various California landscapes.

Fourthly, as noted, categorizing vegetation by plant family has its disadvantages when assessing the success of ROW management for ecological value, and it also insufficient in helping evaluate whether or not treatment is producing the desired goals for utility structure integrity. Therefore, professional vegetation sampling was done at each location in 2017 and 2018, and species level data is now being recorded for all floral resources.

CONCLUSIONS

This study lends support for the potential of IVM in ROWs to increase the value of oak woodlands to pollinators. Pollinator richness at Osborn Preserve was highest in treated ROWs when compared to meadows and oak woodlands. Honey bees in particular show preference for ROWs as opposed to either other habitat types, and sweat bees prefer meadows, albeit to a lesser extent. Since the implementation of the Fairfield Osborn Preserve ROW Vegetation Treatment Plan in 2015, pollinator occurrences in ROW plots have been increasing. We suggest that longer-term research be conducted to better understand the role and possible synergy of factors such as drought, seasonal timing, and successional patterns in plant-pollinator relationships across managed and unmanaged oak woodland habitats.

ACKNOWLEDGEMENTS

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AUTHOR PROFILES

Kerry Wininger

Kerry Wininger is a M.Sc. candidate in Biology and serves as Outreach Coordinator for Fairfield Osborn Preserve with the Center for Environmental Inquiry at SSU. Wininger's research interests focus on relationships between plants, insects, and plant pathogens. She recently published a review paper on this topic in the Annals of the New York Academy of Sciences. Her thesis research investigates how insects influence infection dynamics of the pathogen that causes Sudden Oak Death, *Phytophthora ramorum*, and its foliar host California bay laurel. Wininger serves as coordinator for the Sudden Oak Death Program through University of California Cooperative Extension, Sonoma County and Secretary for the California Native Plant Society's Milo Baker Chapter. She holds Bachelor's degrees in Integrative Biology and Theater from UC Berkeley. Wininger has been working on the pollinator ROW study for four seasons, collecting field data, managing and training field researchers, and working to assess data.

Dr. Victoria Wojcik

Dr. Vicki Wojcik has been working to protect and promote pollinators with Pollinator Partnership (P2) since 2011. As Research Director, she oversees P2's research program, keeping on top of new and emerging pollinator issues and managing a program set that includes pollinator habitat conservation and landscape management assessments; understanding and enhancing agroecosystems; land use and pesticide policy review; support for threatened and critical species; and ecosystem service assessments. Wojcik joined the San Francisco team after completing her PhD in Environmental Science, Policy, and Management at UC Berkeley. In 2015, she returned home to Toronto with the expansion of P2's programs in Canada. Wojcik's interest in pollinators was sparked during her undergraduate studies at the University of Guelph and has continued ever since. Her graduate research focused on understanding how native bees use gardens and habitats in cities. This focus on pollinators in human-dominated landscapes has continued throughout her career.

Chris Halle

Dr. Chris Halle has worked with earth observing systems for more than 30 years, including managing and leading cross-disciplinary research teams to address complex, large-scale projects for industry. His areas of expertise include environmental observation and sampling, data quality control, algorithm development, and data synthesis, and presentation. As the Center for Environmental Inquiry Nature!Tech Lead, he creates industry-academic research collaborations on environmental and technology projects. He assists faculty in scoping and developing projects suitable for classroom instruction, and supervises students undertaking long-term monitoring projects on CEI lands.

Assessment of Decommissioning as a Management Method for Low-Volume Roads in Québec, Canada

Karelle Gilbert and
Sylvain Jutras

Keywords: Low-Volume Roads, Planning, Stream Crossings, Water Management.

Natural gas and hydroelectricity transmission requires the construction of many low-volume roads in public land. In Québec, Canada, a lack of regulations in regard to maintenance has caused a great number of such roads to be abandoned with time. Roads and stream-crossings are left in place without proper maintenance or inspection, which causes these structures to deteriorate. Poorly maintained stream-crossings can obstruct streams and create a barrier for fish passage. They are also an important source of fine sediments, which can harm aquatic ecosystems.

To address this problem, decommissioning of low-volume roads (i.e., replacing traditional stream-crossings by alternative ones such as improved fords) might be a solution. This would allow land access after the intensive use period without damaging the aquatic environment. The objectives of this research are (1) to develop a method for designing improved fords using hydraulic modeling, (2) to measure the impact of improved fords on sediment input and (3) to measure the impact of improved fords on fish passage. This will ultimately lead to an economic analysis of decommissioning as a management method that will help to produce a best management practice (BMP) guide to implement decommissioning in Québec.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

ROWs and Low-Volume Roads

Energy transmission requires the construction of a large number of low-volume roads on public lands. Those roads are used intensively during the construction phase of the transmission right-of-way (ROW). They are then no longer needed, except for maintenance of vegetation control. In some regions, time before two usages can go up to 10 years. In Québec, regulatory norms for those roads are the same as for every road on public land. While there are many norms regarding construction, there is a lack of norm regarding maintenance of the roads once the activity for which they were built is done. It has caused a number of low-volume roads to be abandoned with time. A recent study conducted on 13 watersheds has shown that only 21 percent of the roads were maintained (Figure 1a) (Paradis Lacombe and Jutras 2016).

When vegetation naturally grows back, this lack of maintenance can become an accessibility issue (Figure1b, c). In other cases, it can lead to erosion and washouts (Figure 2).

The major problem appears when sediments washed out from minimally maintained roads reach the hydrographic network. As hot spots for sediment input, stream-crossings are the contact point between roads and streams. Unfortunately, the same study revealed that 54 percent of stream crossings were in a mediocre state or worse (Figure 3) (Paradis Lacombe and Jutras 2016).

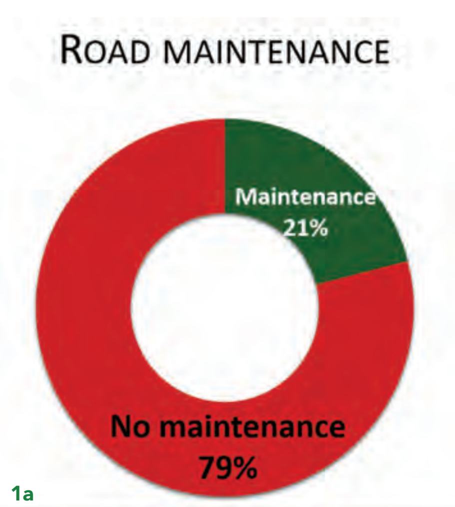

Figure 1a. Percentage of roads maintained on public land (Paradis Lacombe and Jutras 2016)

Figure 1b and 1c. Examples of Minimally Maintained Roads

Figure 2a and 2b. Erosion of roads due to poor water management

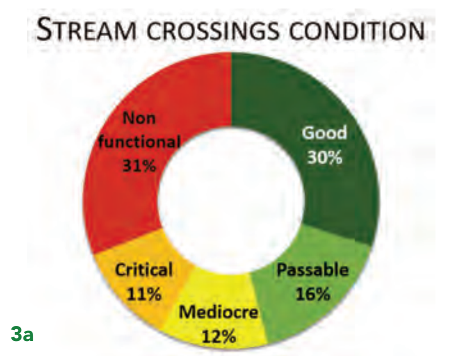

Figure 3a and 3b. Percentage of stream-crossings maintained on public land (Paradis Lacombe and Jutras 2016) and (b) new culvert installed next to old culvert in bad condition

Figure 4. Barriers to Fish Passage

Impact On Aquatic Habitat

Poorly maintained stream-crossings can cause obstruction of the stream and become a barrier for fish passage (Figure 4). They are thus a threat to aquatic habitat quality (Roni 2005; Bérubé et al. 2010; Trottier and Charrette 2011; Paradis Lacombe and Jutras 2016).

Another common problem with stream-crossings in Québec (mainly culverts) is that they often become sites for beaver (*Castor canadensis*) dam construction. These dams can cause failure of the stream-crossings, flooding of the roads, and can lead to massive washouts. In that way, they become an accessibility problem for road users and an environmental hazard (Figure 5).

Figure 5. Important Washouts Due to Beaver Dams

Massive inputs of sediment to the stream can also be harmful for fish by smothering spawning beds and macroinvertebrates on which they feed, causing mortality in species such as brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*). In the same way, siltage of stream beds can impact other aquatic vertebrates such as salamanders (Bérubé et al. 2010).

Considering that there are approximately 400,000 kilometers (km) (250,000 miles [mi]) of road on public land and an average density of 1.2 stream-crossings per km (two per mile) in Québec, water management is an important part of road planning for energy transmission companies. In their long-term planning, three main issues must be taken into account: (1) fish passage, (2) aquatic ecosystem quality, and (3) territory access for locals.

To assess these issues, decommissioning of low-volume roads using improved fords is being considered. Improved fords are stream-crossing structures where the banks and bed of the stream are stabilized with rocks to provide a stable driving surface so that vehicles can cross directly on the streambed (Figure 6). Improved fords were selected for this study because their construction is simple and low cost, they require minimum maintenance, and they represent low environmental risks

Figure 6. Improved Ford on Low-Volume Road, Côte-Nord, Québec

while maintaining access to the territory. While informal monitoring has been conducted to assess the impacts of improved fords on water quality and many best management practice (BMP) guides are available in the U.S. on how to build these structures, not many scientific data exist regarding real impacts of improved fords.

Figure 7a and 7b. Site 51 (a) before construction, August 2018, and (b) after construction, October 2018

Figure 8a and 8b. Site 101+100 (a) before and (b) after construction work, November 2018

Objectives of the Study

That is why four researchers from two Québec universities and two energy companies (Énergir and Hydro-Québec) have put together a study team. This team's main goal is to measure the impacts of decommissioning low-volume roads compared to traditional management methods.

This research project is divided into five main objectives:

1. Develop a method for designing improved fords using hydraulic modeling.
2. Measure the impact of improved fords on sediment input.
3. Measure the impact of improved fords on fish passage.
4. Make an economic analysis of decommissioning as a management method.
5. Produce a BMP guide to implement decommissioning in Québec.

METHODS

At present, four stream-crossings have been chosen for the study. Each is a site where there used to be a culvert that got washed out due to natural deterioration, beaver dam construction, or high flow. They are located on watershed, varying between four and 20 km^2 (1.5–7.7 miles^2). Sites were selected according to water depth (maximum of 50 centimeters [cm]), river width (maximum eight meters [m]), and proximity to road network. On each sites, locals crossed the stream without any stabilization of the river bed or banks. Improved fords have been constructed on each site between October and November 2018. Figures 7 and 8 show two of the sites before and after construction.

Designing Improved Fords

Hydraulic modeling using HEC-RAS software was performed on each site in order to design the improved fords. Diameter of the rocks used and length of rip rap was determined by the sheer force of the flow with a recurrence period of 10 years at the location of the crossing. Streambed level after construction was designed to be lower than the initial streambed level to ensure fish passage, even in low-flow periods. Rocks used were clean and angular. Construction work was done in less than a day for each crossing and only required an excavator and dump trucks to get the material on site.

Sediment Input

To measure sediment input from improved fords, two details were taken into account: sediment input from vehicle crossing and sediment input from construction of the structure itself. Passage-induced sediment was measured before construction (on natural ford) and after construction (on improved fords). In each case, turbidity sensors were installed upstream and downstream from the crossing and water samples were taken at specific time. Water samples were later filtered and total suspended sediment (TSS) was weighed. A regression between turbidity and TSS can then be produced and total induced sediment can be found using the method described in Lane and Sheridan (2002) and Lewis and Eads (2001). Results obtained will then be compared to sediment input from washouts on abandoned roads to compare each management method's impact on the aquatic ecosystem.

Fish Passage

To measure an improved ford's impact on fish passage, fish will be captured from each site and equipped with passive integrated transponder (PIT) tags. Detectors will be placed on the streambed both upstream and downstream from the crossing. This way, fish passage will be registered. The same method will be used on a control section of each stream to compare fish behavior between the stream-crossing and the control section.

Economic Analysis and BMP Guide

Ultimately, results obtained for each aspects of the project will be put together and analyzed to make an economic analysis of the use of improved fords. A BMP guide will then be produce especially for Québec in regard of the findings.

CONCLUSIONS

At present, data acquired are still being analyzed by the study team and no final results are available for publishing. For now, the study has focused on sites where massive environmental impact had already occurred due to the washout of culverts and road material. Of course, the ultimate objective of the project is to be able to think ahead and implement alternative stream crossings in the planning stage of every road construction project. For the years to come, the research team will focus on measuring impact of a combination of temporary bridges (for the intensive use period) and improved fords (for low-volume traffic). This will help build a new long-term vision of road management in Québec.

ACKNOWLEDGEMENTS

This research project is a unique partnership opportunity for energy companies and universities as well as for both provincial and federal government involved. It also leads to the formation of five graduate students in water management methods, which is of direct interest for the industry. Results obtained will help improve management methods in Québec's public land while taking into consideration operational constraints and environmental impact. We would like to thank our partners for their expertise and their support.

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AUTHOR PROFILES

Karelle Gilbert

Karelle Gilbert has completed a Bachelor's degree in Environmental Studies (Environnements naturels et aménagés) at Université Laval. During this time, she has worked for watershed management groups, where she was responsible for promoting sound practices to raise public awareness on the impacts of watershed users on water quality. She has also taken part in a stream monitoring program and laboratory analyses of water samples. She is currently pursuing a PhD in Forest Sciences in the Hydrology Laboratory of Université Laval.

Sylvain Jutras

Professor within the Faculty of Forestry, Geography, and Geomatics at University Laval, Jutras teaches several courses covering hydrology concepts applied to forests, wetlands, agricultural, and peri-urban environments. He is also responsible for an experimental watershed monitored since 1965 (Bassin Expérimental du Ruisseau des Eaux-Volées – BEREV) and a meteorological site that measured—among others—the snow cover (NEIGE site) in the experimental forest "Forêt Montmorency." His fields of expertise are linked to the effects of forest management practices on water, such as forest harvesting and stream crossing maintenance, snow cover measurements in forest, hydrology of peatlands, and stream cartography from light detection and ranging (LiDAR) data. Jutras is also very active within a watershed organization, the CAPSA, of which he is president since 2009.

BMPs to Protect Wildlife Populations and Improve Habitat

P. Chase Bernier,
Jason Magoon, and
Josh B. Holden

Keywords: Best Management Practices (BMPs), Biodiversity, Conservation, Habitat, Habitat Management, Monitoring, Mitigation, National Grid, New England, Operations and Maintenance (O&M), Rare Species, Transmission, Vegetation Management (VM), Wildlife, Wildlife Habitat.

Linear transmission line corridors typically intersect a mosaic of available wildlife habitats that provide a variety of important functions such as shelter, breeding, and nesting habitat, foraging areas, and migration routes. Numerous species are known to utilize transmission rights-of-way (ROWs) from large, highly mobile mammals such as American black bears (*Ursus americanus*) and white-tail deer (*Odocoileus virginianus*) to small, less mobile species such as spotted salamanders (*Ambystoma maculatum*), and eastern box turtles (*Terrapene carolina carolina*). Construction activities on ROWs have the potential to inadvertently harm wildlife populations through habitat loss, fragmentation, land use conversion, and potential direct harm. In a collaborative effort, BSC Group, Inc. and National Grid developed best management practices (BMPs) to avoid, minimize, and mitigate adverse impacts to wildlife habitat. The developed BMPs focused on modified erosion and sediment controls in addition to habitat improvement methods. The design of the modified erosion and sediment controls included different configurations of biodegradable, natural fiber, micro-mesh silt sock with compacted mulch ramps. Micro-mesh safeguards against the potential for entanglement and natural fiber ensures that any material accidentally left in the field post-construction quickly biodegrades. Multiple BMPs to improve wildlife habitat were developed including methods to benefit forage, shelter, cover, and breeding areas. BMPs to improve habitat included native shrub plantings, native seed mixes, large woody debris, rock piles, brush piles, snags, and removal of invasive species. Implementation of these BMPs is now commonplace and has been integrated into standard operating procedures. The modified silt socks are frequently used in areas where reptile and amphibian habitat occurs. The habitat improvement BMPs are utilized in areas not only where valuable wildlife habitat already occurs, but also where marginal habitat occurs and utilization of these BMPs will increase the quality and integrity of the available habitat thereby increasing the likelihood wildlife will utilize these habitats.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Linear electric transmission rights-of-way (ROWs) provide valuable wildlife habitat and serve as critical migration corridors for a wide variety of species. ROWs often intersect a diverse range of wildlife habitats, which provide valuable functions such as cover and shelter, breeding and nesting areas, foraging opportunities, overwintering and hibernation habitat, and migration routes (Yahner et al. 2002; Coniff 2014). In addition to providing high-value wildlife habitat, ROWs are also typically utilized by a wide diversity of wildlife species ranging from common and highly mobile species that are tolerant of anthropogenic alterations, such as white-tail deer (*Odocoileus virginianus*) and American black bear (*Urus americanus*), to small, less-mobile species that are sensitive to changes in their environment, such as marbled salamanders (*Ambystoma opacum*) and wood turtles (*Glyptemys insculpta*).

In addition to the important role of transmission ROWs in providing valuable wildlife habitat functions, they also serve to promote and maintain several habitat community types that are in decline throughout New England. Declining habitats, such as scrub-shrub, successional old fields, and other similar open communities, are typically prevalent along transmission ROWs due to necessary vegetation management (VM) to ensure safe distances to overhead electric lines and management access within ROWs are vital to the success of species that depend on these habitats (DeGraaf and Yamasaki 2001; Foster et al. 2002; Massachusetts Division of Fisheries and Wildlife 2015). Trees, saplings, and similar vegetation threatens the safety and reliability of transmission lines and necessitates the maintenance of low-growth habitat communities. VM plans, which typically consist of rotational mowing schedules, targeted herbicide application, and similar methods, promote early successional communities and habitats with low-height vegetation communities.

As part of their commitment to environmental awareness and stewardship, National Grid identified the need to develop sound and reliable best management practices (BMPs) to maintain and enhance wildlife habitat features and functions that may otherwise be impacted from maintenance and improvement project activities along their electric transmission lines. National Grid, in collaboration with BSC Group, Inc. (BSC), worked to develop a diverse suite of innovative and practicable BMPs that could be implemented in a diverse mosaic of habitats within their service areas of Massachusetts, Rhode Island, New Hampshire, and New York. When developing each BMP, multiple considerations were evaluated, including wildlife habitat functions such as breeding and nesting areas, overwintering/hibernation habitat, migration, forage opportunities, and shelter, in addition to maintaining habitat quality and connectivity. The Interstate Reliability Project in Central Massachusetts provides a case study for the development and implementation of many of the BMPs National Grid now uses on similar projects.

In this paper, we describe the assessment methods used to identify existing wildlife habitat functions in conformance with regulations, development of the BMPs used to protect or improve habitat, and a description of each BMP and its practical implementation. This paper also provides an overview of the process and challenges encountered as well as a discussion on considerations and recommendations for future BMP development and improvement.

BACKGROUND

Wildlife Habitat Evaluation as Part of the Massachusetts Wetlands Protection Act

National Grid evaluated existing wildlife habitat features encountered along the 366 transmission ROWs. Development of the BMPs originated from a requirement as part of the Massachusetts Wetlands Protection Act (MassWPA) (M.G.L. Ch. 131 S. 40) and its corresponding regulations (310 CMR 10.00), which protect wildlife habitat. As part of that requirement, National Grid requested BSC complete a Wildlife Habitat Evaluation (WHE) to identify existing important wildlife habitat as defined under 310 CMR 10.60 and to evaluate any potential impacts to that habitat resultant from the ROW project. Important wildlife habitat is defined within the regulations as areas that provide vital functions for wildlife including food, shelter, migratory or wintering areas, or breeding areas for wildlife. To identify important wildlife habitat, the WHE was conducted in accordance with the Massachusetts Wildlife Habitat Protection Guidance for Inland Wetlands (the Guidance) (Massachusetts Department of Environmental Protection 2006).

METHODS

National Grid provided BSC with the extent of their transmission system including parcels they owned, boundaries of ROWs, and other similar information in addition to the limits of the project area. Through a cooperative agreement, BSC and National Grid worked with the Massachusetts Natural Heritage and Endangered Species Program (NHESP) to acquire shapefiles of the National Grid-owned parcels and

Wetland/aquatic grain/seed plants	Standing water at least part of the growing season
Upland/wetland hard mast and fruit/berry producers	Shrub thickets/streambeds with abundant earthworms
Vernal pools	Medium to large flat rocks in a stream
Live/dead trees >76-cm diameter at breast height (dbh)	Underwater banks of fine silt or clay
Dead standing timber	Undercut or overhanging banks
Small mammal burrows	Vertical sandy banks
Cavities in limbs or trunks of trees	Areas of ice-free open water in winter
Dense herbaceous cover	Mud flats
Large woody debris	Wildlife dens/nests
Shrub and sapling cover	Flooded emergent wetlands
Rock piles, crevices, or hollow logs	Intermittent streams
Rocks, crevices, logs, tree roots, or hummocks under water's surface	
Rocks, crevices, logs, overhanging branches, or hummocks at or within 1-m above water's surface	
Live or dead vegetation overhanging water or offering good visibility of open water	
Sphagnum hummocks or mats, moss covered logs, or saturated logs overhanging or directly adjacent to pools of standing water in spring	
Flat rocks or logs on banks or within exposed portions of streambanks	
Exposed areas of well-drained, sandy soil for turtle nesting (i.e., turtle habitat)	

Table 1.

ROWs depicting the locations of state-listed rare species. BSC also reviewed other available natural resource mapping materials, including wetlands, floodplains, habitats of potential regional or statewide importance, vernal pools, and other similar data sets.

In-field investigations to document important wildlife habitat features and functions through the WHE were also completed along the entirety of the transmission ROW as it occurred within Massachusetts. Qualified biologists reviewed the entire project area for the presence of pre-defined habitat features:

Important habitat features were recorded and mapped as they were encountered in the field. Once in-field mapping was complete, the project area was reviewed for potential impacts to important wildlife habitat features and functions. In addition, the pre-defined habitat features project impacts that would adversely impact habitat continuity, connectivity, and contribute to habitat degradation were also examined as part of the WHE process.

Development of Wildlife Enhancement BMPs

Upon determining which habitat features would be impacted, BSC (in cooperation with National Grid) began developing BMPs to reduce long-term adverse impacts to wildlife habitat. Adverse impact is defined within the regulations as alterations to wildlife habitat features that would substantially reduce the site's ability to provide wildlife habitat functions following two growing seasons or, if removing trees, following replanted sapling maturity. A determination of adverse impact included the evaluation of the project area's ability to provide wildlife habitat functions post-mitigation. Therefore, in order to avoid any adverse impacts, BMPs to replace lost wildlife habitat functions were developed. Wildlife habitat BMPs were developed for each habitat feature type that was to be impacted. Development of each of those BMPs included multiple considerations including type of feature, location, availability in the landscape, and suitable locations for BMP installation.

In-field investigations identified nine important wildlife habitat features that would be impacted by the proposed transmission ROW project:

As mitigation for specific features impacted either permanently or temporally during construction, multiple habitat enhancement areas along the ROW were identified. Several wildlife enhancement areas also coincided with planned wetland mitigation areas along the ROW. Enhancement areas ranged from a handful of square meters up to several hundred in size and included the following important wildlife habitat features.

Upland/wetland hard mast and fruit/berry producers	Shrub thickets/streambeds with abundant earthworms
Vernal pools	Dense herbaceous cover
Live/dead trees >76-cm dbh	Large woody debris
Dead standing timber	Rock piles, crevices, or hollow logs
Exposed areas of well-drained, sandy soil for turtle nesting (i.e., turtle habitat)	

Table 2.

Upland/Wetland Hard Mast and Fruit/Berry Enhancement Planting

Wildlife forage, such as hard mast species and fruit/berry producers, provide a vital wildlife habitat function. Hard mast and fruit/berry producers provide valuable wildlife forage for a wide variety of species. Existing shrubs included highbush blueberry (*Vaccinium corymbosum*) and raspberry (*Rubus* spp.). The selected species for enhancement planting included representative species that were present within the impact areas as well as other native species that provided a more diverse food supply in the areas selected for habitat improvements. Plantings included highbush blueberry, arrowwood (*Viburnum dentatum*), elderberry (*Sambucus* spp.), alder (*Alnus* spp.), spicebush (*Lindera benzoin*), dogwood (*Cornus* spp.), American hazelnut (*Corylus americana*), winterberry (*Ilex verticillata*), serviceberry (*Amelanchier canadensis*), viburnum (*Viburnum* spp.), juniper (*Juniperus* spp.), staghorn sumac (*Rhus typhina*), maleberry (*Lyonia ligustrina*), willow (*Salix* spp.), and other native species.

The location for each individual plant was hand selected by a BSC biologist in the field while crews were installing the enhancement plantings. Locations were selected based on the best available location in consideration of available space, competition, hydrologic regime, and other similar factors. Prior to planting, the plants were inspected for general health. Plants were installed according to the American Standard for Nursery Stock (AmericanHort 2014).

Shrub Plantings

Shrubland habitat provides cover for many species of wildlife in addition to breeding/nesting areas and, depending on the species present, forage. Clusters of shrubs were strategically installed in select areas adjacent to impact areas were shrub cover was present. The clusters consisted of native shrubs of various heights that were planted strategically to provide cover in the absence of tree canopy. Selected species included highbush blueberry, bayberry (*Myrica* spp.), arrowwood, elderberry, alder, spicebush, dogwood, American hazelnut, and winterberry. Many of the shrubs chosen also served as forage via hard mast or fruit/berry producers. Plant location, inspection, and installation followed the same process as the hard mast and fruit/berry producer enhancement plantings.

Alder Thickets Along Stream Beds with Abundant Earthworms

Suitable habitat for American woodcock (*Scolopax minor*) was observed within one of the impact areas adjacent to a stream. That same area also provided shrub thicket habitat with abundant earthworms and a woodcock was observed during field investigations. To improve this habitat and simultaneously reduce potential for erosion, alder and willow plantings were installed along the stream where shrub thicket habitat was absent to create desirable habitat along the streambed.

Trees Less Than 76-cm dbh & Dead Standing Timber

Large trees and snags provide a variety of important wildlife habitat functions. One black willow (*Salix nigra*) snag—76-cm in dbh–was identified within one of the impact areas, meeting the criteria of both live/dead trees >76-cm dbh and dead standing timber. As this was the only wildlife habitat feature providing this function, an existing 76-cm dbh tree located a safe distance from the transmission lines was topped and girdled to create a snag. The location of the created snag was an important factor as locating the snag too close to the transmission lines could result in a significant safety and operational hazard. The location was selected in the field by a BSC biologist who oversaw the topping/girdling to ensure proper implementation. Existing snags were preserved wherever feasible and a number of smaller dbh snags were created with the girdling method described.

Dense Herbaceous Vegetation

Wildlife habitat functions provided by dense herbaceous vegetation include cover, breeding/nesting areas, and forage among others. Dense herbaceous vegetation was maintained and improved in areas where soils were disturbed from construction activity. Disturbed areas were seeded with a native conservation/wildflower seed mix and covered with weed-free straw. The conservation and wildflower seed mix increased biodiversity of grasses and forbs. As an additional benefit, the increase in forb occurrence and diversity improved foraging habitat for pollinator species.

Large Woody Debris / Brush Piles

Large woody debris and brush piles provide cover and breeding/nesting habitat for a range of wildlife. Large woody debris and brush piles were placed strategically along wetland/waterbody and ROW edge habitats within or in the immediate vicinity of the impact areas. Material for both these habitat features was sourced from tree-clearing activities associated with the project and piles were created by placing individual logs, limbs, and branches in irregular piles in specific locations identified by a BSC biologist in the field.

Rock Piles and Crevices

Similar to large woody debris and brush piles, rock piles and crevices provide cover and breeding/nesting habitat for a range of wildlife. Material to create the rock piles was obtained from project excavation materials. Boulders were piled in small clusters that created crevices in between the rocks in strategic locations selected by a BSC biologist. Locations of created rock piles were selected based on closeness to rock piles within the impacted area, sufficient available space, and proximity to other valuable habitats.

Vernal Pools

Vernal pools provide vital important wildlife habitat functions, particularly for obligate vernal pool species such as mole salamanders (*Ambystoma* spp.) and wood frogs (*Rana sylvaticus*). No work was allowed within the pool itself, although project activities did impact vegetative cover and occurred adjacent to the pool. Marbled salamanders were located within a portion of the project area. In order to maintain and improve onsite habitat for this species, multiple habitat features were developed. Representative native shrubs were planted, and rock piles and large woody debris were placed along the edge of the wetland associated with the vernal pool to provide cover. Equipment access through the wetland adjacent to the vernal pool was necessary. To provide consistent, safe, and less adverse cumulative impact to the wetland, GeoWeb material was installed. The GeoWeb was used to provide a stable wetland crossing that also maintained a hydrologic connection within the wetland as well as promoted the growth of wetland vegetation over the crossing. To reduce adverse impacts to resident marbled salamanders, erosion and sediment controls were in place only during the installation of the GeoWeb (no longer than three consecutive days).

Additionally, a daily inspection and maintenance plan was developed and implemented, ensuring that construction activities remained stable and materials did not migrate into the vernal pool. BSC also completed daily sweeps and inspections of the work area during the active marbled salamander season from late August to October. Any salamanders that were encountered were safely relocated outside of the work area. BSC also initiated a contractor education and awareness program which trained construction crews onsite to the specific BMPs and environmental procedures prior to construction.

Exposed Areas of Well-Drained, Sandy Soil for Turtle Nesting (Turtle Habitat)

Wood turtle habitat also occurred within impact areas. National Grid applied for a Conservation and Management Permit (CMP) with NHESP in respect to the Massachusetts Endangered Species Act (MESA) (M.G.L. c. 131A) and its implementing regulations (321 CMR 10.00) as a result of incidental take of wood turtle. As part of the CMP, numerous BMPs were included to maintain and improve habitats utilized by the local wood turtle population, including BMPs for construction timing and restrictions, turtle monitoring, VM, contractor awareness and education, and other BMPs.

Development of Other BMPs to Protect Wildlife Habitat

Construction Timing, Restrictions, and Methods

During construction within mapped wood turtle habitat and during their active period, no earth-disturbing activities were performed. Therefore, grading, installation of work pads and access roads, and restoration activities did not occur between April 1 and November 1. Additionally, equipment access and earth disturbance were avoided within wood turtle habitat between zero meters (m) and 15 m of stream banks from March 1 to November 15. Enclosure fencing was installed around all work pads and staging areas when construction occurred during the active season and when equipment access was necessary within wood turtle habitat during. Full-time turtle monitoring by qualified biologists was provided.

Upon completion of the construction activities, work pads for structures within wood turtle habitat were loamed and seeded with a native conservation seed mix; however, an underlying stable gravel base for future access and maintenance was installed. These areas were allowed to progressively vegetate with typical regular management. Additionally, National Grid typically assumes a maximum six-meter (m) width for access roads. However, National Grid utilized a narrower five-m access road in wood turtle habitat as long as all safety requirements were met.

Construction Monitoring

A wildlife biologist pre-approved by NHESP completed daily sweeps of the construction area and was present onsite during all construction activities and whenever equipment access was necessary in mapped wood turtle habitat between April 1 and November 1. If a turtle was encountered, a NHESP Animal Observation Form was completed and the turtle was photo-documented. If a turtle was encountered before the nesting season (late May – June), the turtle was moved to a safe location in the direction they were traveling but not across a paved road. If the turtle was encountered during the nesting season, nest digging activity was not disturbed and the location of the nest was identified with highly visible flagging to avoid accidental impacts (i.e., strikes) to the nest. Weather forecasts were also monitored during the inactive season for possible early or temporary emergence during unusually warm weather. Turtle monitors were also available to complete sweeps of the construction area during sunny days warmer than 10 degrees Celsius when snow cover was absent.

Vegetation Maintenance

Mapped wood turtle habitats within National Grid transmission ROWs are subject to special conditions afforded in National Grid's VM Plan (VMP) approved by NHESP. Habitat maintenance and improvement activities included contractors preserving low-growing vegetation outside of the active construction areas, requiring earth disturbance with a strong preference for food source such as raspberries, willow, and herbaceous species. Mechanical clearing and mowing of vegetation were avoided during the active season, especially during the peak season from May 15 to September 15. However, if vegetation maintenance was unavoidable, blade heights were set no lower than 18 cm from the ground and mowing occurred in low gear at low speed in order to allow turtles time to react and to provide sufficient ground clearance. In compliance with the VMP and National Grid's operation and maintenance plan (OMP), vegetation and maintenance activities continue to be managed regularly in wood turtle habitat, utilizing time of year restrictions and measures that avoid adverse impacts to turtles.

Contractor Education and Awareness Program

All contractors working in wood turtle habitat were trained in positive wood turtle identification and general life history, habitat requirements, and behavioral notes prior to construction. Contractors were also instructed to contact National Grid and BSC if a turtle was encountered, as opposed to moving the turtle. Lastly, crews were trained in good housekeeping methodologies to discourage an increase in wood turtle nest predation.

Other BMPs

In addition to the BMPs described above in detail, multiple other BMPs benefitting wood turtles and their habitat were employed. Erosion and sediment controls were installed and regularly maintained throughout the project area within wood turtle habitat to protect water quality and to serve as a physical barrier to avoid direct impacts to wood turtle habitat. In addition, dewatering discharge was also pumped into dewatering basins consisting of filter fabric contained within straw bale basins and located in upland areas on well-vegetated surfaces.

Structure foundation excavations were covered with plywood or other sturdy material when left unattended to prevent turtles from becoming trapped in the excavation. Additionally, parking and staging areas were limited or avoided, when feasible, within wood turtle habitat. Construction equipment was also monitored regularly for leaks and secondary containment was required in addition to refueling occurring a minimum of 30 m from wetlands and waterways.

Development of Sediment and Erosion Control BMPs for Amphibians and Reptiles

In early 2018, National Grid requested that BSC also develop BMPs for erosion and sediment controls to reduce potential impediments to migration and potential entanglement hazards of rare amphibians and reptiles. More specifically, National Grid routinely used filter tubes as sediment controls on construction projects. Frequently, those projects require access across, through, or in rare species habitat. Small, slow-moving amphibians and reptiles, such as the marbled salamander, blue-spotted salamander (*Ambystoma laterale*), eastern box turtle, Blanding's turtle (*Emydoidea blandingii*), and other similar species may be impacted by construction resultant from temporary impediments to migration, exclusion from available habitats, or other impacts. The use of filter tubes often presents an impassable barrier to these species, requiring them to divert long distances around the obstructions and/or presents an entanglement hazard should they attempt to cross this barrier.

BSC evaluated multiple BMP designs to provide safe passage of these species across sedimentation control barriers for use in applications where sedimentation barriers bisected available migration routes and prevented migration of species to suitable nesting sites, breeding areas, and overwintering habitats. Numerous considerations, including filter media, mesh material and diameter, slope, available materials, ability and likelihood of species to cross, and application were included when developing the BMPs. BSC also coordinated with NHESP on the design of the BMPs and incorporated their comments into the final designs. The final BMPs included a computer-aided design and drafting (CADD) figure depicting the correct installation of each configuration in "plan view" and cross section, example photographs, and a detailed written description of how to install the BMPs and their appropriate applications.

Once finalized, the BMPs were incorporated into National Grid's Environmental Guidance document, which provides the environmental standards all construction projects must meet. The modified filter tube design is now frequently utilized in areas where reptile and amphibian habitat occurs and the installation of sedimentation controls may pose an impediment to migration or an entanglement hazard.

Three different configurations were designed for amphibian and reptile sedimentation control passage. Two of the configurations consisted of biodegradable, natural fiber, micro-mesh filter tubes combined with compacted mulch ramps. The third design also utilized a compacted mulch ramp, but consisted of traditional silt fencing. Utilizing micro-mesh in the filter tubes safeguards again the potential for wildlife entanglement that would otherwise result by utilizing a wider mesh size. The natural fiber ensures that material that is accidentally left in the field post-construction will biodegrade quickly and will neither persist in the environment nor will contribute to discarded plastic refuse.

The first amphibian and reptile crossing consisted of paired compacted wood mulch ramps on either side of a continuous section of filter tube. Paired ramps with maximum slopes of 2:1 were to be spaced approximately 15 m apart. This configuration was intended to be employed in areas with steep slopes, high sheet flows, or other areas where a periodic break in sedimentation controls is inappropriate.

The second and third crossings consisted of similar configurations, but included different materials: filter tubes and silt fence. Both consisted of compacted wood mulch ramps with maximum slopes of 2:1 situated between the gaps of overlapped sediment controls. The gap between the controls were between 0.5 m and one m, with the controls overlapped a minimum of 0.6 m. This configuration was designed to be utilized in relatively flat areas with minimal sheet flow and a low risk of the compacted mulch washing out.

DISCUSSION

National Grid is one of the primary providers of electric service throughout the northeast, and as such, understands the important role it serves in providing reliable, safe, cost-effective electricity. However, National Grid also understands the ecological value its ROWs provide for wildlife habitat and the important habitat functions those habitats provide. As part of their environmental stewardship, National Grid is dedicated to maintaining and improving wildlife habitat along their transmission ROWs as much as practicable through a combination of VM, habitat enhancements, contractor education, environmental monitoring, and other BMP methodologies.

The wildlife habitat BMPs developed and implemented by BSC and National Grid provided an ecological enhancement to important wildlife habitat functions in areas that would otherwise have lost specific features resultant from necessary transmission ROW maintenance and improvements. Additionally, the BMPs developed to decrease amphibian and reptile migration impediments, increased habitat connectivity, and continuity to targeted species groups, while maintaining sufficient sediment control measures to protect water quality. The following sections provide a detailed review of the BMPs, as well as recommendations for future BMPs and/or proposed improvements to existing BMPs that could be implemented to better increase the habitat quality and condition of available wildlife habitat features and functions along National Grid's transmission ROWs.

Wildlife Habitat Enhancement BMPs

In-field collaboration with and training of construction crews proved invaluable when implementing the various BMPs to maintain and improve wildlife habitat features. The onsite presence aided in ensuring the BMPs were properly constructed, located in appropriate areas, and that necessary in-field decisions could be implemented in-situ, thereby nearly eliminating construction delays and improving the quality of the various wildlife habitat enhancements. Onsite biologists were effectively able to aid construction crews in creating the habitat BMPs by directing which, where, and how enhancements should be constructed. They were also able to provide in-field guidance and changes that benefited both wildlife habitat function and future transmission ROW projects.

Ensuring proper access via walk-aheads, sweeps, and turtle monitoring to ensure proper access with minimal impacts to turtle nesting by the qualified biologists was exceptionally helpful. No impacts to any turtle nesting areas was encountered and only one access needed to be relocated. Additionally, turtle exclusionary perimeter fencing with one point of entry effectively ensured that wood turtles did not accidentally enter the construction area and avoided any turtle strikes. However, while effective in excluding wood turtles from construction areas, other species that were able to enter the exclusion area became trapped and had to be relocated and released prior to the start of construction.

The native conservation seed mix provided its own set of unique challenges. Obtaining sufficient volumes of the seed proved difficult and crews ran out of seed on multiple locations, which resulted in project delays. In future projects, pre-ordering ample amounts of the necessary seed, if possible, would likely reduce the potential of delays. Additionally, germination of the seed mix was slow; however, when hydroseeded, germination appeared to be more successful. When seeding turtle habitat enhancement areas in the future, hydroseeding and/or adding a fertilizer with the seed would likely improve germination rates. Subsequent inspections of the conservation seed mix spread at the work pads showed that whatever species were present adjacent to the pads eventually invaded the restored pad area and outcompeted the seeded species.

Despite the numerous successes we experienced with the developed BMPs, we also experienced several challenges. All-terrain vehicles (ATVs) trespassing throughout the ROW continued to be problematic and likely impacted turtle nesting areas and other wildlife habitat. Additional efforts to monitor ATV use may have reduced any potential impact this unauthorized access may have caused. Reducing and/or eliminating ATV intrusion onto ROWs is challenging; however, there are multiple methods to discourage this trespass including locked gates, course riprap access roads, boulders, and others that may have aided in reducing adverse impacts from ATVs.

Many of the erosion and sediment controls installed required constant checks and repairs for gaps, breakage, and other faults. Many of the necessary repairs to these controls were resultant from common snapping turtles (*Chelydra serpentina*) and white-tail deer that consistently broke through the controls. Utilization of alternative erosion and sediment control methods (e.g., filter tubes, coir logs, etc.) may have resulted in less frequent maintenance, thereby reducing cost and construction downtime. Additionally, access maintenance (i.e., plowing) during winter often damaged controls. Adding visual markers spaced accordingly may have reduced the probability that controls were damaged.

The GeoWeb matrices installed within wetland habitat failed to function as designed. Even post-installation, the crossing was still too wet to allow for safe equipment passage and required swamp matting. Additional engineering and/or alternative products may have resulted in a better functioning crossing.

Amphibian and Reptile Sedimentation Control Crossings

The amphibian and reptile sedimentation control crossings have been incorporated into National Grid's environmental guidance document. Efficacy of the BMPs is largely dependent on their successful construction and implementation. Contractor training would likely improve their effectiveness. Additionally, future efforts to create pre-formed ramps that could be installed in concert with the filter tubes instead of constructing compacted wood mulch ramps could also improve the BMP's efficacy.

Other Recommendations and Future BMPs

As part of National Grid's commitment to ecological stewardship, they are continually updating the environmental guidance document to incorporate new methodologies to maintain and improve habitat through new BMPs and improvements, updates, and revisions to existing BMPs. The following sections provide possible new BMPs to develop as well as recommendations for improvements to existing BMPs already in implementation.

Pollinators

Additional BMPs to maintain and improve valuable wildlife habitat could include identifying suitable areas that provide habitat functions for pollinators such as bees, butterflies, and other similar species. As part of this BMP, areas that currently provide or have the potential to provide pollinator-specific habitat functions (specifically forage) could be improved by planting and/or seeding those areas with native flowering species. Examples of species that attract pollinators include coneflower (*Echinacea spp.*), black eyed susan (*Rudbeckia spp.*), speedwell (*Veronica spp.*), coreopsis (*Coreopsis spp.*), lupine (*Lupinus spp.*), and milkweed (*Asclepias spp.*)

Target Species BMPs

Many of the BMPs developed benefited multiple species of wildlife by providing a range of habitat functions or provided habitat that a variety of species typically use. However, future BMPs could be developed to target individual species, or groups of species, in areas where it is determined a particular species or species group is declining or some other similar concern is present. For example, BMPs targeting ruby-throated hummingbirds (*Archilochus colubris*) could include the planting of preferred native, forage species such as cardinal-flower (*Lobelia cardinalis*), bee-balm (*Monarda* spp.), and jewelweed (*Impatiens capensis*). Another example includes the New England cottontail (*Sylvilagus transitionalis*), whose habitat needs to coincide with vegetative communities typically found on ROWs.

Inclusion of Wildlife Habitat Enhancements into Environmental Guidance

National Grid has developed a comprehensive environmental guidance document that includes numerous potential erosion and sediment controls that may be employed in a variety of circumstances depending on project and site conditions. National Grid is also continually updating that guidance to include new BMPs and update existing

BMPs. The previously described sediment controls with amphibian and reptile crossings and ramps have recently been added. However, National Grid has currently not developed guidance specifically regarding wildlife habitat outside of VMPs and OMPs regularly prepared by National Grid and approved by NHESP. A habitat enhancement-specific environmental guidance document or inclusion of habitat improvement BMPs into existing guidance documents may prove invaluable for future projects by providing consistent, reproducible, and referenceable standards and outcomes.

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ComEd Pollinator Habitat Modeling

Chris Pekar and Sara Race

Keywords: Geographic Information Systems (GIS), Pollinator Habitat, Vegetation Management (VM).

Populations of pollinating insects are known to be declining worldwide due to reasons centering around habitat loss. In northern Illinois, Commonwealth Edison (ComEd) owns and operates more than 8,520 kilometers (km) (5,300 miles [mi]) of overhead electric transmission lines. ComEd also owns and manages tens of thousands of acres of associated rights-of-way (ROW), which provide or could provide habitat for pollinating insects—several of which are known to be of conservation concern. We completed a geospatial modeling effort to gain a better understanding of how ComEd's ROW might contribute to the conservation of pollinators. We sought to answer two questions:

1. Where does potentially suitable pollinator habitat exist within ComEd's ROW?

2. Where do opportunities exist to enhance or create suitable pollinator habitat within ComEd's ROW?

The results of the first question models suggest that mapping potentially suitable pollinator habitat can prove useful in predicting where to expect pollinators for planning purposes and regulatory compliance. The results of the second question models were used to identify portions of ROWs for field assessment to determine suitability for pollinator habitat enhancement. Of the 13 sites visited, four are recommended for pollinator habitat enhancement, and another four sites are recommended for implementation of other conservation strategies.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Populations of pollinating insects are declining worldwide due to habitat loss, degradation, and fragmentation; eradication of nectar plants and/or host plants; pollution and pesticide use; non-native species and diseases; and climate change (Schwartz 2016). Pollinating insects play a crucial role both in human food systems and in natural ecosystems, and many plant species are unable to pollinate without the assistance of pollinating insects. In response to this, numerous stakeholders across North America have emerged to determine means of reversing population declines of pollinating insects. One of the key stakeholder groups to emerge has been the electric utility industry due to the potential for pollinator habitat enhancement along the electric transmission rights-of-way (ROWs) owned or managed by electric utilities (Coniff 2014).

Commonwealth Edison (ComEd) has a long history of incorporating habitat protection into the management of its ROW. ComEd has restored hundreds of acres of natural prairie habitat on buffer lands and ROWs in Illinois since the inception of ComEd's Prairie Program (Program) in 1994. In 2005, ComEd was selected for a Conservation and Native Landscaping Award given by the U.S. Environmental Protection Agency (EPA) and Chicago Wilderness for work at select Program sites. All Program sites are located within ComEd landholdings and selected for restoration to native Illinois prairie. These sites are actively managed and typically undergo a regime of invasive plant eradication, native plant seeding, and prescribed burning.

ComEd is taking a leading role among utilities implementing pollinator conservation strategies. One current initiative is to identify and manage appropriate portions of ROW for pollinator habitat. These "Pollinator Program" sites will be similar to sites that ComEd manages as part of its existing Prairie Program. However, whereas the Prairie Program's goal is to establish and maintain high-quality native prairie communities, the focus of the Pollinator Program will be to establish and provide pollinator habitat with a high percentage of pollinator-friendly plant species used for foraging, nesting, and stopover. Pollinator Program Site standards are in development.

The intent of this study was to answer two critical questions:

1. Where does potentially suitable pollinator habitat likely exist within ComEd's ROW?
2. Where do opportunities exist to enhance pollinator habitat within ComEd's ROW?

We have addressed these questions by reviewing the relevant literature and developing four spatially explicit geographic information systems (GIS) models—two models to answer each of the questions above. The map outputs of all models cover the extent of ComEd's service territory in northern and central Illinois.

We performed a desktop analysis using the enhancement model outputs to identify approximately 60 sites along ComEd's ROW that may be suitable for pollinator habitat enhancement. We short-listed 13 sites for field review within the immediate Chicago Region. The intent of the field review was two-fold. First, we wanted to determine if the enhancement models are, in fact, useful tools in identifying pollinator enhancement sites. Second, we wanted to identify pollinator enhancement sites that can be actively managed in a "Pollinator Program" akin to ComEd's Prairie Program.

Background on Pollinators in the Chicago Region

As previously noted, populations of many pollinating insect species are declining across the U.S. The U.S. Fish and Wildlife Service (USFWS) has responded via agency action. The rusty-patched bumblebee (RPBB) was listed as an endangered species on March 21, 2017 (USFWS 2017a), and the rattlesnake-master borer moth is listed as a candidate species (USFWS 2017b). Also, species with substantial 90-day findings within ComEd's service territory include the yellow-banded bumblebee (USFWS 2017c), monarch butterfly (USFWS 2017d), and regal fritillary (USFWS 2017e). These five pollinator species were the focus of this study because of both their declining populations and regulatory status.

Current Land Use Composition of ComEd's ROWs

Although ComEd maintains more than 8,500 kilometers (km) (5,300 miles [mi]) of electric transmission ROW, previous efforts to identify suitable prairie restoration sites on ComEd's ROW demonstrated that identifying ideal habitat restoration sites is more challenging than one might assume. While almost any site can be actively managed for various habitat goals, the cost and likelihood of success can vary significantly due to the influence of off-site factors, such as impacts associated with recreational trespassing and herbicide drift from adjacent agriculture fields.

Thus, not all sites are equally suitable and understanding existing land use is the first step in determining site suitability. Of course, there are nuances. An agriculture-dominated ROW with agricultural fields on either side is typically an unsuitable site, but an agriculture-dominated ROW with natural areas on either side may be an ideal site.

To provide context for this study, we used GIS to determine percentages of the various land cover categories both within the ComEd Service Territory Study Area (Table 1-1) and within 100 feet of ComEd transmission lines (Table 1-2). The distance of 100 feet from transmission line was selected to provide an efficient characterization of ComEd's variable-width ROW. The U.S. Geological Survey's (USGS) National Land Cover Dataset was used as the land cover dataset (NLCD 2011).

Cultivated crop is by far the dominant land cover both within ComEd's service territory and within 100 feet of ComEd transmission lines. Millions of acres of pollinator habitat have been lost within ComEd's service territory, leaving only a fraction of pre-settlement original pollinator habitat. Therefore, any pollinator habitat enhancement implemented along ComEd's ROW can provide significant conservation benefits by either bolstering existing blocks of habitat or providing connectivity between existing blocks of habitat.

LITERATURE REVIEW

The intent of the literature review was to gain a clear understanding of the population trends, life histories, and breeding and foraging preferences of the target species. To focus the literature review, we created a matrix with the target species along the x-axis and different habitat and life history aspects along the y-axis and then attempted to populate each cell in the matrix with findings from the literature review. Works reviewed and cited in the literature review are provided in Appendix A. The information gathered from the literature review provided the basis for the construction of the spatially explicit GIS models.

A guiding theme identified during the literature review is that, for the purposes of this study, pollinators can be lumped into two broad taxonomic groups: Lepidoptera (butterflies and moths) and native bees. Species within each of these groups exhibit similar enough habitat preferences and life histories with other species in the taxonomic group to make these groups feasible and useful modeling targets. Key findings related to native bees follow below.

- Yellow-banded bumblebees have not been observed in Illinois since the 1950s and are considered an

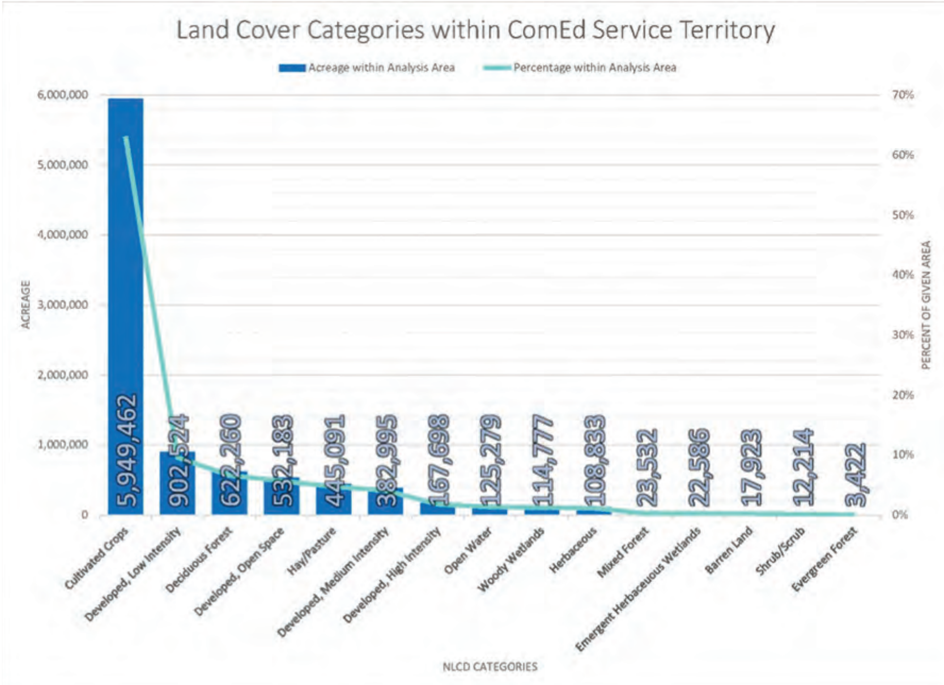

Table 1. Breakdown of Land Cover Categories within ComEd Service Territory Study Area

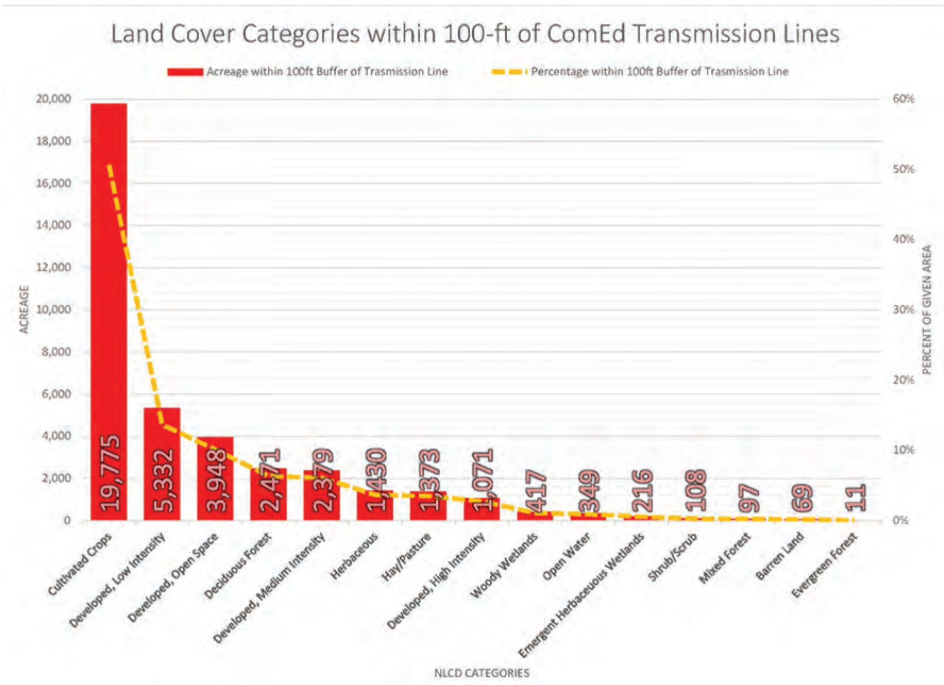

Table 2. Breakdown of Land Cover Categories within 100 Feet of ComEd Transmission Lines

inhabitant of northern forests rather than central prairies. *Based on this, the yellow-banded bumble bee was removed as a focus species* (Evans et al. 2008).

- Native bees, including the RPBB, generally emerge earlier in the year than do Lepidoptera species and are reliant on late spring and early summer flowering plants for nectar (Holm 2014).
- Most native bee species prefer a mix of prairie, old field, and forested habitat. This allows the bees to feed on forest-dwelling spring ephemeral wildflowers in the spring and prairie-dwelling forbs species in the summer and fall (Holm 2014).
- 70 percent of local native bee species nest in tunnels and other voids in the ground, often in loose soils (NRCS 2014).
- Neonicotinoid insecticides have been shown to adversely affect bee species (Evans et al. 2008).
- The RPBB's maximum dispersal distance is estimated to be six miles (USFWS 2017f).

Key findings for Lepidoptera follow below.

- Many Lepidoptera species prefer open blocks of habitat greater than 40 hectares (ha) (100 acres) (Davis et al. 2008).
- Herbicides and use of herbicide-tolerant corn result in an estimated loss of 861 million milkweed (*Asclepias* spp.) stems in the midwestern U.S. since 1999, which is thought to be primary reason for the crash in monarch butterfly population (Thogmartin et al. 2017).
- Adult rattlesnake-master borer moths feed on a wide variety of nectar plants, but the larvae feed exclusively on the rattlesnake-master (*Eryngium yuccifolium*) plant roots and stems (Holm 2014).
- Adult regal fritillary butterflies feed on a wide variety of nectar plants, but the larvae feed exclusively on certain violet species, including bird's-foot violet (*Viola pedata*), prairie violet (*Viola pedatifida*), and arrowhead violet (*Viola sagittata*) (WDNR 2017).
- The rattlesnake-master borer moth maximum dispersal distance is estimated to be two miles (Mankowski et al. 2014).

METHODS

Based on the findings of the literature review, we created four models:

- Lepidoptera Habitat Suitability Model
- RPBB Habitat Suitability Model
- Lepidoptera Enhancement Suitability Model
- RPBB Enhancement Suitability Model

Each model was created via the following process:

1. Outline model parameters
2. Identify corresponding GIS data layers
3. Determine intra-layer scoring
4. Convert all data layers to rasters
5. Re-classify intra-layer features to reflect intra-layer scoring
6. Add rasters together to create model output layer

The following GIS data layers were used to build the four models, though each model only included layers corresponding to habitat preferences within the model definitions (Tables 3-1 through 3-4).

Illinois Natural Areas Inventory (INAI) Sites

The INAI is administered by the Illinois Department of Natural Resources (IDNR). It provides a set of information about high-quality remnant natural areas and habitats of endangered species.

NRCS Soil Survey Data (SSURGO)

The Natural Resources Conservation Service (NRCS) Soil Survey data layer, typically mapped at a scale of 1:12,000, depicts different soil units and contains a wide variety of attribute data. In these models, hydric soil ratings and soil textures were used (Soil Survey Staff).

National Land Cover Dataset (NLCD)

The NLCD is published by the U.S. Geological Survey (USGS). It is a raster layer with a 30-meter (m) cell size. Data is acquired via satellite, and each cell is classified into a pre-determined land cover category (NLCD 2011).

Protected Areas

For this project, we created a custom protected areas layer by supplementing the USGS's Protected Areas Database with Forest Preserve District boundaries in the Chicago-area counties. Small municipal parks were removed from the custom layer because they generally offer little pollinator habitat (USGS 2016).

iNaturalist Records for Select Plant Species

iNaturalist is an innovative online biodiversity data collection platform. Users collect global positioning system (GPS) locations of field observations of flora and fauna via mobile devices such as smartphones. Images are also

Input Layer	Criteria Category	Intra-layer Score	Data Source
INAI Sites	Within INAI Site	3	IDNR
	Not Within INAI Site	0	
Land Cover	Grassland/herbaceous areas > than 100 acres	5	NLCD
	Grassland/herbaceous areas < than 100 acres	4	
	Shrub/scrub, wetlands, pasture, developed – open space	3	
	Forests, developed - medium intensity, developed - low intensity developed	2	
	Barrens	1	
	Cultivated Crop, developed - high intensity	0	

Table 3. Input Layers and Scores for Lepidoptera Habitat Suitability Model

collected with the observation so other users can verify correct species attribution (iNaturalist 2017). We used iNaturalist data to determine recorded observations of host plant for the rattlesnake-master borer moth (rattlesnake-master) and the regal fritillary (*Viola* spp.).

National Elevation Dataset (NED)

The NED is another nationwide raster layer published by the USGS. It is a digital elevation model that can be used to determine land elevation and calculate slope and aspect. We used the NED to create an aspect layer (USGS 2017).

USFWS RPBB High Potential Zone

The USFWS has published multiple iterations of the RPBB high potential zone. The USFWS created this layer by integrating RPBB observation locations and land cover (USFWS 2017g).

RESULTS

All models were created by identifying relevant layers, assigning intra-layer scores, converting each layer to raster, and then adding all raster layers together. All layers in each model were weighted equally. Below—in sections 3.2.1 through 3.2.4—each model input criteria are displayed in tabular format, and the raster model output is depicted on a map along with a shapefile

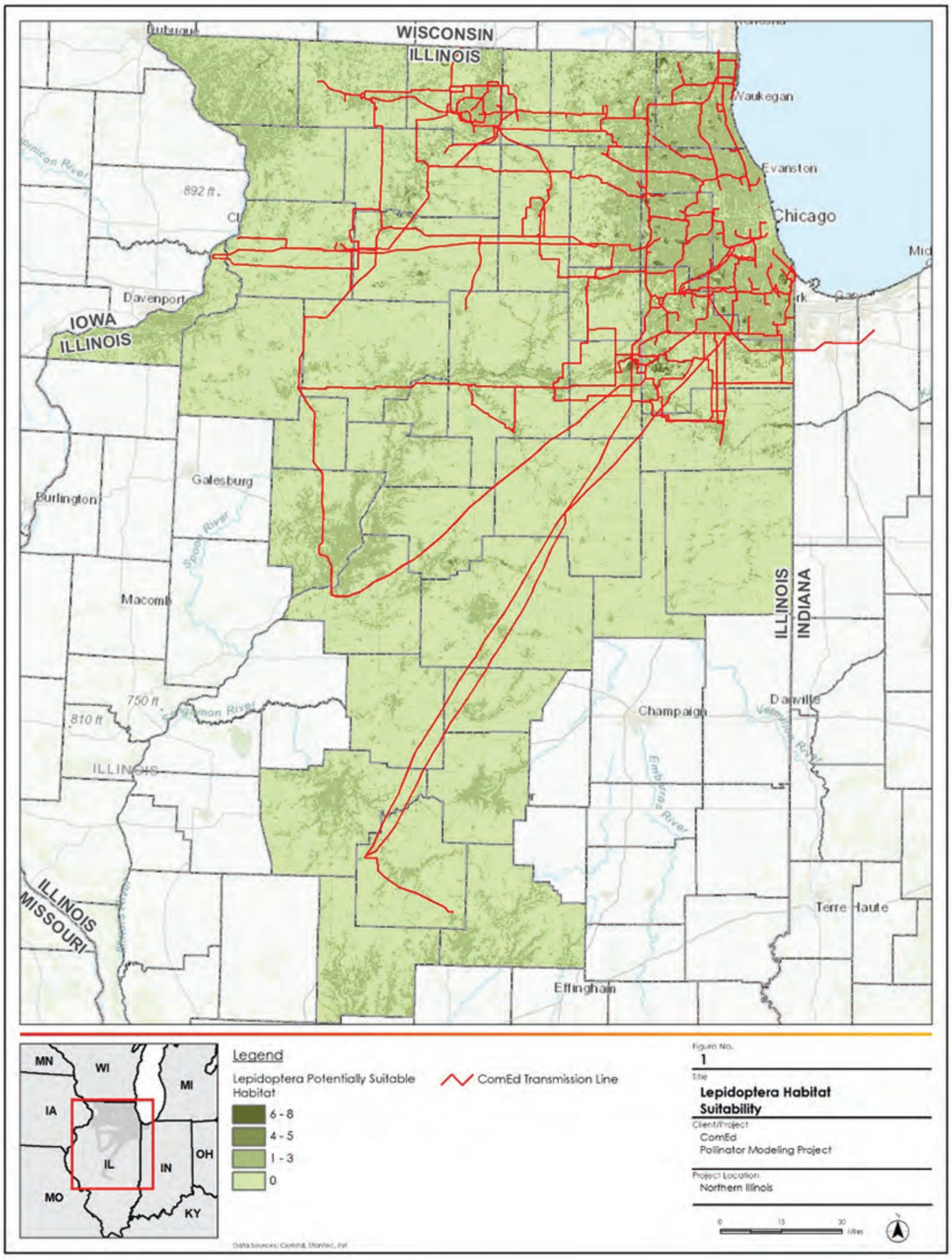

Figure 1. Lepidoptera Habitat Suitability Model Output

representing ComEd's electric transmission lines.

Multiple iterations of the enhancement suitability models were performed to increase the utility of the models during the desktop review. Input layer modifications included:

- Removal of small urban parks from the protected areas database as they likely would not provide existing pollinator habitat.
- Increased scoring for cultivated crop inside protected areas are ideal enhancement or even restoration sites, because they have a full conversion of cultivated crop in ComEd ROW surrounded by natural communities within a protected area.
- Decreased scoring within cultivated crop areas and 50-m buffers to avoid sites adjacent to areas of high pesticide and herbicide use.

Lepidoptera Habitat Suitability Model

The Lepidoptera habitat suitability model is a broad model that attempts to identify areas utilized by both resident and migrant Lepidoptera species. Key habitat characteristics include large blocks of grassland/herbaceous areas and remnant natural areas.

RPBB Habitat Suitability Model

The RPBB model attempts to identify areas suitable for use by the RPBB. Key habitat characteristics include loose soils, remnant natural areas, and a northwest aspect.

Lepidoptera Enhancement Suitability Model

The Lepidoptera enhancement suitability model attempts to identify areas suitable for land management activities implemented with the intent of enhancing Lepidoptera foraging and breeding habitat. Target Lepidoptera species include the monarch butterfly, regal fritillary, and rattlesnake-master borer moth. Key habitat characteristics include grassland/herbaceous areas greater than 40 ha (100 acres); setbacks from ROW crops to minimize effect of herbicide drift; cropped areas inside protected areas due to increased success of management activities; and proximity to protected areas and/or host plants.

The Lepidoptera enhancement suitability model parameters are detailed in Table 3-3, and the output map is shown in Figure 3-4. While a maximum value of 30 was possible, the highest attained value is 25. While reviewing the Lepidoptera enhancement suitability output map, we qualitatively determined that areas with a value of 13 or higher tended to yield the highest potential pollinator program

Input Layer	Criteria Category	Intra-layer Score	Data Source
INAI Sites	Within INAI Site	3	IDNR
	Not Within INAI Site	0	
Soils	Fine sand, fine sandy loam, loamy course sand, loamy fine sand, loamy sand, gravelly sandy loam, sand, sandy loam	5	NRCS
	Gravelly loam, cobbly loam, cobbly silt loam, stony loam, very artifactual loam	4	
	Loam, silt loam	3	
	Silty clay loam	2	
	Clay loam	1	
	Muck, mucky sandy loam, mucky silt loam	0	
Land Cover	Shrub/scrub, mixed forest, deciduous forest, grassland/herbaceous	5	NLCD
	Evergreen forest, hay/pasture, barrens, developed – open space	3	
	Woody wetlands, emergent herbaceous wetlands, developed – low intensity	2	
	Developed – medium intensity, Cultivated Crop	1	
	Developed – high intensity, open water	0	
Aspect	Northwest	5	NED
	North, west, northeast	3	
	East	2	
	South, southeast, southwest	1	

Table 4. Input Layers and Scores for RPBB Habitat Suitability Model

sites suited for Lepidoptera habitat enhancement. These areas represent approximately 965 ha (2,384 acres), or approximately six percent, of the acreage within a 100-foot wide buffer of ComEd's transmission lines (Figure 3-3).

RPBB Enhancement Suitability Model

The RPBB enhancement suitability model attempts to identify areas suitable for land management activities implemented with the intent of enhancing RPBB foraging and breeding habitat. Key habitat characteristics include setbacks from ROW crops to minimize effect of herbicide drift; cropped areas inside protected areas due to increased success of management activities; loose soils for suitable nest tunneling; and proximity to protected areas and/or RPBB high potential zones.

The RPBB enhancement suitability model parameters are detailed in Table 3-4, and the output map is shown in Figure 3-6. While a maximum value of 35 was possible, the highest attained value is 34. While reviewing the RPBB enhancement suitability output map, we qualitatively determined that areas with a value of 19 or higher tended to yield the highest potential pollinator program sites suited for RPBB habitat enhancement. These areas represent 875 ha (2,162 acres), or approximately six percent, of the acreage within a 100-foot wide buffer of ComEd's transmission lines (Figure 3-5).

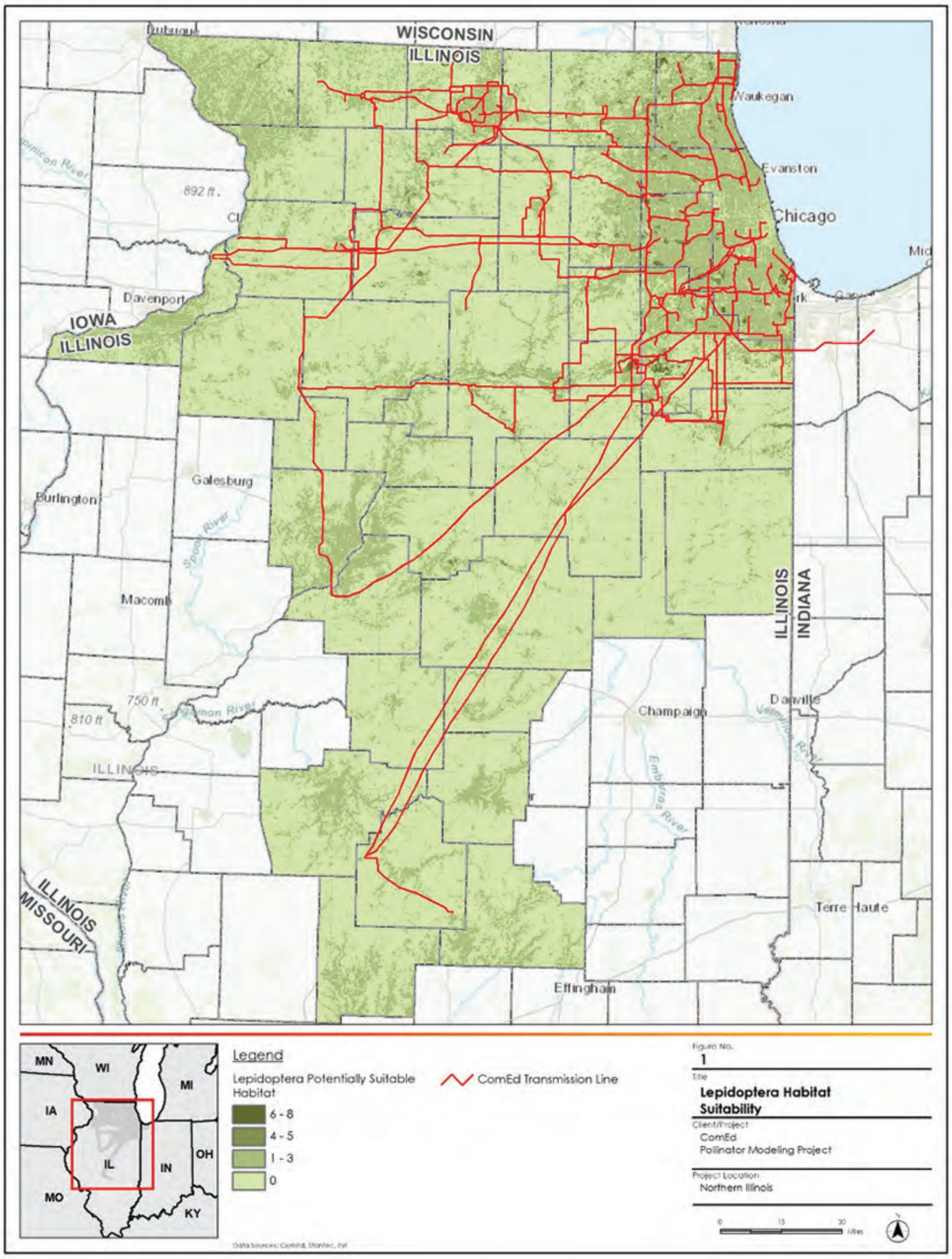

Figure 2. RPBB Habitat Suitability Model Output

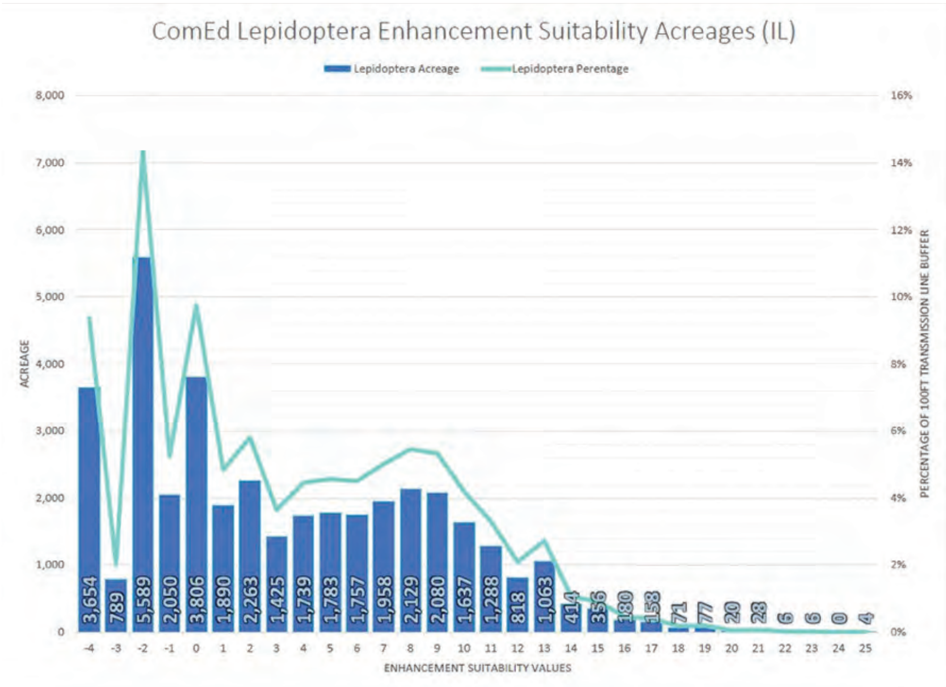

Table 5. Lepidoptera Enhancement Suitability Acreages

Input Layer	Criteria Category	Intra-layer Score	Data Source
Soils	Non-hydric soils	5	NRCS
	Partially hydric soils	3	
	Hydric Soils	1	
Land Cover	Grassland/herbaceous areas > than 100 acres	5	NLCD
	Grassland/herbaceous areas < than 100 acres	4	
	Shrub/scrub, wetlands, pasture, developed – open space	3	
	Forests, developed - medium intensity, developed - low intensity developed	2	
	Barrens	1	
	Cultivated Crop, developed - high intensity	0	
Distance from Cultivated Crop	Cultivated Crop plus adjoining 50-meter buffer	-5	NLCD
Cultivated Crop Inside Protected Areas	Cultivated Crop Inside Protected Areas	10	NLCD & PAD-US
Protected Areas (not including municipal parks and golf courses)	Within protected area	5	PAD-US & Forest Preserve Districts
	Within 0 - 0.5 mile	4	
	Within 0.5 - 1 miles	3	
	Within 1 - 1.5 miles	2	
	Within 1.5 - 2 miles	1	
iNaturalist Records *Eryngium yuccifolium*(129) iNaturalist Records: Regal Fritillary (12); *Viola pedata* (24); *Viola peditifida* (22); *Viola sagittata* (8)	Within 0.25 miles	5	iNaturalist
	Within 0.25 - 0.5 mile	4	
	Within 0.5 - 1 miles	3	
	Within 1-1.5 miles	2	
	Within 1.5-2 miles	1	

Table 6. Input Layers and Scores for Lepidoptera Enhancement Suitability Model

Desktop Assessment

Upon completion of the habitat modeling, a desktop assessment was performed using a GIS-based web map containing the two enhancement model output layers, orthophotography, ComEd transmission lines, and ROW and protected areas shapefiles. Users panned through ComEd's service territory, seeking areas where elevated suitability scores were bisected by or adjacent to ComEd transmission lines. Orthophotography was reviewed to assist in determining whether a given location was to become a desktop site. Sites were also selected to provide geographic diversity within ComEd's service territory. Opportunities to work with a variety of stakeholders (e.g., Forest Preserve Districts, IDNR) were valued as well.

Twenty-six potential Lepidoptera enhancement sites were identified during the desktop assessment. These were identified using the Lepidoptera enhancement model layer and are generally characterized as being part of large open blocks of land.

Thirty potential RPBB enhancement sites were identified during the desktop assessment. These were identified using the RPBB enhancement model and are generally characterized by their proximity to forested areas.

The areas identified during the initial desktop review do not represent an exhaustive list of potential enhancement sites. They represent areas

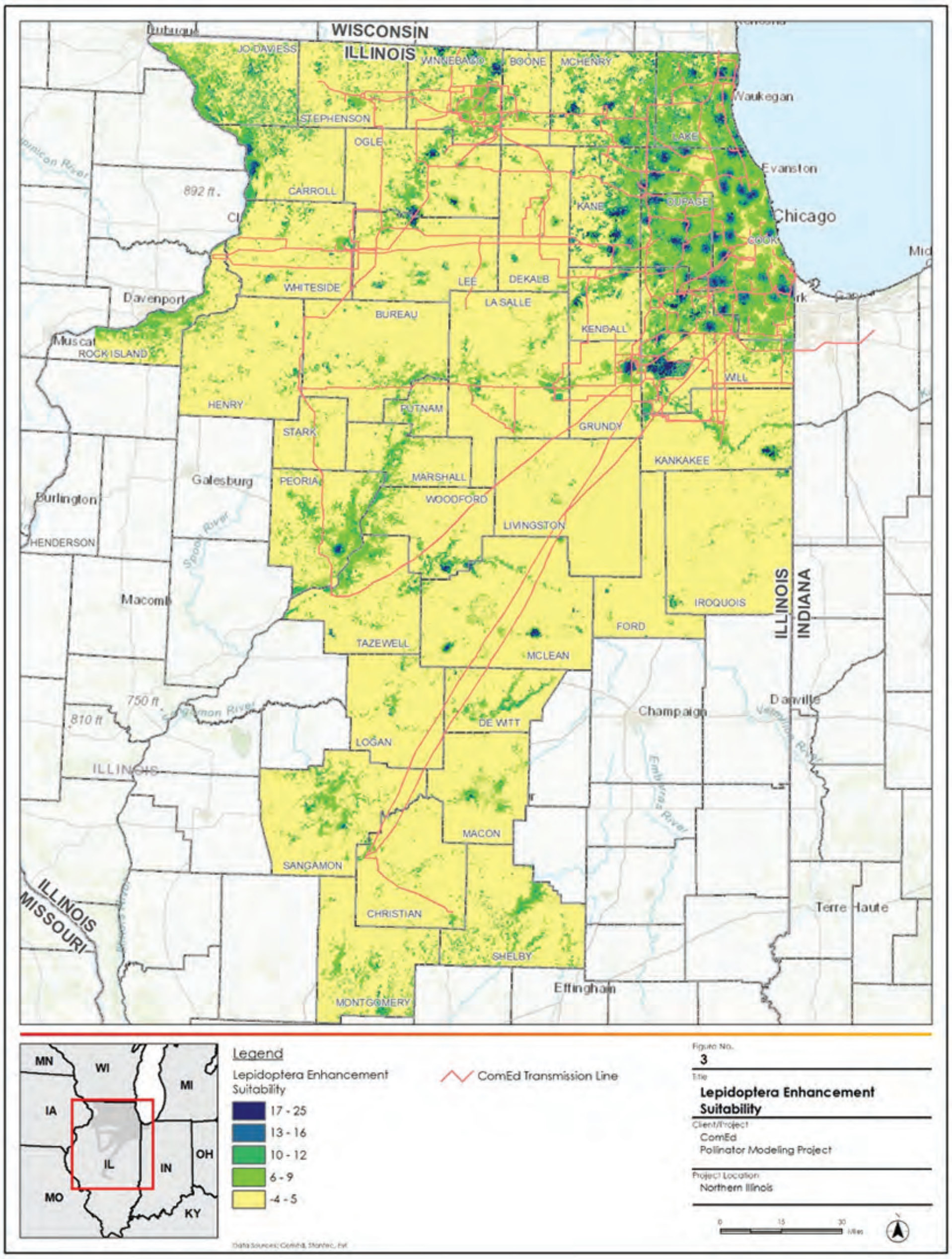

Figure 3. Lepidoptera Enhancement Suitability Model Output

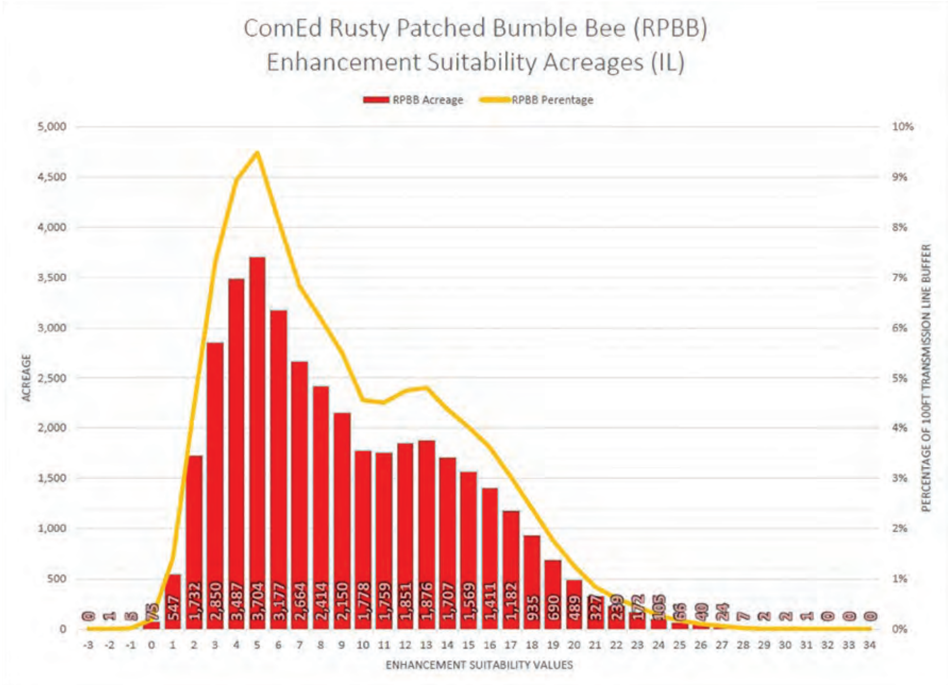

Table 7. RPBB Enhancement Suitability Acreages

Input Layer	Criteria Category	Intra-layer Score	Data Source
Soils	Fine sand, fine sandy loam, loamy course sand, loamy fine sand, loamy sand, gravelly sandy loam, sand, sandy loam	5	NRCS
	Gravelly loam, cobbly loam, cobbly silt loam, stony loam, very artifactual loam	4	
	Loam, silt loam	3	
	Silty clay loam	2	
	Clay loam	1	
	Muck, mucky sandy loam, mucky silt loam	0	
Land Cover	Shrub/scrub, mixed forest, deciduous forest, grassland/herbaceous	5	NLCD
	Evergreen forest, hay/pasture, barrens, developed – open space	3	
	Woody wetlands, emergent herbaceous wetlands, developed – low intensity	2	
	Developed – medium intensity, Cultivated Crop	1	
	Developed – high intensity, open water	0	
Aspect	Northwest	5	NED
	North, west, northeast	3	
	East	2	
	South, southeast, southwest	1	
Distance from Cultivated Crop	Cultivated Crop plus adjoining 50-meter buffer	-5	NLCD
Cultivated Crop Inside Protected Areas	Row Crop Inside Protected Areas	10	NLCD & PAD-US
Protected Areas (not including municipal parks and golf courses)	Within 2.5 miles	5	PAD-US & Forest Preserve Districts
	Within 2.5-6 miles	3	
	Greater than 6 miles	1	
Proximity to USFWS RPBB High Potential Zone Centroid	Within 2.5 miles	5	USFWS
	Within 2.5-6 miles	3	
	Greater than 6 miles	1	

Table 8. Input Layers and Scores for RPBB Enhancement Suitability Model

with high scores within potentially restorable areas. Other factors, such as potential stakeholder partnerships, may increase the value of enhancement sites.

Field Review

After the initial desktop assessment was performed, a secondary effort was performed to select subsets of both Lepidoptera and RPBB sites and create a set of sites to be field reviewed (see Figure 5-1). These sites were selected based on their high predicted enhancement suitability score and adjacent land use (based off review of orthophotography).

The field review occurred October 3-5, 2017. While late in the growing season, many Composites (e.g., *Aster* spp.) and other pollinator forage plants were either still in bloom or readily identifiable. Site characteristics were recorded on the Pollinator Field Verification Form (blank version is found in Appendix B) created specifically for this project. After each field visit, each site was assigned a score of 1-10, with 10 representing the highest quality sites and one (1) being the lowest quality sites.

Recommendations

The field review provided identification of two extremely high-quality sites on transmission ROW previously unknown—one site adjacent to Braidwood Nature Preserve and the other site adjacent to Sand Ridge

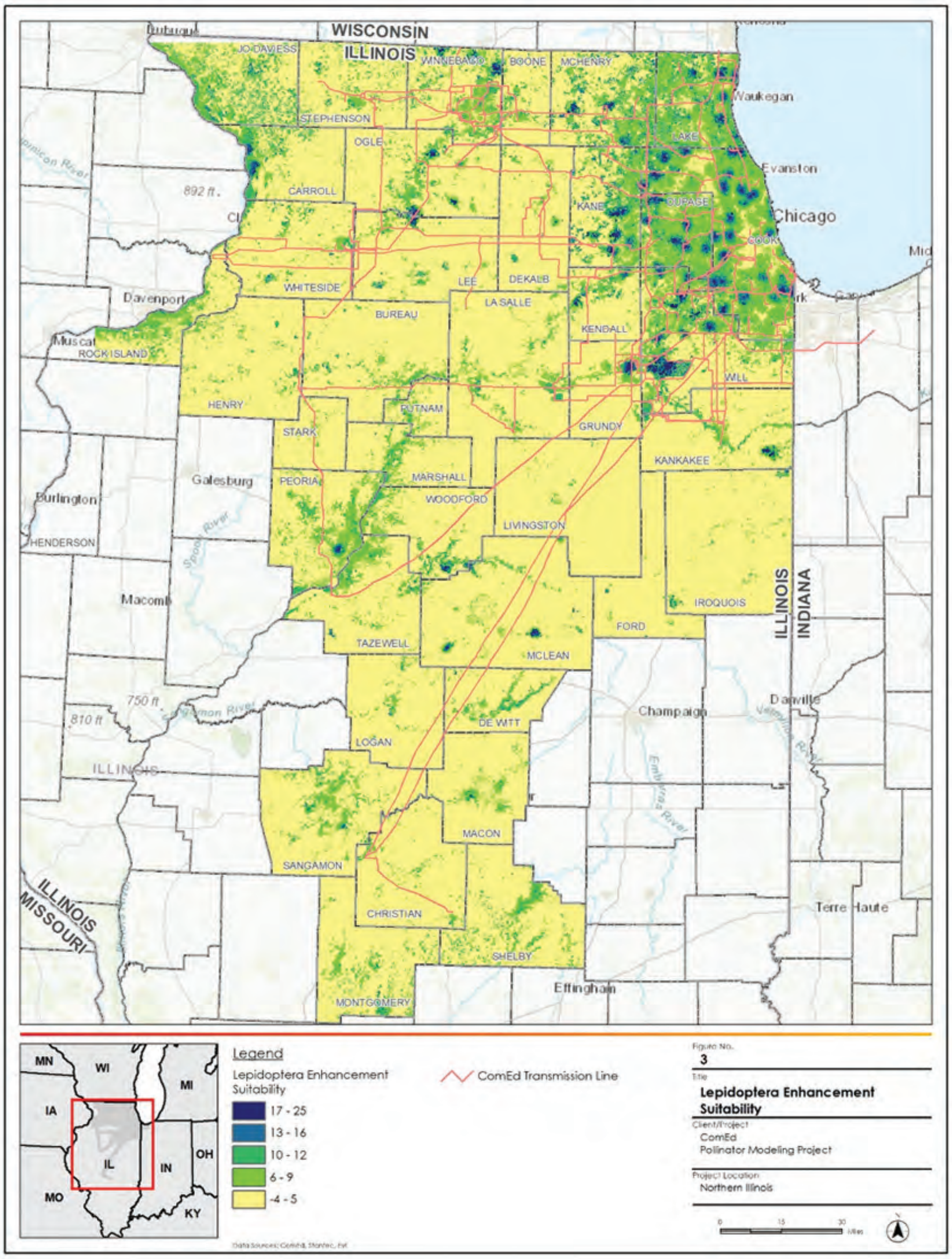

Figure 4. RPBB Enhancement Suitability Model Output

Savanna Nature Preserve. These sites, located in Will County, are high quality, intact natural areas and as such, we recommend them for immediate enrollment in the Prairie Program. These sites are each characterized by unique native plant communities that should not be altered with supplemental seeding. They will, however, benefit from yearly invasive species treatments and regular burning to preserve the integrity of the existing plant communities. This work may be completed in coordination with the Forest Preserve District of Will County and the Illinois Nature Preserves Commission.

Four sites are recommended for enrollment as Pollinator Program sites (see Table 5-1). The goal of Pollinator Program sites is to enhance habitat for pollinators. While some invasive species treatments may be recommended, pollinator habitat enhancement is primarily secured via supplemental seeding of plants species used by pollinators for foraging or breeding. The definitions and standards for Pollinator Program sites will need to be developed as part of future efforts.

Two sites are recommended for consideration as Propagation Sites. We understand that ComEd is working with a native plant nursery, Taylor Creek Restoration Nursery, to identify portions of ComEd's ROW that could be used as propagation sites for native pollinator plants such as milkweed. These two sites are well suited for this since they are currently ROW cropped. If they are not used as Propagation Sites, these sites could become Pollinator Program sites.

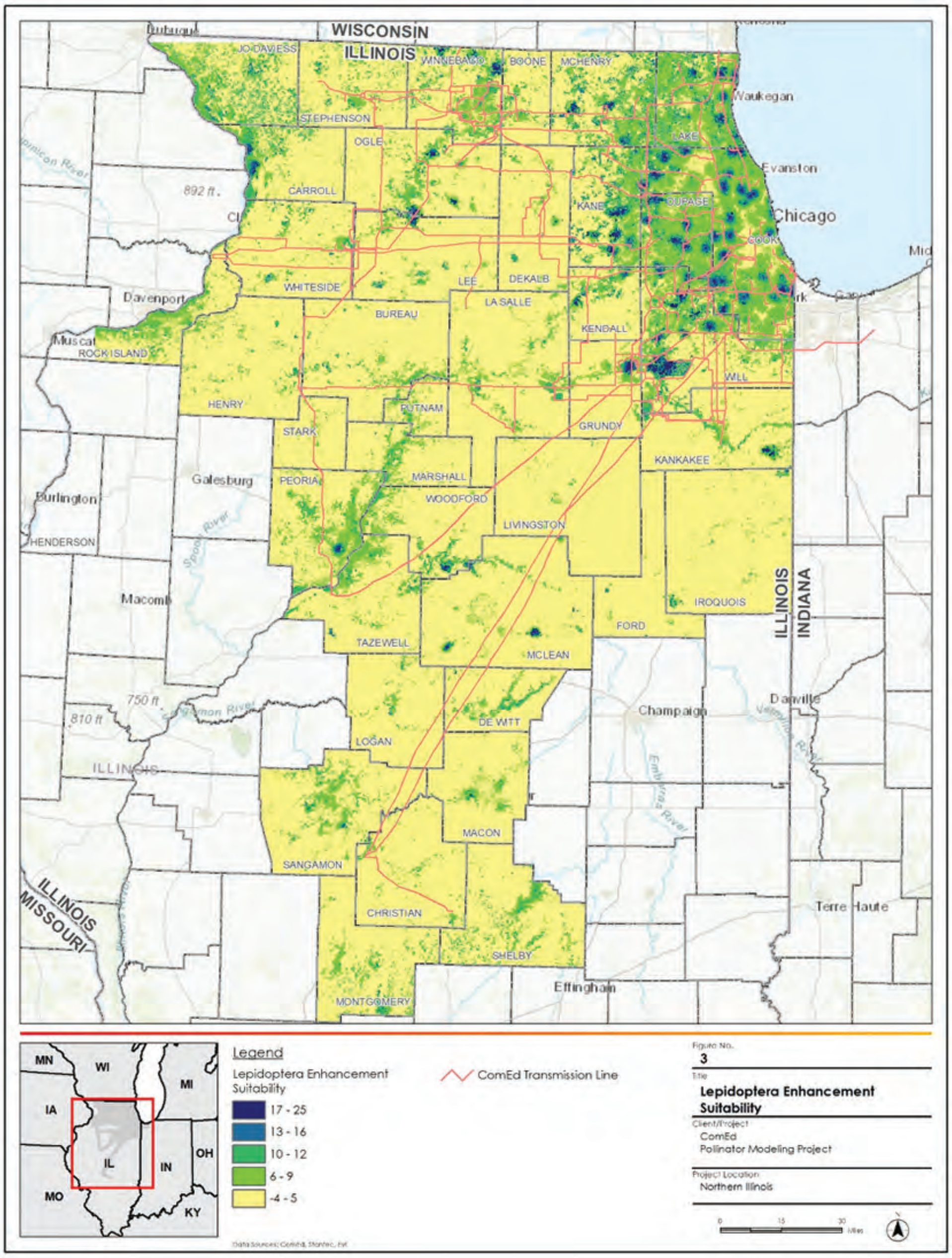

Figure 5. Locations of Field Reviewed Sites

CONCLUSIONS

The Lepidoptera and RPBB enhancement model output layers will provide value for years to come. We found them to be highly effective visualization tools when used in a desktop mapping search for potential Pollinator Program sites. By design, the enhancement model output layers synthesize enormous amounts of data in a way that allows the user to view the landscape in a truly different manner than when reviewing aerial photography alone. Users are drawn to both high-scoring areas, as well as low-scoring areas between high-scoring areas for further detailed consideration. From a conservation perspective, locating Pollinator Program sites in high-scoring areas is beneficial because it enhances existing blocks of pollinator habitat. Locating Pollinator Program sites in low-scoring areas between high-scoring areas is beneficial because it provides connectivity between existing blocks of pollinator habitat. We expect that the enhancement model output layers will be used for additional desktop site identification and that the set of desktop-identified sites will continue to be used as a starting point for future field assessments.

This process can be applied to other geographies as well. The steps would be similar as to what was performed here:

1. Identify target species
2. Perform literature review to determine life histories and habitat preferences of target species
3. Define model parameters and identify corresponding GIS data layers
4. Determine intra-layer scoring
5. Convert all data layers to rasters
6. Re-classify intra-layer features to reflect intra-layer scoring
7. Add rasters together to create model output layer

Multiple iterations are typically necessary to generate an output layer that optimally allows the user to read the landscape in a new and meaningful way. Our hope is that other utilities and ROW holders undertake a similar process to identify and ultimately create additional pollinator habitat across all U.S. geographies.

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AUTHOR PROFILES

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Sara Race is a Senior Environmental Compliance Specialist for ComEd, an electric utility company that serves most of northern Illinois. In her role, Sara is responsible for managing environmental compliance programs related to wetlands, land use, and threatened and endangered species. In addition, she oversees the company's stewardship and biodiversity programs, including ComEd's prairie and pollinator program. She is currently involved working with many NGOs and government agencies to advance common stewardship and land management goals. Sara holds a Bachelor's degree in biology from the University of Colorado, Boulder and a Masters in Environmental Management from the Illinois Institute of Technology.

Chris Pekar

Chris Pekar, GISP is a Principal with Stantec Consulting, Inc.'s Midwest Environmental Services team. He particularly enjoys using GIS to identify opportunities to enhance wildlife and pollinator habitat across urbanized landscapes and supporting ComEd's prairie program. Chris holds a Bachelor's degree in biology from the University of Colorado, Boulder and a Masters in GIS from Penn State University

Compensating for Wetland Losses in Powerline ROWs: Following Up On A Hydro-Québec Project

Alexandre Beauchemin

Keywords: Compensation, Creation, Habitat, Mitigation, Wetlands.

Within the last few years, many Hydro-Québec projects have required impact mitigation and compensation measures in powerline rights-of-way (ROWs). Wetlands (mostly), as well as terrestrial habitats, have thus been created, restored, enhanced, or conserved by applying different techniques. A portfolio of nine projects completed since 2010 (seven wetlands and two terrestrial habitats) in Québec will first be presented. This paper will then describe the creation of a 0.4-hectare (ha) wetland in a drainage basin in a powerline ROW connecting the 315/25-kiloVolt (kV) Anne-Hébert substation in an industrial landscape near Québec City. Before designing the revegetation plan, a topographical survey and a water balance study were conducted to select plant species and determine the best locations for them. Results show an increase in the number of plant species (from 54 to 89 species) five years post-construction, most of them being native species (75 percent) typical of wetland conditions (69 percent). Quick planting and seeding of the bare ground helped prevent nearby invasive species (*Phalaris arundinacea* and *Salicaria purpurea*) from colonizing the wetland. Climatic data have been analyzed for the 2010–2016 growing seasons and compared to a 1981–2010 baseline, showing a statistically significant increase in degree-days with stable precipitation. Warmer conditions in the future should be considered when selecting species to plant. Resilience of the wetland, indicated by the rapid colonization and diversification of vegetation, appears to be strong enough to withstand future maintenance work on the retention pond, which will be very infrequent. The ecological value of the constructed wetland is superior to that of the wetlands lost and will be maintained long-term, even if maintenance work has to be done. This project is an example of synergy between engineering and biology to build greener civil works.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

In the past decade, the wetlands-related requirements for project permitting in Québec have become much more stringent. This has led Hydro-Québec to make increasing use of mitigation and compensation measures in its line and substation projects. The utility has therefore developed a portfolio of creation, conservation, restoration, and improvement projects that have enabled it to consolidate its expertise, which was previously based on compensation measures for hydroelectric development projects (Table 1).

Creating wetlands and habitats in powerline rights-of-way (ROW) involves numerous constraints in terms of design, such as maximum vegetation height and preserving work areas and access roads. Nevertheless, when properly designed and located in the right areas, such projects have proven effective and resilient, despite their small size in some cases. For wetlands, a complete water balance survey is crucial, especially when creating new wetlands. Invasive plant species must also be managed, and certain sites should even be avoided in the case of very aggressive species (*Reynoutria japonica*). Finally, in areas open to the public, there should be some control of access by all-terrain vehicles (ATVs), at least while the vegetation is taking root. Access control is also needed in order to reduce the problem of illegal dumping. This article will present the results of a follow-up study on new vegetation in a compensation wetland created in a powerline ROW as part of the construction of a transformer substation.

The 315/25-kiloVolt (kV) Anne-Hébert substation was built in 2010 in the François-Leclerc industrial park in Saint-Augustin-de-Desmaures to meet the growing demand for electricity in municipalities in the western part of the Communauté métropolitaine de Québec. Because the substation construction destroyed 1.08 hectares (ha) of wetlands at the head of the Rivière Charland, a new wetland was

Project	Type of project	Type of work	Surface Area (ha)	Description
Wetlands				
Anne-Hébert	Substation and powerline	Creation	0.4 ha	Construction of a drainage basin and revegetation
Beaupré	Substation	Creation	0.4	Excavation of a basin, construction of a flood-capturing dike and revegetation
Blainville	Substation and powerline	Conservation and enhancement	3.3	Acquisition of land for conservation purposes (rare plants: *Woodwardia virginica, Fimbristylis autumnalis, Rhynchospora capitellata*), revegetation aimed at salamanders (protected species: *Hemidactylium scutatum*), excavation of ponds, coarse woody debris left
Ste-Eulalie	Powerline	Peatland restoration	1	Burial of mineral material (from road construction), leveling and revegetation (rare plant: *Bartonia virginica*)
Chénéville	Powerline (maintenance)	Peatland restoration	0.1	Removal/burial of mineral material, leveling and revegetation
Romaine	Powerline	Peatland restoration	0.6	Removal of mineral material, leveling and revegetation
Henri-Bourassa	Substation	Creation	0.4	Construction of a filtering marsh
Terrestrial				
Bout-de-l'Île	Substation and powerline	Habitat enhancement and creation	12	Tree and shrub plantations, seeding, construction of snake hibernacula, coarse woody debris left and removal of an invasive exotic species
Henri-Bourassa	Substation	Habitat enhancement	1	Construction of snake hibernacula (species of special concern: *Storeria dekayi*) and revegetation

Table 1. Mitigation and Compensation Projects in Hydro-Québec ROWs (2010–2018)

created as a compensation measure. The lost wetlands constituted of shrubby swamp (77 percent), wet meadow (21 percent) and marsh (two percent), and were of recent (<30 years) and anthropogenic origin (abandoned cultivated field and industrial settling basin). Vegetation diversity and structure were of poor qualities based on semi-quantitative and qualitative site observations, with notable presence of invasive species (Génivar 2009). Lost wetlands were located at the head of the Rivière Charland, which helped regulate flow and water quality of the river (Hydro-Québec 2011a). By breaking the hydrological connection between the wetlands and the river, the construction of the substation affected their hydrological and biogeochemical functions.

To offset this impact in 2010, Hydro-Québec constructed a retention pond to collect substation runoff during operation in an area where the soil holds water easily. A 0.41-ha basin was excavated west of the substation, with a dike, a drainpipe, and a weir for discharging overflow. At the outlets of the substation drainage ditches, two settling basins were excavated so the sediment could be concentrated in two specific areas of the retention pond. The retention pond can hold the equivalent of a 100-year flood, which it then releases gradually into the Rivière Charland.

A special planting program was carried out to enhance the pond's ecological value. The retention pond banks were hydro-seeded in 2010 with a commercial, six-species seed mix at a rate of 265 kilograms (kg)/ha. The following year, more than 2,500 shrubs and grassy plants from 32 species were planted in the pond. The planting locations were based on topological and water balance surveys aimed at ensuring adequate water inflows versus evapotranspiration and seepage losses (Aecom 2011). The end result was a combination of several different wetland types: marsh, shrub swamp, wet meadow, submerged grass beds, and open water.

In 2011, when the work was completed, the pond had 54 plant species, including those already present naturally. A before-and-after comparison of the area's ecological value, based on Joly et al. (2008) suggested guidelines, showed that the created wetland has a higher value, even though it is smaller than the lost wetland (Hydro-Québec 2011b). This is because the hydrological and biogeochemical functions are maintained, while the biotic and abiotic functions are enhanced (Hydro-Québec 2011b). Nevertheless, additional compensation was required in the form of a financial contribution to a conservation organization, as well as a follow-up study five years after completion of the substation.

This paper presents the follow-up study conducted in 2016 on the Anne-Hébert substation retention pond. The resulting data were used to evaluate the success and viability of the wetland, as well as to validate the *a priori* comparative analysis of the ecological value of the created wetland vs. the lost wetland (Hydro-Québec 2011b).

METHODS

Abiotic study

Water Level

A Solinst Levelogger water pressure sensor (model 3001 LT F15/M5, accuracy ±0.3 centimeters [cm] at maximum depth of five meters [m]) was installed in a PVC standpipe piezometer pierced at different heights. To correct the water level readings for fluctuations in atmospheric pressure and changes in elevation, a Solinst Barologger air pressure sensor (model 3001 LT F5/M1.5, accuracy ±0.05 kPa) was also installed nearby. The sensors were programmed to record data every 20 minutes. Levelogger 4.1.2 software was used to apply the barometric compensation. The corrected data were then exported to Microsoft Excel 2010. Outlying values (which occurred mainly when the sensor was taken out of the water for data downloading) were removed, and the data were aggregated into hourly and daily averages.

Weather Conditions

Daily total precipitation and temperatures (T°MIN, T°MAX and T°AVE) for the growing season (April to November) for 2010–2016 were obtained online (*http://climat.meteo.gc.ca/*) for the weather station closest to the site—namely, Québec/Jean-Lesage Intl (# 701S001), located about nine kilometers (km) away. A few missing precipitation data units were filled in using averages from the three closest stations: Beauséjour (# 7020567; 24.5 km away), Lauzon (# 7024254; 28.7 km away), and St-Flavien (# 7027259; 31.0 km away). Similarly, missing temperature data were filled in using data from Université Laval/Ste-Foy (#701Q004), which is the weather station closest to the reference station. For comparison purposes, historical data for 1981–2010 were also obtained online (ECCC 2016). The data obtained were used either as-is (daily precipitation) or aggregated into monthly averages (precipitation and temperature).

Definitions Used (Growing Season, Thermal Index, Hydric Index)

Based on the meteorological data obtained, the thermal index (degree-days) and water index (total monthly precipitation) were calculated for 2010–2016 and compared with the 1981–2010 normals. The growing season is variable from one year to the next and can also be defined differently, depending on the source consulted and the plants studied. For purposes of comparison with the historical "normal" calculated by Environment and Climate Change Canada (ECCC), the definitions used were primarily those of the ECCC (ECCC 2016), but other definitions were used when necessary (Ouranos 2015).

Biological Follow-Up

Flora

Vegetation inventories were conducted in July 2016. Species were listed by wetland type and each was assigned a coverage index. All the ecosystems were inventoried until all species present were listed.

Species identification was mainly done *in situ*, but some specimens were collected for validation at the Louis-Marie herbarium at Université Laval. Species nomenclature follows that of Vascan (Brouillet et al. 2010+). Key 2 and procedure P2 of Bazoge et al. (2015) were adapted and used to determine whether the vegetation was indicator of wetlands.

For most species, the indicator status was taken from Appendix 1 of Bazoge et al. (2015). In cases where the indicator status was not given in Bazoge, the wetlands plant list for the U.S. Midwest and Northeast was consulted (Lichvar et al. 2016). The region covered by this list is adjacent to Québec. Other publications (not listed in the references: mainly from the U.S. Department of Agriculture and the U.S. Forest Service [USFS]) were also used when the indicator status was not given in Lichvar et al. (2016). For two plants found in the area (*Salix* sp. and *Galeopsis ladanum*), no status has been defined; therefore, as prescribed in procedure P2, these plants were removed from the analyses.

RESULTS

Abiotic Study

Retention Pond Water Level

The level in the retention pond ranged between 73.84 and 74.25 m above sea level during the follow-up study (June 9 to September 12, 2016), for a total fluctuation of 41 cm. Water level variations were closely linked to daily precipitation, although the maximum level varied according to rain episodes. No rainfall episode exceeded the pond's capacity, and the highest level observed (74.25 m) was 45 cm below the weir crest (74.70 m) designed for a 100-year flood. The raw data, recorded every 20 minutes, show that after an episode of rainfall heavy enough to generate a peak, it takes about 50 hours for the water level to show a 30-cm decrease.

	2010-2016		1981-2010
	Average	*Standard deviation*	
Last spring frost (last spring day with Tmin < 0oC)	6-May	*+/- 9 days*	11-May
First fall frost (first fall day with Tmin < 0oC)	5-Oct	*+/- 7 days*	3-Oct
Frost-free season (in days)	150	*+/- 9 days*	145
Total annual degree-days	1880.9	*+/- 72 degree-days*	1732.9

Table 2. Climate Conditions for 2010–2016 and 1981–2010

Climate Conditions

The temperature data show that all the variables measured are affected by climate change. In comparison with the 1981-2010 baseline period, on average the monthly temperatures (max, min, and average), the length of the frost-free season and the number of annual degree-days are all higher for 2010-2016 (Table 2).

On average, the last spring frost is five days earlier and the first fall frost two days later compared with the averages for 1981–2010, but these differences are not significant (Student's t-tests, =0.05, p>0.3). The number of annual degree-days is significantly higher for 2010-2016 than for the previous 30 years (Student's t-tests, =0.05, p=0.0207), although the length of the frost-free season did not vary significantly (Student's t-tests, =0.05, p=0.3264), nor did the average monthly temperatures for April–November. It should be noted, however, that when the monthly averages are aggregated for April–November, the Student's t-test approaches a significant difference (=0.05, p=0.0526).

As for cumulative precipitation for April–November, which includes the growing season, the data do not show any significant differences between 2010–2016 and 1981–2010 (Student's t-tests, =0.05, p=0.4840); precipitation during the two periods therefore seems to be similar in quantity. The monthly averages do not show any clear trends, with some being higher for the baseline period and others for the post-project period.

Overall, 2010 and 2012 were warmer (total annual degree-days), but dryer (total annual precipitation), than the average for both 2010–2016 and 1981–2010. 2011 was also warmer than average, but precipitation was in the normal range.

Biological Follow-Up

Flora

Within the created wetland, vegetation differed from one type to the next in terms of both diversity and density. The wet meadow and the marsh had dense coverage (nearly 100 percent), whereas the shrub swamp, five years after planting, still had less than 50 percent coverage.

A total of 89 plant species were inventoried in the created wetland: 15 shrubs and 74 grasses (Appendix 2). The vegetation is largely dominated by native species, which make up 75 percent of the species inventoried. Of the 87 species whose indicator status was defined, 60 (69 percent of the species present) indicate the presence of wetlands (Table 3). The vast majority (80 percent) of the inventoried species colonized naturally, and the majority (64 percent) of those naturally colonizing species are typical of wetlands.

Of the 32 plant species planted in 2011 (Aecom 2011), 18 were inventoried in 2016 for a colonization rate of 56 percent after five years. Of the nine shrub species planted, six were inventoried in the new wetland. Among the latter, one special-status species (MDDELCC 2016), namely Kalm's St. Johnswort (*Hypericum kalmianum*), was planted in 2011 and inventoried in 2016 (Figure 9). As for the grasses, 12 of the 23 species planted were still present in 2016.

Two invasive alien species were observed in the wetland: common water reed (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*). The latter was found in all the wetland ecosystems except the submerged grass beds and open water, but it was not dominant, with a coverage ranging between one percent to less than 25 percent coverage, depending on the wetland type. The common water reed was found in the shrub swamp, the wet meadow and the emergent marsh, with a coverage of less than one percent in each. This species therefore has a marginal presence in the created wetland at the present time.

DISCUSSION

Effectiveness of the Retention Pond as a Compensation Measure

Hydrological and Biogeochemical Functions

According to the data gathered, the retention pond is meeting its objective in terms of hydrology. After a rainfall episode, it stores the water and then releases it gradually, according to the flow rates prescribed by the city of Saint-Augustin-de-Desmaures, in order to reduce downstream erosion. The pond level data and the precipitation data are well correlated and show that the pond, as designed and built, does perform a hydrological function. The maximum level reached during the 2016 follow-up study was well below the weir crest. At that time, the pond had a good margin of capacity available to store more water. The main function (hydrological) of the wetlands affected by the substation construction was therefore compensated.

Since water quality was not measured during the environmental follow-up, very limited conclusions can be offered in that regard. However, based on qualitative observations made during field visits, it can be stated that the water arriving in the pond from the drainage ditch in the industrial area north of the substation is relatively free of sediment. No cloudy water was noted; the water was clear and the bottom of the ditch was always visible. The same was observed for the water in the pond and the water released into the river. Although these observations are only qualitative, sediment does not appear to be a particular problem.

Biological Functions

The biotic functions of the created wetland are better than those of the destroyed wetland. The entire area of the retention pond is indeed a wetland, as shown by the vegetation studies, and the vast majority of the species inventoried are native and have colonized naturally. In addition, most of the dominant species have colonized naturally, are typical of wetlands, and are native. Natural colonization is an

Total wetland					
	OBL*	FACW*	U*	Undetermined	**Total**
Number of native species	21	29	16	1	**67**
Number of species introduced	1	9	11	1	**22**
Total number of species	22	38	27	2	**89**
Wetland/Upland	Wetland		U		
Number of species / (Proportion)	60 / (69%)		27 / (31%)		
	OBL	FACW	U	Undetermined	**Total**
Number of species planted during construction still present 5 years after	9	7	2	0	**18**
Number of species colonized naturally	13	31	25	2	**71**

*Wetland indicator status: OBL=Obligate, FACW = Facultative Wetland and Facultative, U=Facultative Upland and Upland. Adapted from Lichvar et al (2016).

Table 3. Species Observed in the Created Wetland

important factor since it reflects environmental conditions—soil humidity in particular. Based on this parameter, it may be expected that more wetlands species will colonize in the retention pond with time, further enriching its diversity. Vegetation comparisons between lost and created wetlands are limited because of different vegetation data qualities (complete survey in present study; semi-quantitative and qualitative survey in Génivar 2009). Despite this limit, observations are sufficiently contrasted to argue that the vegetation diversity of the created wetland (89 species) is better than that observed in the lost wetlands. For instance, the number of dominant species, as per Bazoge et al. (2015), in the created wetland is far exceeding the total number of main species observed in the lost wetland (respectively 27 and 10 species). Moreover, Kalm's St. Johnswort—a species likely to be designated threatened or vulnerable—has established a healthy presence in the area. This was one of the species included when the new wetland was planted.

The fact that the planting was done very soon after the pond was constructed had the beneficial effect of curbing the arrival of invasive alien species. Common water reed, which had been abundant before the project, is significantly less present in the new wetland. This positive impact contributes to the wetland's integrity and viability.

The retention pond also serves as a wildlife habitat. For example, it is directly used by four anuran species and seven bird species (specific inventories conducted in 2016, data not presented). Signs of use by white-tailed deer, common garter snakes, and muskrats have also been observed on several occasions, along with small fish in the pond. However, no comparison can be made since no wildlife inventory was conducted in the lost wetlands.

Concerns Regarding the Integrity and Viability of Man-Made Wetlands

During the talks on compensation measures, the authorities expressed some doubt about wetlands creation as an acceptable compensation measure, especially when the pond serves a dual function (civil engineering and environmental). However, according to a report commissioned by the MDDELCC, "[…] The only sustainable wetland management methods for achieving the objective of no net loss are the restoration and creation of wetlands" (translation) (Pellerin and Poulin 2013). Construction of the Anne-Hébert substation retention pond and the subsequent follow-up study provide further support for wetland creation as a compensation measure, as long as the initial conditions are favorable. Creation is a good choice when the hydraulic conditions lend themselves to wetland development (i.e., sufficient water inflow and poor soil drainage), which together contribute to a high water table. In the present case, the conditions were favorable: in particular, rock is present near the surface (less than 60 cm deep) and the area has a natural tendency to form wetlands from uncultivated farmland. In addition, after the pond was created, it was rapidly colonized by aquatic vegetation. These observations were subsequently confirmed by a water balance survey. In other words, the new wetland had all the right conditions to be a success, even though it was man made and came about because of civil engineering requirements. This is a commendable effort to make industrial facilities greener, and other project developers should be encouraged to follow this example.

The wetland's viability depends on a multitude of factors that are beyond the company's control (prolonged drought or flooding, climate change, invasive alien species, etc.). Nevertheless, based on the parameters measured, there is reason to be confident that the wetland will be viable. Vegetation diversity is on the rise and consists mainly of native aquatic plants, which contributes to the wetland's resilience. Resilience is important for surviving stochastic events such as drought, flooding, and disease—especially for a small area like the retention pond.

Concerns have been expressed about the impact of maintenance work—since this is a civil engineering project and by definition will require maintenance—on the wetland's ecological value and viability. These concerns must be addressed. First of all, like all civil engineering works, the retention pond was designed to keep maintenance needs to a strict minimum. No periodic maintenance is planned; however, the retaining structures may need repair from time to time, or dredging may be necessary if there is an unusual amount of silt buildup. Such work should be seen as short in duration, limited in scale, and occurring occasionally across a long period of time. In addition, since maintenance will not take place over the entire wetland, but will be limited to the jobsites, mitigation measures can be applied to reduce the impacts. Thanks to the wetland's resilience as shown by the observed rapidity of the vegetation colonization, any areas affected by maintenance can be expected to recover quickly. In other words, since the frequency of maintenance is exceeded by the speed of vegetation growth, the ecological value and functions of the wetland will be preserved in the long term.

Development Techniques Used and Areas for Improvement

Importance of the Water Balance Survey

It may seem obvious, but the motor driving the development of typical wetland vegetation is, first and foremost, abiotic. Namely, water. The quantity of water, how long it stays, and how well its presence is synchronized with the seasonal growth cycle, all play a decisive role in the kinds of vegetation that will grow there. Before any decision to create a wetland, these parameters must be rigorously documented from existing data on precipitation, temperature, topography, and soil. For this reason, following the initial observations of permanent water and aquatic vegetation in 2010, a water balance survey was conducted before the planting program was drawn up (Aecom 2011). A water balance survey can be summed up as the calculation of water inflows (precipitation and runoff) and water losses (evapotranspiration, seepage, discharge) for the growing season in order to ensure that the inflows are greater than the losses. It is a tool used to assess the risk inherent in a project and help the proponent decide whether or not to go ahead. When used in conjunction with very precise land surveying, it helps determine the best locations for planting, thus reassuring government authorities as to the probability of success and making them more likely to accept wetland creation as a compensation measure. In the present case, as soon as the project was undertaken, all the water balance survey parameters were promising and generated confidence in the success of the new wetland.

A water balance survey, combined with topographical data, is crucial for determining the best planting locations for wetland vegetation. Such vegetation is dependent on the presence of abundant water for a sufficient length of time. Certain species have more tolerance for prolonged or permanent flooding. It is therefore essential to determine exactly where they should be planted so that they will have the best conditions for growth.

Seeding and Planting

The planting success rate is 56 percent of the species planted, which is somewhat disappointing given the number of plants planted for each species. As for the 44 percent that did not survive, the reasons for their failure are not known. Since the species, the planting substratum (inorganic substratum beneath the excavated pond bottom), the size of the plants, and when they were planted (July) are all known parameters, it would be interesting to refine the analysis for a future project in order to improve the success rate. No doubt one of the lessons learned from this planting program is the value of using a wide variety of species, given that the risk of failure is often impossible to predict with the available data.

Hydroseeding, although limited to the pond banks, yielded impressive results in terms of height, density, and diversity. There are two possible reasons for this: the hydroseeding process and the organic substratum applied to the pond banks. The banks were covered with a commercial mix of seed, fertilizer, and mulch at a rate of 265 kg of seeds per ha, which is the manufacturer's recommended rate for rapid revegetation. In addition, before seeding, a layer of organic substratum was spread over the banks to promote plant growth. The substratum came from the topsoil stripped before excavation and contained seeds that were able to sprout and take root, thus producing greater diversity. The seeding of a grassy cover may have created a microenvironment favorable to the growth of other grasses and shrubs, as shown by the diversity and density of the grasses and the greater height of the shrubs on the pond banks as compared to those in the shrub swamp.

It is interesting to note that all but one of the six species seeded gave way to other species, most of them native. It may therefore be advantageous to use a mix of fast-growing seeds, even though they are not necessarily native species. Companion plants (in this project, annual ryegrass) can be helpful in the initial seeding of other species. One way in which the project might have been improved would be to seed the shrub swamp to promote vegetation density and create a microenvironment that would be cooler and damper in the summer, as well as better insulated in the winter thanks to the snow trapped in the thatch. The establishment of grass beds also promotes the production of a layer of organic matter, especially if the grasses are nitrogen fixers that enrich the soil and perform well in poor soils.

Rapid Revegetation

The revegetation was done very soon after the pond was excavated: the pond banks were seeded immediately, and the planting took place the following year. This may have had the effect of curbing recolonization by invasive alien species, which had been abundant before the project and are still found in nearby areas. Rapid planting is important in order to initiate the biological processes without delay while limiting invasion by undesirable species.

Species Selection and Climate Change

Wetland creation must be seen within a timeframe of several decades or even forever. With this in mind, climate change becomes an important consideration in wetland design, especially in the selection of species to plant. The climate data analyzed for this study show a warming within the past 30 years, which translates into a statistically significant increase in degree-days. It is possible that certain species that do not actually thrive at a given latitude because of harsh climate may, in future, find the conditions suitable. Therefore, selecting species to implement solely on the basis of actual range distributions could result in diminishing returns, particularly in terms of the wetland's resilience against climate change. It is not yet clear how to factor this in, since the observation is only made after the fact. However, hardiness zones and species distribution could be inputs to consider. It may also be interesting to use wetland creation to introduce species that are not now present but whose presence is anticipated and desirable in the long term. Such wetlands could serve as propagation hubs for desirable types of vegetation while countering the aggressive spread of alien species.

CONCLUSIONS

The retention pond excavated in wetlands for the construction of 315/25-kV Anne-Hébert substation is an example of synergy between engineering and biology toward the objective of building greener civil structures. It is now possible to blend industrial or urban infrastructure into the environment, and it is a challenge that has become more important to meet as more and more wetlands are lost. This project shows that the creation of functional and diversified wetlands is an effective way of compensating the impacts of a development when the abiotic conditions are favorable and when the project is carefully designed and executed.

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Alexandre Beauchemin is a biologist (McGill University), with a Master's in Environmental Sciences (Université du Québec à Montréal), who works as an environmental advisor at Hydro-Québec since 2004. He has acted as a large-mammal and vegetation specialist on major hydroelectric developments (Eastmain-1, Eastmain-1-A/Rupert river diversion, Romaine hydroelectric complex) and high-voltage powerlines and substations projects. Throughout his career, he has been involved with scientific and practical issues regarding impact assessment, mitigation, compensation, and follow-up, mainly in the field of large mammals and vegetation.

White-tailed deer have been studied by Hydro-Québec within the last several decades. The findings of these studies show that powerline rights-of-ways (ROWs) that cross their winter yards can provide accessible browse for deer. Special care needs to be taken when managing this prolific and expanding species. Hydro-Québec has designed a hierarchical selection key aimed at identifying yards in areas in need of special vegetation management (VM) plans while avoiding exacerbating issues associated with deer overabundance. Elements composing the selection key are presented and discussed.

Customized Approach for Ungulate Habitat Management In ROWs: White-Tailed Deer Winter Yard Selection

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Keywords: Evaluation, Utility Lines, Maintenance.

Environmental Concerns in Rights-of-Way Management
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INTRODUCTION

Rights-of-way (ROWs) are open areas that can both provide benefits for ungulates (feeding; Garant and Doucet 1997) and entail costs (risk of predation; Smith et al. 2008; Whittington et al. 2011). The animals' use of these areas (selection or avoidance) appears to stem from a compromise (Laurian et al. 2012) and may reveal major differences between species. White-tailed deer (*Odocoileus virginianus*) may use line ROWs for winter feeding (Garant and Doucet 1997), whereas moose (*Alces alces*) are more or less neutral to them (Ricard and Doucet 1999), and forest-dwelling woodland caribou (*Rangifer tarandus caribou*) generally avoid them (Lesmerises et al. 2013). These pronounced behavioral differences must be incorporated into ROW planning, design, and management in order to provide the right mitigation measures for the right species. It is also important to consider other parameters (demographics, limiting factors, social and economic values, legal protection tools, management tools, etc.) likely to help in decision-making for optimal resource allocation. This article sets out to describe the decision-making process involved in applying specific measures for managing Hydro-Québec operations in white-tailed deer habitat.

Generally speaking, white-tailed deer populations in North America have grown rapidly since the 1960s and 1970s as a result of changes in their environment and reduced hunting and predation pressure (Côté et al. 2004; Waller and Alverson 1997). In Québec, the continental population of white-tailed deer (i.e., excluding Île d'Anticosti) rose significantly in recent decades—from 155,000 deer in 1995 to 241,600 in 2008 (Huot and Lebel 2012). When present in high densities, deer can come into usage conflict with humans as they are involved in highway collisions and cause ecological impacts and economic losses (Côté et al. 2004; de Bellefeuille and Poulin 2004; Dussault et al. 2005; Stromayer and Warren 1997; Waller and Alverson 1997; Widenmaier and Fahrig 2006).

At our latitudes, deer are at the northern limit of their range and winter accounts for much of their mortality (Dumont et al. 1998). The deer demographic picture varies widely from region to region; in some, the area's support capacity has been exceeded, while in others, this is not the case (Huot and Lebel 2012). White-tailed deer have adapted to the harsh climate in two ways: by building up fat reserves (as much as 30 percent of their weight) and through winter use of coniferous forest habitats where the microclimate is less harsh relative to their annual home ranges (Hébert et al., 2013). Year after year, the deer return faithfully to these places where the climate is more conducive to winter survival (less snow on the ground, favorable sunshine, etc.), and may travel dozens of kilometers (km) to shelter there. In Québec, these places are fairly well known. The largest (>250 hectares [ha]) are called *white-tailed deer yards*, are mapped under the *Regulation respecting wildlife habitats* (RWH), and are protected on public land (RWH, c. C-61.1, r. 18). In 2015, Québec had 307 white-tailed deer yards: 37 percent in forests that are publicly owned, and therefore protected by the Regulation, and 63 percent in privately owned forests. Hydro-Québec's transmission grid crosses 93 of these deer yards.

To manage and utilize this population (1,045 jobs,152,000 hunters, $111 million in annual spinoffs: ÉcoRessources 2014), Québec's Ministère des Forêts, de la Faune et des Parcs (MFFP) established a white-tailed deer management plan for 2010–2017 (Huot and Lebel 2012).

Based on its own studies carried out in recent decades (Garant and Doucet 1997), and with a view to updating its corporate policy in this regard and helping to achieve the management plan objectives (Huot and Lebel 2012), Hydro-Québec has developed a key for selecting white-tailed deer yards where operations management plans could beneficially be developed and implemented. The method developed is based on criteria that are recognized by the MFFP and are easy to apply and update. Hydro-Québec has voluntarily included deer years in privately owned forests in its effort, even though these are not covered by any legal protection. The company's efforts to improve food habitat availability and quality will enable it to play a part in reaching some of the management plan's objectives (Huot and Lebel 2012).

METHOD

To select the deer yards crossed by transmission lines for which it would be desirable to develop operations management plans, various criteria were defined. The criteria were chosen on the basis of the white-tailed deer's biology and its social and economic value as a game species in Québec. The three criteria selected are 1) white-tailed deer population level management objective, 2) winter harshness, and 3) hunting level. These criteria were then organized in a hierarchy in the selection key and were assigned thresholds. The selection key is intended to identify the deer yards where it would be desirable to develop an operations management plan, and assign them a priority as objectively as possible (Priority 1 or Priority 2).

Criterion 1: Population-Level Management Objective

Each deer hunting zone has a deer population level objective (Huot and Lebel 2012). Three deer population level objectives were established in the management plan: increase stabilization and reduction in deer populations. These objectives are based on current population densities, support capacity of the habitats present, social acceptability of the deer, and interest by hunters (Huot and Lebel 2012). The management objective thus integrates various components that are important to consider in making decisions pertaining to white-tailed deer management. Moreover, as this objective most clearly reflects the MFFP's analyses of the situation prevailing in a specific hunting zone, it seems important to adhere to the goals that ensue from it. For example, in Hydro-Québec's view, it would not be desirable to apply measures promoting white-tailed deer in a hunting zone that has an objective of reducing their population.

Criterion 2: Winter Harshness

Winter harshness, defined by the depth to which the deer sink into the snow, is an important limiting factor for deer in Québec. Particularly harsh winters can lead to a white-tailed deer mortality rate in excess of 40 percent in Québec (Potvin et al. 1981; Cantin and Pichette 1989). Potvin et al. (1981) observed that the majority of mortalities were by starvation, namely a negative energy balance over an extended period, but winter harshness can also mean an increase in predation rate (Nelson and Mech 1986a; Nelson and Mech 1986b; DelGiudice 1998; DelGiudice et al. 2002). Deer yards in hunting zones that experience harsher winters should be favored for the application of operations management plans so as to promote the deer's winter survival.

Criterion 3: Hunting Level

This criterion first represents the importance of hunting on population demographics as hunting is a major factor in regulating deer populations (Huot and Lebel 2012). For instance, overhunting of deer in the 1960s in western and central Québec is one of the factors that led to a marked decrease in populations until the 1980s and 1990s (Lesage 2001; Laplante 2015). This criterion also indicates the social and economic importance of hunting. White-tailed deer hunting provides substantial economic spinoffs in Québec and is of considerable interest to hunters (ÉcoRessources 2014; Huot and Lebel 2012). It is consequently important to manage this resource well in order to maintain the social and economic benefits it provides to Quebecers.

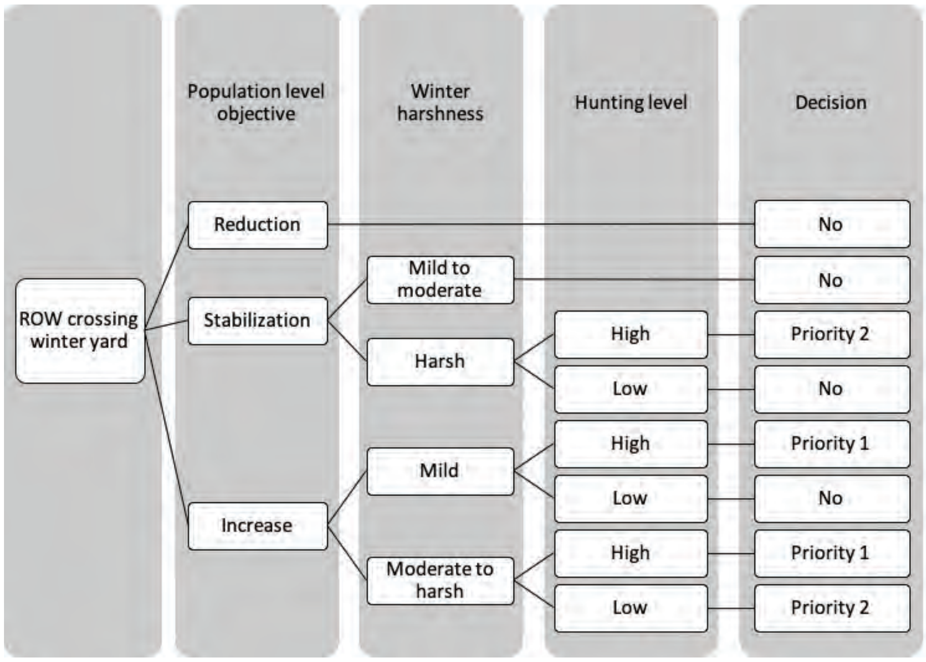

Figure 1. Selection key developed by Hyrdo-Québec to identify white-tailed deer yards crossed by powerline ROWs that should be the subject of operations management plans

Establishing a Hierarchy of Criteria and Decision-Making Thresholds

Each criterion corresponds to a level in the selection key and is arranged in a hierarchy (Figure 1). The first level corresponds to criterion *1*: *white-tailed deer population level*, the second level corresponds to criterion *2*: *winter harshness*, and the third and final level corresponds to criterion *3*: *hunting level*. The thresholds set for each criterion were applied in order to filter the deer yards crossed by a Hydro-Québec transmission line at each level. Deer yards that do not reach the third level will not have operations management plans. Deer yards that reach the third level of the selection key may have a Priority 1 or Priority 2 management plan, depending on the hunting level criterion.

Application of the Key and a Posteriori Visual Analysis

The selection key was applied to the deer yards crossed by Hydro-Québec transmission line ROWs without regard to the size of the area crossed or the location where the transmission lines cross the deer yard (in the center or on the edge). Some deer yards are actually affected by the ROWs either very little or only on the edge of their area. These two parameters (size of area and crossing location) influence the effect the ROW may have on a deer yard, as well as the effectiveness of the operations management plans. It is consequently important to take them into account and adjust the selection accordingly. The mapping of each deer yard selected was therefore analyzed visually a posteriori and deer yards crossed by transmission line ROWs only on the edge or over a small surface area (<10 ha) were rejected.

RESULTS

According to the 2015 MFFP data, there were 307 white-tailed deer yards in Québec: 113 privately owned and 194 with mixed or public ownership. Of these white-tailed deer yards, 93 were crossed by transmission line ROWs. One of these deer yards (Saint-Émélie-de-l'Énergie) is in hunting zone 15 east, which does not have a hunting management plan; there are consequently no data on the different criteria used in the selection key (Lebel and Huot 2012), and the zone must therefore be excluded from the analysis. The selection key was thus applied to 92 deer yards. At the outset, 56 deer yards were rejected because of their population reduction objective (n=24) or mild winter (n=32). Of the 36 deer yards selected following application of the key, 12 were excluded a posteriori because the transmission line ROWs crossed only the edge of the deer yards (one case), the area crossed was small (<10 ha; four cases), or both situations were present (seven cases).

In the end, following application of the key and a posteriori visual analysis of the deer yards, a total of 24 areas were selected for the development of operations management plans: eight deer yards for Priority 1 plans and 16 areas for Priority 2 plans.

CONCLUSIONS

Application of the selection key, combined with a posteriori cartographic analysis, led to the selection of 24 white-tailed deer yards out of the 93 yards crossed by Hydro-Québec transmission line ROWs, for which it would be desirable to develop operations management plans in order to promote winter survival by deer.

The next step will be to identify the lines and spans that could be targeted by these plans, as well as the operations that could beneficially be managed on the basis of the deer's needs and habitats. The possible measures to be developed and implemented will be discussed with the operator of these lines in order to balance the environmental objectives with system operating and safety constraints. Since the selection key specifies two priority levels, it would be possible to begin with Priority 1 deer yards, then follow with Priority 2 deer yards.

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AUTHOR PROFILE

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Alexandre Beauchemin is a biologist (McGill University), with a Master's in Environmental Sciences (Université du Québec à Montréal), who has worked as an environmental advisor at Hydro-Québec since 2004. He has acted as a large-mammal and vegetation specialist on major hydroelectric developments (Eastmain-1, Eastmain-1-A/Rupert river diversion, Romaine hydroelectric complex) and high-voltage powerlines and substations projects. Throughout his career, he has been involved with scientific and practical issues regarding impact assessment, mitigation, compensation, and follow-up, mainly in the field of large mammals and vegetation.

The development of a Pollinator Site Value Index (PSVI) for use in utility rights-of-way (ROWs) was prompted by the need to quantify the plant community changes following a management regime from traditional cutting-mowing to integrated vegetation management (IVM). This paper describes the methods of the PSVI and its progression.

Specific pollen and nectar data for the full complement of plant species native to the U.S. was explored for hymenopteran pollinators, but sufficient data were found in the literature for just the two eusocial genera, *Apis* and *Bombus*, and only for the Mid-Atlantic region and a few adjacent U.S. states. Thus our objective became to quantify the botanical changes in a ROW as time progresses using a PSVI based on pollen and nectar values, along with eight additional metrics, limiting us to the non-native species, *Apis mellifera* L. (Western or European honey bee), and the native genus *Bombus sp*. Latreille (bumblebees).

Using the PSVI, we document the botanical community changes and their relative pollinator benefit that occurs on six ROW case studies in four states (Maryland, Michigan, North Carolina, and Tennessee). A baseline assessment is made following typical ROW maintenance by hand and/or by mechanical cutting of trees and brush, which is an ecologically disruptive and often erratic cycle, and our research follows the gradual establishment of a more stable and compatible vegetation cover during the implementation of an IVM regime.

Formulation of PSVI to Measure the Benefits of ROW Habitat Change for Pollinators (*Apis* and *Bombus spp.*) Following the Management Transition From Traditional Cutting-Mowing Practices to IVM

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Keywords: Apis Honey Bee, Bombus Bumblebee, Eusocial Pollinators, FAC-003, Integrated Vegetation Management (IVM), Pollinator Site Value Index (PSVI), Rights-of-Way (ROWs).

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INTRODUCTION

The syndrome colony collapse disorder (CCD), also known as Multiple Stress Disorder (MSD) in Can-ada, was formerly named in late 2006 following a dramatic rise in the number of disappearances of western or European honeybee (*Apis mellifera* L.) colonies in North America. European beekeepers had observed similar phenomena in many countries of the European Union, with the Northern Ireland Assembly receiving reports of declines of >50 percent (Shannon 2009). However, CCD had been known for several years prior to that date. The global concern and response among the entomological scientific community since then has been significant, with copious research studies that have been conducted to determine the reason. The results have shown that there is no single cause, but a multiplicity of events surrounding the issue. Ironically, in our view, without the advent of CCD, there would not have been the focus on pollinators through the U.S. Federal Strategy on Pollinators (Vilsack 2016), or on our native bees that there has been, of which there are roughly 4,200 species in the U.S.—80 percent of which are pollen and nectar generalists. In North America, native bees do not congregate in hives as honey bees do. Approximately 70 percent of native bees are ground-nesting species, with the remaining 30 percent being cavity nesters (eight), along with 46 native bumblebee (*Bombus sp. Latreille*) species.

With the cause for concern for honey bees, the authors, who have done extensive integrated vegetation management (IVM) and botanical documentation on utility rights-of-way (ROWs) for nearly three decades, are interested in evaluating the relative importance of habitat to native pollinators derived from various IVM techniques, especially comparing widely accepted mowing maintenance with the judicious use of herbicides. Mowing is often used as a wholesale vegetation clearing tech-nique that "sets back" the plant community from late successional tree dominance to one that allows germination of more light dependent grasses and forbs. Our research, however, has documented that this early successional plant community is short lived, often only for one growing season, as the cut trees and invasive plants quickly grow back and reestablish their dominance. We used multiple year studies of the same areas and analyzed plant community changes when only cutting/mowing was practiced, compared against adjacent areas where the addition of various herbicides and IVM application techniques were used.

Figure 1. Restored Pollinator Habitat at Patuxent NWR

A search of the scientific literature found no single index that could be applied directly to evaluate and qualify the value of botanical communities to insect pollinators in utility ROWs. Furthermore without a critical analysis of our field data for various VM practices, there is no way to empirically determine the value of a given area to a range of pollinators, and the relative benefit or cost of a chosen practice; hence our pursuit and development of a Pollinator Site Value Index (PSVI).

In the U.S., there are more than 24.5 million hectares (ha) (61 million acres) estimated to be in all ROWs (Holt 2016, *personal communication*). Of that, approximately 19.5 million ha (48 million acres) are in utility (oil, gas, and electric) ROW, providing a huge potential pollinator habitat resource.

METHODS

The PSVI concept generates a cumulative estimate of a botanical community's value to native pollinators at a specific location that is representative of the general ROW conditions being managed for an ecosystem type. We originally based this on a broad and comprehensive set of factors that included scoring various VM practices (i.e., mowing, broadcast, or selective spraying and herbicide chemistry). However, an IVM program allows all control method tools in the tool box to be considered without bias. The vegetation manager must choose the most appropriate control method based on the conditions found and the management objective(s) of the site. Subsequently the metrics were paired down to just five (Table 1) that provide a snapshot of present plant community conditions relative to their value to pollinators.

Using the data elements in the table, similar to other biological indices (Cretini and Steyer 2011), a scale was developed ranking each plant species for its pollen and nectar values to a particular pollinator and these values are subsequently combined for a total PSVI for any site (Lindtner 2014).

After much research, it became apparent that, of the eusocial hymenopteran pollinator insects, only the European Honey Bee (*Apis mellifera*) and the native bumblebee genus, *Bombus sp*., had enough pollen source value (PSV) and nectar source value (NSV) data available to allow any model to proceed. To date, the values used for pollen source are not entirely objective (i.e., they are not based on laboratory analyses), but are the result of extensive qualitative field work conducted by Peter Lindtner, who, in his text, also provides an NSV rating, similarly quantified (Lindtner 2014).

Generally, ROW VM is constrained in ways biologists typically do not heed. In particular, an electric ROW must exclude tall growing plants, which threaten safety, reliability, sight distance, or access. A natural gas ROW has similar needs, plus exclusion of woody root systems that can damage under-ground pipes. Thus, trees and dense shrubs must be removed and VM practices should direct ecological succession towards low-growing, early successional plant communities dominated by grasses, herbs, and forbs. Thus, our PSVI snapshot of the present plant community conditions relative to pollinator value is designed to help guide future VM practices that can either maintain or improve upon the ecosystems' relative value to a particular pollinator.

Field data collection is established at sites that are representative of the typical ecosystems crossed by the ROW, referred to as the case study plot, enumerating the species found in that plot and estimating the percent cover of each species. Sometimes identification could only be made to the genus level. Ideally, vegetation sampling should occur biannually, in the spring and late sum-mer, when knowledge of each species found can provide the number of flowering months in which those plant species supply nectar/pollen.

For analytical purposes, each plant species is coded with several variable tags, which we found convenient for data analysis. For example, there is a 0/1 variable on each plant species, which identi-fied it as an undesirable tree that could grow to impede a powerline above, or cause damage to a pipeline through root damage below. Therefore, at each ROW site, we carefully track the percent cover of these undesirable trees with time as the land undergoes management changes.

	SITE VEGETATION VARIABLE METRICS	Max Rating
1	Forbs, vines, & small shrubs: pollinator plant species DIVERSITY INDEX (# pollinator beneficial species/site)	50
2	Breeding and over-wintering habitat quality. Bare ground, snags, pithy stems. Area S/M/L Rating = % survey	50
3	Annual Nectar Source Value (NSV) total cf (core food)	500
4	Annual Pollen Source Value (PSV) total cf (core food)	500
5	FLOWERING MONTH RANGE: Month range	100
	Total Annual Estimate (TAE cf) (core food)	**1200**

Table 1. Site Vegetation Variable Metrics

Similarly, a small group of plants was identified using a 0/1 coding as having nectar/pollen containing substances poisonous to bees, such as diterpenoids, andromedotoxin, and grayanotoxin (Jansen et al. 2012). Another useful variable for coding each plant species was to mark invasive, non-native plants, which could be targeted for managed removal. A variable was also used for the percent cover of dead vegetation and bare ground, which constitute positive nesting areas for native bees (Arathi et al. 2017).

The model component "Site Vegetation Variable Metrics" (Table 1) is a combined score of five metrics that includes weighing the percent cover of a plant species by the specific food value of that species for a particular pollinator, thus ranking the quality of pollen or nectar from 1 to 5, multiplied by 100:

1. The number of pollinator beneficial species found on the site has a maximum value of 50.
2. Breeding habitat scored up to a maximum value of 50.
3. Nectar quality per pollinator plant scored up to a maximum value of 500.
4. Pollen quality per pollinator plant scored up to a maximum value of 500.
5. Number (range) of flowering months per pollinator plant scored up to a maximum value of 100.

A Flowering Month Index (FMI) was developed by taking the flowering period for the mid-Atlantic for *Apis* bees to be 10 months (February to November). Each floristic species surveyed, with a percentage no more than one, was referenced as to its flowering period in months (Brown and Brown 1984 & 1972). Each monthly encounter was then listed and a final total made for a specific survey season and then divided by 10, giving a monthly average. The average was simply multiplied by the monthly range to give a FMI.

A combination of the five metrics results in a single PSVI score for the site per pollinator under study, with a maximum score of 1,200. Noteworthy is the fact that most of the Total PSVI Model's maximum score is due to the two metrics on nectar and pollen source values.

In each of the case studies presented, a single area or block was plotted and surveyed. Area size varied across locations. The placement of these plots was not random in the ROWs, but typically the researchers attempted to place a plot in order to characterize a certain geographic part or ecosystem type representative of the entire ROW (e.g., upland or wetland, or centerline [wire or pipe zone], and lateral or border zone area, etc.).

RESULTS & DISCUSSION

Case Study 1: BGE Electric Transmission ROW at Patuxent National Wildlife Refuge in Maryland

Historically, this ROW vegetation had been maintained by periodic topping of tall trees, or their selective removal with chainsaws, to provide clearance from high-voltage electric transmission conductors. Incompatible tall growing trees and poor access for line maintenance were not compatible with new electric reliability standard FAC-003 that was promulgated following the 2003 large-scale electric blackout of 50 million people in the U.S. and Canada, where trees were determined to be a contributing factor. Baltimore Gas & Electric (BGE) had developed successful habitat restoration partnerships with the U.S. Fish and Wildlife Services (USFWS) at other transmission ROWs, and the Service biologist encouraged similar partnering at the Patuxent Research Refuge near Washington, DC. (Johnstone and Haggie 2014). The refuge manager agreed to adopt IVM techniques, but did not want mowers used because they would pulverize all vegetation and possibly rut soils, causing erosion and sedimentation into the Chesapeake Bay watershed. Instead, the tall trees and invasive shrubs were broadcast treated with a tractor-mounted Radiarc sprayer that was tilted upward at a 30-degree angle so the spray droplets arched upward to cascade down, duplicating the action of a helicopter application. This was followed the next year with a selective treatment with hydraulic sprayers. Thus it provided an example of ROW reclamation without cutting to get vegetation into compliance with FAC-003, and the success of habitat restoration using selective herbicide chemistry.

	Patuxent PSVI METRICS Autumn Olive (*ELUM*) Case Study	**Max rating**	**2011**	**2015 *Apis***	**2015 *Bombus***
1	Forbs, vines, and small shrubs: DIVERSITY INDEX (#/pollinator beneficial species/site)	50	12	14	14
2	Breeding and over-wintering habitat quality. Bare ground, snags, pithy stems. Area S/M/L Rating = % survey	50	0	5	5
3	Annual Nectar Source Value (NSV) total cf	500	6	41	83
4	Annual Pollen Source Value (PSV) total cf	500	5	34	52
5	FLOWERING MONTH RANGE: Month range value May - October = 6	100	2	23	23
	Total Annual Estimate (TAE cf): sum of lines C1 to C5 = PSVI cf	**1200**	**25**	**117**	**177**

Table 2. Patuxent Autumn Olive Case Study

One site was 96 percent dominated by incompatible trees and the invasive shrub autumn olive (*Elaeagnus umbellata* Thunb.) (ITIS code ELUM) (USDA 2019). Baseline data were collected in 2011 and again four years later in 2015 after IVM had been instituted. In the fourth year of follow-up, only one percent of the plot was documented as having undesirable plants.

Since a significant amount of pollinator research has been conducted in the Mid-Atlantic region of the U.S., we were able to glean the differences in plant benefit to the European honey bee (*Apis*) and the native bumblebee genus (*Bombus*). These differences are noted in the following Table 2, where herbicide applications increased pollinator habitat benefit for the honey bee almost five-fold, and for the bumblebee, seven-fold, from baseline in 2011.

We chose not to include values for various VM tools because this could be considered arbitrary. As an example, in this case study, the choice of first using a broadcast herbicide treatment was determined by following the wishes of the refuge manager partner; he did not want mowing performed. Instead of cutting first to allow full sunlight to germinate dormant plants, we started by broadcast spraying selective herbicide chemistry that could target trees and invasive brush while releasing the dormant seed bank of early successional plants. Thus, it should not be scored lower than if we chose to mow first. Backpack application treatment with non-selective chemistry would also be inappropriate due to the height and density of the target brush; it is very difficult to successfully spray 4.5-meter (m)-tall trees (15 feet [ft]) trees with a backpack and not cause collateral damage to non-target plants.

We are also not using a value for adjacent land usage since we have no control as to how that adjacent habitat may be managed. In this case study, the electric ROW and adjacent land is all within a national wildlife refuge; however, forested habitat borders one side of the ROW while an access road with invasive plants borders the other side. Attaching values to these two very different habitats is arbitrary at best. The values that are considered are derived solely from the diversity of plants occupying the site and their relative pollen, nectar, and nesting values when the snapshot of habitat is being evaluated.

	Apis	*Bombus*	Total
Nectar plus Pollen score 2014	117 (12%)	177 (18%)	294
Non-beneficial or non-living Score	883 (88%)	823 (82%)	1706
Total	1000 (100%)	1000 (100%)	2000

Table 3. Grand Total PSVI Autumn Olive (*ELUM*) Site for 2015

Apis and Bombus Analysis

PATUXENT AUTUMN OLIVE Site 2015 Post-IVM Treatment HONEY BEE (*Apis*) BUMBLEBEE (*Bombus*)						
A	B	C	D	E	F	G
APG Code	Species ≥1%	% cover	Specific N/P*	Site N/P (CxD)	# Flowering Months	*Apis/Bombus* NSV/PSV x100
ACMI	*Achillea millefolium L.*	1	0/0 1/1	0.0/0.0 0.01/0.01	5,6,7,8,9,10,11 = 7	0/0 1-Jan
CIDI	*Cirsium discolor*	4	3/2 3/3	0.12/0.08 0.12/0.12	7,8,9,10 = 4	8-Dec 12-Dec
ERHI12	*Erechtites hieracifolia*	14	1/1 4/2	0.14/0.14 0.56/0.28	7,8,9,10 = 4	14/14 56/28
GNOB	*Gnaphalium obtusifolium*	2	1/1 1/1	0.02/0.02	8,9,10,11 = 4	2-Feb 2-Feb
LECU	*Lespedeza cuneata*	2	3/2 3/2	0.06/0.04 0.06/0.04	8,9,10 = 3	4-Jun 4-Jun
PYTE	*Pycnanthemum tenuifolium*	1	3/2 2/1	0.03/0.02 0.02/0.01	7,8,9 = 3	2-Mar 1-Feb
RUBUS	*Rubus sp.*	1	3/3 3/3	0.03/0.03	5,6 = 2	3-Mar 3-Mar
SOCA3	*Solanum carolinense*	1	1/1 1/1	0.01/0.01	5,6,7,8,9,10 = 6	1-Jan 1-Jan
Subtotal:		26				
	Dead Vegetation	5				
	Undesirable Trees	1	0	0		
Other:		68				
Total:		100		Apis Bombus	FMI = 23.1	41/34 83/52

Table 4. Patuxent Autumn Olive (*ELUM*) Site 2015 Honey Bee (*Apis*) Bumblebee

At the autumn olive study, each plant species was given the pollen/nectar expert value scores of 0 to 5 for *Bombus* (Lindtner 2016, *personal communication*), and then were multiplied by the percent cover to determine the PSVI food site value and to allow for a comparison with *Apis* (4). At baseline, the PSVI for *Apis* and *Bombus* were identical (value=25) because there were only three plant species involved: round-leaf greenbrier (*Smilax rotundifolia* L.), highbush blueberry (*Vaccinium corymbosum* L.), and fox grape (*Vitis labrusca* L.), with only three percent cover and total nectar/pollen values the same for both *Apis* and *Bombus*.

Following herbicide treatment four years later, four plant species out of a total of eight, had different scorings for nectar and/or pollen between *Apis* and *Bombus*. The species common yarrow (*Achillea millefolium* L.), field thistle (*Cirsium discolor* [Muhl. ex Willd. Spreng]), American burn-weed (*Erechtites hieraciifolius* (L.) Raf. ex DC.), and narrowleaf mountain mint (*Pycnanthemum tenuifolium* Schrad.) had higher food values for *Bombus* compared to *Apis*. This difference in nectar and pollen scores between the two genera at follow-up (117 versus 177) was statistically significant at the 0.01 level, as shown in Table 3.

(Chi-square statistic=23.1587, p-value < 0.00001, statistically significant at the 0.05 level)

A list of the plants that did provide pollinator habitat for both *Apis* and *Bombus* bees can be seen in Table 4. Note that none of the pollinator plants are dominant and in total occupy no more than 26 percent of the potential cover.

Figure 2. Patuxent Autumn Olive (*ELUM*) Restored Site

	Patuxent PSVI METRICS Sericea Lespedeza Case Study	Max rating	2012	2014 *Apis*	2014 *Bombus*
1	Forbs, vines, and small shrubs: DIVERSITY INDEX (#/pollinator beneficial species/site)	50	12	23	23
2	Breeding and over-wintering habitat quality. Bare ground, snags, pithy stems. Area S/M/L Rating = % survey	50	0	0	0
3	Annual Nectar Source Value (NSV) total cf	500	4	72	106
4	Annual Pollen Source Value (PSV) total cf	500	2	45	81
5	FLOWERING MONTH RANGE: Month range value May - October = 6	100	8	54	54
	Total Annual Estimate (TAE cf): sum of lines C1 to C5 = PSVI cf	**1200**	**26**	**194**	**264**

Table 5. Patuxent Sericea Lespedeza (*LECU*) Case Study

Case Study 2: Patuxent National Wildlife Refuge, Sericea Lespedeza Study in Maryland

This site was located only one span east of the previous study and dominated by invasive sericea lespedeza (*Lespedeza cuneata* (Dum. Cours. G. Don) (ITIS code LECU), which utilities and state highways often plant to control erosion. This low-growing species would not normally be treated for utility access, reliability, or maintenance needs, but was broadcast herbicide treated with selective chemistry to help restore native early successional plant communities as part of the USFWS refuge partnership. Again, we were able to gauge the benefits of the plant community transition for both Hymenopteran genera using just the five metrics. Botanical documentation was performed at baseline in 2012, and again in 2014, which noted increased pollinator habitat benefit for the honey bee (seven-fold) and bumblebee (10-fold).

Apis and Bombus Analysis

At the Lespedeza study, each plant species was also given the 0 to 5 pollen/nectar expert value scores for *Bombus* (Lindtner, *personal communication*, 2017) and then were multiplied by the percent cover to determine the PSVI food site value and to allow for a comparison with *Apis*. At baseline, the PSVI values for *Apis* and *Bombus* (value=26) were identical because there were only two plant species involved: common milkweed (*Asclepias syriaca* L.) and Carolina horse nettle (*Solanum carolinense* L.), with only 2% cover and nectar/pollen values, the same for both *Apis* and *Bombus*.

After herbicide treatment, four plant species had different scorings for nectar and/or pollen be-tween *Apis* and *Bombus*. The species common yarrow (*Achillea millefolium* L.), annual ragweed (*Ambrosia artemisiifolia* L.), and sleepy catchfly (*Silene antirrhina*) had food value for *Bombus*, but not *Apis*.

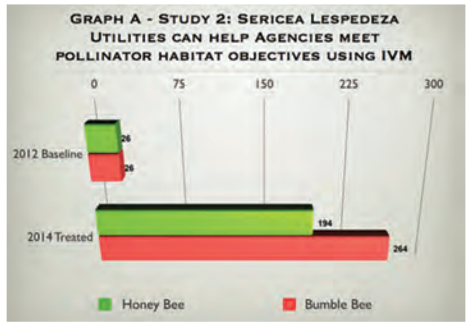
At the follow-up year, the difference in total PSVI between *Apis* and *Bombus* was mostly due to having 17 percent cover from Sleepy catchfly (*Silene antirrhina* L.), which had no value for *Apis*, but a value 2/2 for *Bombus*, which—when multiplied by the 17 percent cover—gave Bombus a higher total score. The difference in nectar and pollen scores between *Apis* and *Bombus* at the follow-up, 194 versus 264, was statistically significant.

Case Study 3: Patuxent Wildlife Research Center Shrub Retention Study (*KALA*)

At this site, data were collected at baseline in 2011 and after herbicide treatments four years later in 2015. No mowing had been performed here either—only periodic tree topping. Instead of a broadcast treatment with a tractor-mounted Radiarc sprayer, this site was selectively treated the first year with hydraulic sprayers and in subsequent years with backpacks to retain the desirable native shrub community and only target species that were invasive or could grow too tall in the wire zone of the transmission line. Our expectation was not to increase pollinator habitat, but to conserve the existing shrub/scrub community and allow it to thrive, thus joining the woodland on either side to provide a wildlife corridor crossing on the ROW.

At baseline, the plot was 14 percent covered by undesirable trees. IVM was introduced the second year and continued as needed through the follow-up years. At the fourth year of follow-up, only one percent of the plant community was composed of undesirable trees.

This site had a baseline number of pollinator beneficial plant species of 32, which decreased to 18 in the follow-up



Graph A. Patuxent Sericea Lespedeza (*LECU*) Case Study

	Patuxent Shrub Retention Study (*KALA*)	Max rating	2011 *Apis*	2011 *Bombus*	2015 *Apis*	2015 *Bombus*
1	Forbs, vines, and small shrubs: DIVERSITY INDEX (#/pollinator beneficial species/site)	50	32	32	18	18
2	Breeding and over-wintering habitat. Bare ground, snags, pithy stems.	50	1	1	15	15
3	Annual Nectar Source Value (NSV) total cf	500	51	100	49	107
4	Annual Pollen Source Value (PSV) total cf	500	46	44	46	44
5	FLOWERING MONTH RANGE: May - Oct = 6	100	34	45	12	18
	Total Annual Estimate	**1200**	**164**	**222**	**140**	**202**

Table 6. Patuxent Shrub Retention Case Study (*KALA*)

Pollinator	2011 Total PSVI Baseline	2015 Total PSVI 4th IVM Year	Total
Apis	164	140	304
Bombus	222	202	424
Total	**386**	**342**	**728**

Table 7. Patuxent Shrub Retention Case Study Summary

Four Plant Species with different Nectar and Pollen Values	Specific N/P for *Apis* cf. *Bombus* Max = 5/5	Percent Cover 2011/2015	PSVI 2011 *Apis Bombus* N/P N/P	PSVI 2015 *Apis Bombus* N/P N/P
Castanea pumila	3/3 3/2	2% 2%	6/6 6/4	6/6 6/4
Ilex opaca	3/3 4/3	1% 1%	3/3 4/3	3/3 4/3
Kalmia latifolia	0/0 1/0	48% 57%	0/0 48/0	0/0 57/0
Leucothoe racemosa	0/0 1/0	1% 0	0/0 1/0	0/0 0/0
Total		**52% 60%**	**9/9 59/7**	**9/9 67/7**

Table 8. Patuxent Shrub Retention Case Study Statistics

year. The breeding and over-wintering metric was 1 at baseline and increased to 15 four years later. The flowering month metric was 34 at baseline and decreased to 12 the follow-up year.

The annual nectar source values and pollen source values based on *Apis* showed a baseline score of 51, which decreased slightly to 49 at follow-up. Results for the pollen total was 46 at baseline and an identical follow-up of 46 four years later. The combined scores of the "Site Vegetation Variable Metrics" were 164 for the baseline year and 140 at follow-up four years later. The percent cover of pollinator plants was 73 at baseline and 77 at follow-up, which was not statistically different.

The dominant species on this site was mountain laurel (*Kalmia latifolia* L.) (ITIS code KALA) at 48 percent for baseline and 57 percent four years later after IVM. This plant is not fed on by *Apis*, but is utilized as a nectar source by *Bombus*. At baseline, the nectar score for *Bombus* was 100, which rose slightly to 107 at follow-up. The pollen baseline score was 44 and an identical follow-up of 44 four years later. The combined scores of the "Site Vegetation Variable Metrics" were 222 for the baseline year and 202 at follow-up. The small decrease was not statistically significant.

The strength in the PSVI approach is that the plant species found in a plot can be scored inde-pendently for the benefit to multiple pollinators. Central to this ability remains the weighting sys-tem whereby each plant is given a score from 0 to 5 for the food benefit to a particular pollinator. It is a relative—not an absolute—index.

Separate analysis and statistical testing found that at the KALA Shrub Retention Study site, there was no statistically significant change in the percent cover of beneficial plants or in the total PSVI scores for *Apis* and *Bombus* separately in the course of the five-year study period, exactly as we predicted in the IVM Plan.

(Chi-square statistic=1.1699, p-value=0.2794, not statistically significant at the 0.05 level)

The most important fact is that mountain laurel was by far the most dominant species, with 48 percent of coverage at baseline and 57 percent at the fourth year follow-up. Furthermore, this species scored a nec-tar value as favorable, with a minimal 1 for *Bombus*, but a 0 for *Apis*. Since its percent cover was so large, it significantly affected the totals.

While the pollen value for Chinquapin chestnut (*Castanea pumila* (L.) Mill.) scored a 2 for *Bombus* compared to a 3 for *Apis*, this had little effect, since the percent coverage was only two percent at both measures. The nectar value for American holly (*Ilex opaca* Aiton) is a strong 4, but with just one percent cover, this does not significantly impact the totals. It is important to note that both of these tree species grow too tall to be compatible with reliability standards if growing in the centerline wire zone of the electric transmission ROW, and thus are target species.

Case Study 4A and 4B Wetland: ITC Transmission at Huron-Clinton Metropark in Michigan

Past practice had been periodic tree-topping to provide clearance from high voltage electric transmission conductors. This resulted in poorly formed, six-m-tall (20 ft) trees that inhibited line maintenance access and was not sustainable with new electric reliability standard FAC-003. A partnership agreement was formed between the utility and the Metroparks, where the trees and brush would be removed by chainsaws and mowers, followed with herbicide applications to successfully convert the plant community back to its post-glacial historic oak savanna, minus the incompatible oaks within the ROW.

At this site, botanical data were collected within three consecutive years (2006–2008) for *Apis*. The first year was a baseline after a reclamation tree removal and mowing operation to return the transmission ROW into compliance with FAC-003 clearance standards. Typically, the clearing of trees and shrubs allows the germination of lower-growing grasses and forbs.

Figure 3. Selective Backpack Treatment

Figure 4. Retained Mountain Laurel Shrubs

After clearing, the centerline or wire zone of the electric transmission ROW-cut stubble was broad-cast treated with herbicides to control trees and invasive plants, primarily autumn olive (*Elaeagnus umbellata* Thunb.), spotted knapweed (*Centaurea maculosa* auct. non Lam.), and Canadian thistle (*Cirsium arvense* [L.] Scop.), while releasing vestigial prairie grasses from the existing seed bank. This would meet the objective of providing ready access for line maintenance crews while favoring a grass dominant prairie plant community under the conductor area.

After one growing season, the lateral or border zone was selectively treated to target the trees and invasive shrubs while avoiding herbicide spray on beneficial forbs. This would favor broadleaf flowering plants that should meet the objective of improved pollinator and bird habitat. The third-year herbicides were applied selectively with backpacks to both areas to complete eradication of incompatible trees and invasive plants. The result was two separate plant communities for different zones of the ROW.

The centerline wire zone after tree clearing had a baseline of undesirable trees covering 17 percent of the plot, followed by zero percent and three percent in the two years of IVM. The combined scores of the "Site Vegetation Variable Metrics" were 262 for the baseline year, compared to 183 and 215 at follow-ups. This was a statistically significant difference. Compared to the baseline, total PSVI scores were lower after the IVM treatments, which is expected, since the objective of the IVM plan was to favor grass species in the centerline for ROW maintenance access purposes.

The lateral buffer zone started with the same baseline following brush clearing, but was selectively treated with herbicides instead of broadcast treated, with the objective to conserve and release pollinator beneficial herbs and forbs. Thus, total PSVI scores increased from the baseline of 262 to 366 and 401 at follow-ups.

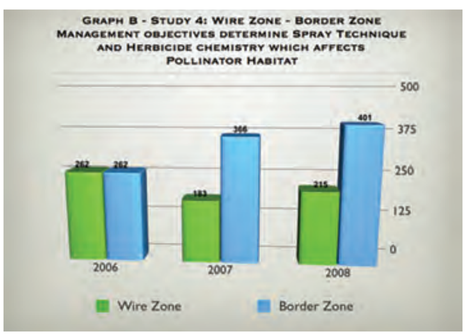
The PSVI summary in Tables 9 and 10 clearly show the relative value of the two different IVM strategies, with the selectively treated border or lateral zone being roughly twice as beneficial to pollinators as the grass-favored central wire zone.

	Stoney Creek PSVI METRICS Wetland Centerline Wire Zone	Max rating	2006	2007	2008
1	Forbs, vines, and small shrubs: DIVERSITY INDEX (#/pollinator beneficial species/site)	50	34	13	23
2	Breeding and over wintering habitat quality. Bare ground, snags, pithy stems. Area S/M/L Rating = %	50	5	8	0
3	Annual Nectar Source Value (NSV) total cf	500	118	80	104
4	Annual Pollen Source Value (PSV) total cf	500	85	72	65
5	FLOWERING MONTH RANGE: May - October = 6	100	20	10	23
	Total Annual Estimate	**1200**	**262**	**183**	**215**

Table 9. Stoney Creek Wetland Centerline Wire Zone

	Stoney Creek PSVI METRICS Wetland Border Zone	Max rating	2006	2007	2008
1	Forbs, vines, and small shrubs: DIVERSITY (#/pollinator beneficial species/site)	50	34	27	23
2	Breeding and over wintering habitat quality. Bare ground, snags, pithy stems.	50	5	0	0
3	Annual Nectar Source Value (NSV) total cf	500	118	183	197
4	Annual Pollen Source Value (PSV) total cf	500	85	139	152
5	FLOWERING MONTH RANGE: May-Oct = 6	100	20	17	29
	Total Annual Estimate:	**1200**	**262**	**366**	**401**

Table 10. Stoney Creek Wetland Border Zone



Graph B. Wire and Border Zone Pollinator Habitat

Figure 5. Stoney Creek Border Zone Pollinator Forbs

Case Study 5: Duke Energy, Baccharis Study Site on Electric Transmission ROW Spray vs. Mowing in Durham, North Carolina

This electric transmission ROW had been routinely mowed and the case study began in spring 2015 to establish the baseline plant community response to cutting. The ROW center area was dominated by eastern baccharis (*Baccharis halimifolia* L.) (ITIS code BAHA) and was split into two studies.

The first tracked the plant community succession after mowing only, while the adjacent area tracked the plant community where selective backpack treatments were used in the fall of 2015.

This study reinforces what we have consistently seen in other case studies across the country: that there is a one-year positive response to the regrowth of pollinator-friendly plants right after mowing, but this response quickly diminishes the following year after tree, brush, and invasive plant competition increases and reinstates dominance. The mowed plot rose from 165 baseline to 266 the following year, but then took a precipitous drop to 88—about half the baseline value. Selective spraying gives us a slight drop in pollinator habitat one year following treatment, but then climbs higher to 197 with more flowering diversity and an added benefit of over-wintering habitat in the form of dead stems, leaf litter, and bare soil. There was not a statistically significant difference between the total PSVI scores of *Apis* and *Bombus*.

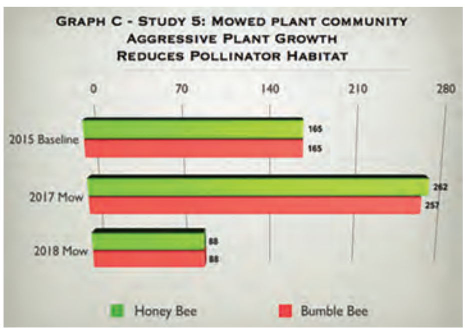
Figure 6. Durham Baccharis Mowed ROW Case Study

	Durham PSVI METRICS *Apis*	Max rating	2015	2017 Mow	2017 Spray	2018 Mow	2018 Spray
1	Forbs, vines, and small shrubs: DIVERSITY (#/pollinator beneficial species/site)	50	6	6	6	5	18
2	Breeding and over wintering habitat quality. Bare ground, snags, pithy stems.	50	5	0	1	0	3
3	Annual Nectar Source Value (NSV) total cf	500	85	145	75	44	83
4	Annual Pollen Source Value (PSV) total cf	500	66	111	61	33	71
5	FLOWERING MONTH RANGE: May - Oct = 6	100	3	4	7	6	22
	Total Annual Estimate	**1200**	**165**	**266**	**150**	**88**	**197**

Table 11. Durham MOW: Spray Case Study Comparison (*Apis*)

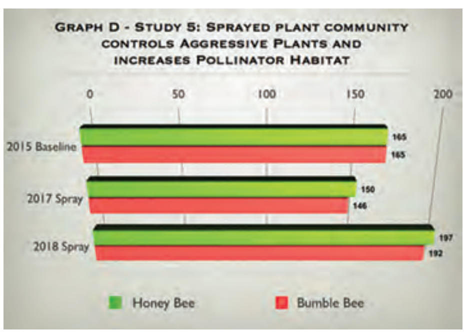
Case Study 6: Columbia Gulf Natural Gas Transmission ROW Partnership with USACE, J. Percy Priest Lake, Pig Island ROW in Nashville, Tennessee

This natural gas transmission ROW had been routinely hand-cut every five years to allow for cathodic testing and maintenance of three high pressure natural gas transmission pipelines. In 2006, a partnership was formed between the natural gas energy company (NiSource [Columbia Gulf] and now TransCanada) and the U.S. Army Corps of Engineers (USACE) to allow for mowers, transported by pontoon boat, to clear incompatible trees and shrubs from the island ROW (Johnstone and Haggie 2014). This was followed one year later with a broadcast herbicide treatment by ATV in 2007, and selective backpack treatments the following growing season and again in 2012.



Graph C. Mowed Pollinator Habitat (*Apis – Bombus*)

Figure 7. Durham Mowed Case Study 2018



Graph D. Sprayed Pollinator Habitat (*Apis – Bombus*)

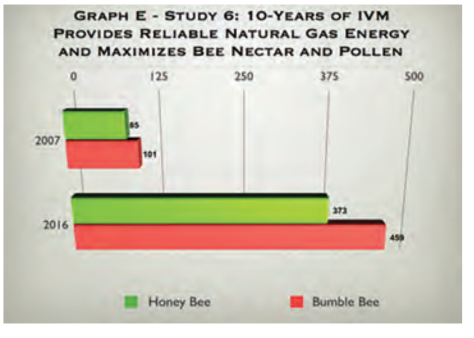
Figure 8. Durham Sprayed Case Study 2018

Note the increase in breeding and over-wintering habitat for *Bombus* in 2007. This was due to the large amount of dead, woody debris following the cutting of vegetation that previous winter. This debris naturally decays with time and is absent in 2016.

This successful partnership allowed the natural gas company to more safely and readily access their ROW for maintenance at lower costs, and to prevent woody root systems from damaging underground pipes. The agency also benefited by having the natural gas pipeline provide improved pollinator and wildlife habitat on this recreational and hydroelectric reservoir. *Apis* habitat improved 4.4 times, while *Bombus* demonstrated a 4.6 times increase in habitat quality. These habitat improvements were shared with other ROW companies and natural resource agencies in educational field workshops in 2009 and again in 2017.

	Pig Island Case Study, Interpipeline Zone (Mow-Spray) Nashville, TN	Max rating	2007 *Apis*	2016 *Apis*	2007 *Bombus*	2016 *Bombus*
1	Forbs, vines, and small shrubs: DIVERSITY INDEX (#/pollinator beneficial species/site)	50	23	23	23	23
2	Breeding and over wintering habitat quality. Bare ground, snags, pithy stems.	50	0	0	20	0
3	Annual Nectar Source Value (NSV) total cf	500	31	175	28	228
4	Annual Pollen Source Value (PSV) total cf	500	20	146	19	176
5	FLOWERING MONTH RANGE: May - Oct= 6	100	11	29	11	32
	Total Annual Estimate	**1200**	**85**	**373**	**101**	**459**

Table 12. Pig Island Natural Gas Pollinator Habitat 10-Years *Apis* and *Bombus*



Graph E. Natural Gas: 10 Years of Improved Pollinator Habitat

Figure 9. Pig Island Natural Gas ROW 2009

CONCLUSIONS

The notion of using an index to track pollinator beneficial changes in vegetation will one day be replaced with actual, scientifically obtained, nutrition-analyzed measurements of these values from field samples. However, using a defensible index at the same sites, and across many years, proves valuable in optimizing ROW management for both its pollinator and industrial functions today.

A core PSVI involving the weighing of percent cover by pollen and nectar source values to create an index with a maximum of 1,000 for pollen and nectar proved to be robust. The math is simple. The core PSVI was easy to calculate. We were able to calculate a core PSVI value for every site for *Apis* and *Bombus* separately. There was considerable variation and little duplication in the core PSVI estimates. No site had a zero score. The maximum at any site in these sets of data never exceeded 40 percent of the core PSVI maximum of 1,000.

A total PSVI included the pollen and nectar core PSVI and then incorporated a measure of pollinator beneficial plant diversity, a pollinator breeding habitat score and a FMI. Summing these five factors increased the maximum for the total PSVI to 1,200.

Changes with time in the total PSVI could be detected at the 0.05 level of statistical significance. Focusing in on statistically significant results can weed out what apparently looks different, but does not meet the standard of statistical testing as arbiter.

The pollen and nectar source values for *Apis* and *Bombus* were very similar. However, there were situations when statistical differences were found between the core PSVI of the two. If a few key plant species can be scored differently between *Apis* and *Bombus*, that should be looked into further. In this study, however, the lesser data on the *Bombus* could be replaced with *Apis* pollen and nectar source values.

A skilled botanist was required to identify plant species found in the case study plots. More than 90% of the species found constituted less than 10% coverage of the plot. We made sure any percent cover data collection ended up totaling 100 percent so statistics could be performed without undue assumptions.

We note that 15 plant taxonomic orders consistently dominate in providing pollinator food, among them are namely: *Asterales*, which includes the family Asteraceae (asters); Caryophyllales, which includes the family Polygonaceae (smartweeds); *Fabales*, which includes the family Fabaceae (leg-umes); *Lamiales*, which includes the family Lamiaceae (mints); *Gentianales*, which includes the fam-ily Asclepiadaceae (milkweeds); *Myrtales*, which includes the family Onagraceae (evening primroses) and Sapindales, which includes the family Anarcardiaceae (sumacs). The authors predict that it may be possible in the future to use satellite imagery or develop a phone camera app that could analyze the infrared signature from a photograph of a site, and capture the plant community to discern the important pollinator species. Other criteria can add or detract from the overall value of an area to pollinators (adjoining land use, management practices), but the snapshot of the existing plant community determines its PSVI for that moment.

Our PSVI score also provides a measure of the success of an IVM strategy in meeting the ROW man-agement objectives:

- We can discern the success of native habitat restoration when applying a broadcast treatment of selective herbicide chemistry to undesirable non-native plants (Case Studies 1 and 2)
- We can discern the success of selective herbicide treatments in conserving shrub habitat beneficial to pollinators (Case Study 3)
- We can compare the habitat differences resulting from a wire zone broadcast herbicide treatment favoring grass species against a border zone selective herbicide treatment favoring forbs (Case Study 4)
- We can directly compare the relative pollinator habitat benefits of a mowing or selective herbicide treatment regime (Case Study 5)
- We can measure the long-term success of converting an overgrown ecosystem using mowing followed by broadcast and selective herbicide treatments (Case Study 6)

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Managing Utility Corridors for Wildlife Habitat

Jacob Johnston

Keywords: Corridor, Habitat, Native, Utility, Wildlife.

With proper vegetation management (VM), utility corridors offer potential to connect natural landscapes and improve habitat conditions for various wildlife species while carrying out their primary job of delivering safe and reliable utilities. Incorporating habitat features (diversity of native plants, brush piles, nest boxes, and bat houses, for example) can return valuable resources to wildlife species suffering rapid habitat decline from increased urbanization and offers the opportunity for building positive relationships between the utility and a community concerned with the environment. This paper discusses a selection of natural and human-assisted habitat features available for wildlife species that can be implemented throughout transmission corridors via VM and community engagement.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Utility corridors run the gauntlet, traversing both the physical and the social landscape. Kilometer (km) after km and tower after tower, they distribute energy to cities and towns, but also carve their path through the wilderness, disconnecting habitats and disturbing environments. Sometimes these disturbances from construction and maintenance causes friction with nearby communities concerned with the wildlife species residing there. With the proper management, however, utility rights-of-way (ROWs) have the potential to actually connect natural landscapes and improve habitat conditions for certain wildlife species while still carrying out their primary jobs of delivering reliable utilities (Bérubé et al. 2008).

Yards and parks may be obvious sites for providing wildlife habitat, but even obscure places like medians, cemeteries, and vacant lots can be productive habitat with proper plants and thoughtful management (Figure 1). As urban and residential areas continue to expand, it will be increasingly important to incorporate plants and sustainable designs into new and existing infrastructure. Utility corridors for natural gas and electricity are a prime example of this potential.

ROWs total more than 252,000 km (157,000 miles [mi]) of high-voltage electric transmission lines covering more than four million hectares (ha) (11 million acres) across the U.S. and wind through myriad land cover types and terrains. They are actively managed by utility companies. Their ubiquity and accessibility present a valuable canvas for offering habitat features and resources for local wildlife species. Implementing best management practices (BMPs) for birds and pollinators into power and natural gas line corridors can often meet the vegetation management (VM) goals of utility companies. The men and women who manage these expansive spaces are poised to become not just "maintainers," but "stewards" of these extensive landscapes.

Figure 1. New and existing infrastructure should include considerations for environmental remediation. This recently built median diverts storm water to a bioswale that recharges groundwater, provides pollinator habitat, and meets the needs of the roadways.

Figure 2. A male Karner Blue butterfly on native late purple aster growing in pine barrens. This short, slow-growing habitat was created within utility corridors in New York to promote the endangered butterfly.

Currently, federal law requires proper clearances on high-voltage powerlines and imposes strict penalties for noncompliance. These regulations have resulted in an increase in transmission reliability, but have also resulted in a more aggressive approach to VM, reducing habitat availability and fragmenting the landscape (Eldegard et al. 2015). Often, vegetation is managed with indiscriminate mowing along—and tree removal across—wide swaths of the landscape. This type of VM can sometimes raise alarms in nearby communities and create conflict among stakeholders.

Fortunately, the new word buzzing around utility lines is "stewardship." What started as simply using less herbicides has led to erecting Osprey nest platforms and creating Karner Blue Butterfly (*Lycaeides Melissa samuelis*) meadows (Forrester et al. 2005) within ROWs (Figure 2). This emerging focus on plant and animal biodiversity has started to shape a new paradigm of VM geared towards wildlife habitat (Russell et al. 2018), soil conservation, and invasive species control, along with appropriate powerline clearance.

Some utility services have shifted towards a system of integrated VM (IVM) (EPA 2016) in ROWs. One particular IVM practice promotes a combination of planting zones across the utility corridor along with prescribed vegetation solutions. The Wire Zone includes low-growing plants like grasses and wildflowers, providing clearance, and easy access. The Border Zone allows shrubs and small trees that block out taller species and, beyond that, larger trees are allowed to remain. This layered structure promotes dual goals of safe, reliable electric service with abundant and diverse vegetation across utility areas. Planting zones also provide the opportunity to introduce a wealth of important environmental services, including ecological connectivity.

Ecologists describe the value of connectivity in the landscape as an increase in the availability *and* accessibility of habitat resources across a track of terrain. Larger patches of habitat resources, called a refuge, can be connected via smaller patches called stepping stones (Figure 3). Greater connectivity, however, can be achieved through longer corridors of similar habitat types and resources. Abundant habitat resources along ROWs can improve wildlife resiliency in a changing climate through increased connectivity across the landscape by allowing greater mobility of species in pursuit of shifting resources (Lampinen et al. 2018). Using a combination of IVM planting zones and BMPs for important bird or pollinator species, we predict ROWs can be built and managed to recreate ecological corridors, combining habitat connectivity with facilitated line access, and long-term line clearance with the diversity of structure and vegetation wildlife species depend on.

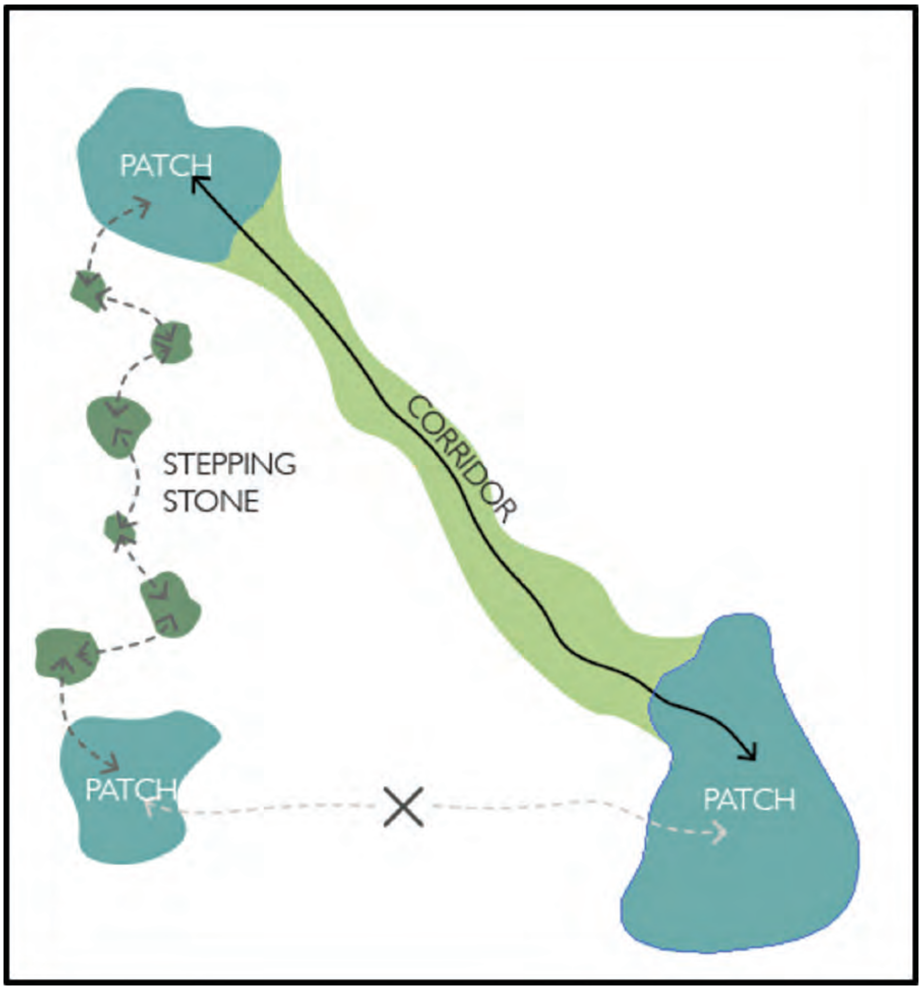

Figure 3. Connectivity between habitat refuges, or large habitat patches, can be achieved through stepping stone patches or, even better, corridors of contiguous habitat.

METHODS

Research from various fields of ecological and social sciences was combined to better understand the potential for incorporating habitat features into the VM plans of existing and planned utility corridor projects. Habitat requirements for various migratory, residential, and breeding birds were identified and examined for commonalities to potential and existing VM regimes within utility corridors. Landscape conditions and habitat features often frequented by other types of wildlife species were also evaluated for practical implementation into VM plans and have been suggested and presented as facilitated practices to help ensure acceptance and greater adoption by planners, managers, and foresters.

RESULTS & DISCUSSION

Bird and Pollinator Habitat

Wildlife species require native plants and diverse structure (Narango et al. 2017; Tallamy D. W. 2009; Tallamy and Shropshire 2009). The vegetation requirements in ROWs generally call for vegetation that does not impede the functionality of the utility service and is easy to manage. These are not mutually exclusive and accomplishing each of these objectives can be achieved using a region's local native plants and plant communities to replicate early successional or young forested habitats. Native plant communities require less management and resource inputs than non-native plant selections, as well as offer a selection of the necessary low-growth vegetation habits desirable under powerlines.

Abundant and diverse selections of native plants provide the important resources wildlife species need during the seasonal times they need them. Resources like pollen and nectar in spring and summer, fruits and berries from summer through winter, nest sites for birds and solitary bees, and host plants for monarch caterpillars and other pollinators can be integrated into a planting plan that addresses the needs of all stakeholders (Narango et al. 2017). Dense grasses and wildflowers can occupy the wire zone and can be managed with annual or biennial mowing in the late fall to control woody intrusions, but still protect nesting birds and larval bees. The border zone can offer native fruit-producing shrubs and small trees, which provide shelter and winter resources, but also inhibit intrusion from larger trees. Choosing or managing for native plant varieties to occupy planting zones can help create long-lasting, low-maintenance, high-value environments beneficial to utilities and wildlife species.

Figure 4. Golden-Winged Warbler breeding habitat consisting of open shrublands adjacent to mature forests. Similar habitat can be recreated and easily maintained along utility corridors in the Northeast.

Matching Management to Wildlife Habitat

The Golden-Winged Warbler (*Vermivora chrysoptera*), federally listed as endangered, is, like many migratory songbirds, suffering population declines due to habitat loss (Aldinger and Wood 2014). Its northern breeding range previously consisted of a mosaic of open shrublands amid mature woods (Figure 4). This landscape pattern was historically abundant as wildfires, storms, and beaver dams regularly opened up large spaces in mature forests which would fill in with grasses, shrubs, and small trees.

As land around the Great Lakes became more developed, increases in agriculture opened up even more areas of shrubland and improved the habitat availability for Golden-Winged Warblers. Eventually, however, as agriculture became less common, those farms grew into forests and the current management of wildlands has prevented previous natural forces, like wildfires, to create new openings, making this unique habitat increasingly rare.

Conservation groups have recognized the similarities between Golden-Winged Warbler habitat requirements and ROW vegetation goals, and some have catered specific recommendations for vegetation managers in larger transmission corridors to improve the habitat value of these areas (Kubel and Yahner 2008). These recommendations include plant species compositions and timing guidelines for mowing and other management practices. In creating these recommendations, conservationists and utility managers can find common ground that works for both interests.

Brush Piles

Maintaining a young forest or early successional habitat in ROWs requires ongoing maintenance as shrubs and trees will eventually encroach on zones they are too tall for. This happens naturally as slow-growing, shade-tolerant species make their way up through the grasses and shrubs, seeking more light and space. Invasive plant species can move in faster and more aggressively and will also need to be managed. Creating brush piles throughout ROWs—using the branches from cleared saplings and shrubbery—is a cost-saving way to provide habitat resources for wildlife. Brush piles provide shelter for birds, small mammals, and reptiles. They attract food sources for owls and other raptors and can protect young, native seedlings from over-browsing by herbivores. Place them out of the way, where they will not need to be moved or worked around as wildlife species make it their home.

Logs and Snags

Larger trees are carefully managed in ROWs to prevent damage to wires or towers in the event they fall over from old age, disease, or breaking in a storm. While this wood is usually removed from site, leaving the downed wood as logs within ROWs can provide a unique and important habitat feature for wildlife species. Woodpeckers especially appreciate the beetle-filled decay. Small mammals, reptiles, and amphibians will use downed wood for shelter, paths, and runways, or as perches. Logs provide substrate for mushrooms and mosses to grow and eventually decompose, creating valuable soil resources to help sustain healthy vegetation.

Snags can be created by topping dead and dying trees to a height that is acceptable to powerline clearance regulations, but are still left standing tall enough to provide valuable habitat resources. A snag is full of bugs and larvae for hungry birds, offers perching places for raptors, and provides cavities that some nesting birds, like the Red-breasted Nuthatch (*Sita conadensis*) above, require for successful nesting. Large snags created within the tree zone, along with a selection of deterrent strategies in high damage areas, may even help alleviate issues with woodpeckers excavating utility poles (Parker et al. 2008).

Bat Houses

Beyond native vegetation, ROWs offer a unique opportunity to introduce a number of other valuable features for wildlife species suffering from a lack of suitable habitat. Bat houses (Figure 5) are easy to acquire or build and provide safe, healthy, and comfortable roosting

Figure 5. Bat houses should be mounted high and in open clearings. They provide safe roosting places for maternity colonies and can help bats recover from the fungal pathogen causing white-nose syndrome.

Figure 6. Hibernacula can be made from piled rocks and logs and provide dens and other forms of shelter for various types of wildlife species.

places for bats when they are not hibernating. In the last decade, White-nose syndrome, a deadly fungal disease in bats, has decimated some populations in the eastern U.S. Offering bat houses in ROWs managed with native vegetation will provide healthy roosting places that can help bats recover from the fungal pathogen (Wilcox and Willis 2016). Bats are also important predators of insects and provide millions of dollars' worth of ecosystem services from plant pollination to pest control—each bat can eat thousands of flying insects per night (Cleveland et al. 2006).

Coverboards, Hibernacula, and Bare Ground

Habitat for amphibians, reptiles, and small mammals can be created in ROWs by adding simple structures like coverboards and hibernacula. These are places where small animals can safely shelter and moderate their temperatures on hot summer days or cold winter months. Coverboards can be wood or metal sheeting placed on the ground. Hibernacula are shelters for hibernating animals and can be made from rocks, mud, and downed woody debris to create underground or enclosed spaces. The debris—rocks, logs, dirt, etc.—from creating and maintaining utility ROWs can be used to build these features where appropriate along the corridor.

Leaving open, sandy, or rocky spaces free of vegetation offers another beneficial resource. Many native bees require bare ground to burrow into for nesting cavities (Moissett 2010). Butterflies also require bare ground and will "puddle" in wet mud, sand, or gravel to collect essential minerals for mating and reproducing (Adler and Pearson 1982; Otis et al. 2006; Sculley and Boggs 1996). Several species of birds, like swallows (*Hirundinidae*) and American Robins (*Turdus migratorius*), also use mud to build and secure their nests. Various ROW construction and maintenance activities can, and often do, create opportunities to leave bare ground habitat for nesting wildlife species. As these areas fill in with vegetation as time passes, new and continuing management will offer new opportunities to leave behind bare ground, and piled debris.

Figure 7. Utility corridors offer easy ways for communities to access natural areas for recreation and outdoor experiences.

CONCLUSIONS

As with homes, parks, and nature preserves, providing habitat and attracting wildlife species comes with the responsibility of preventing the enhanced areas from becoming ecological traps, hazards, or sinks for the species being promoted. Timing of mowing, pesticide and herbicide application, tree pruning, and invasive species management have seasonal timing concerns, like sensitive nesting periods, that can be mitigated by understanding key life cycles and habitat needs. Bee houses and nest boxes require regular maintenance to be safe, successful, and to prevent spread of disease whereas some features, like snags and brush piles, can be left behind, essentially gaining value with age.

Of critical importance is the fact that communities often feel a strong attachment to the environment around them (Larson et al. 2018) either through recreation, conservation, or purely aesthetic reasons (Jorgensen and Stedman 2001). Recreation can connect individuals and communities with the outdoors and create a greater appreciation for nature, wildlife, and conservation (Larson et al. 2018). ROWs can offer an opportunity for this as well.

Major anthropogenic disturbances to the environment, like utility corridors being cut through the nearby forest, can cause local uproar at town halls and other community assemblages. We believe utility companies can mitigate this response by developing a plan with local residence and conservation groups to incorporate wildlife habitat and sustainable practices into the VM of the corridor (Clark et al. 2008). For example, utility foresters can advise on placement of habitat features, like bee houses and nest boxes, while community members take responsibility for their upkeep. Proactive considerations could include adding flags or markers to powerlines to reduce bird collisions(A.E and S.H 1991), or insulated perches for raptors to prevent electrocution (Dwyer and Mannan 2007). The possibilities are as endless as the corridors themselves.

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Mitigating for Species at Risk with Critical Habitat on Linear Infrastructure Projects in Canada

Dana Drumm and
Trevor Friesen

Keywords: Biophysical Attribute, Critical Habitat, Habitat Restoration, Measurable Target, Mitigation, Recovery Strategy, Species at Risk, Species At Risk Act (SARA), Trans Mountain Expansion Project (TMEP).

Recent approvals of federally regulated projects in Canada indicate a trend toward increased reporting, mitigation, and habitat restoration requirements related to direct and indirect project effects on terrestrial wildlife species at risk and their critical habitat. The Trans Mountain Expansion Project (TMEP) is an example, with National Energy Board (NEB)-approval conditions requiring the preparation of Wildlife Species at Risk Mitigation and Habitat Restoration Plans (HRP) for selected wildlife species with federally identified critical habitat. With these changing regulatory expectations, early consideration of species at risk and their critical habitat is an imperative component of project planning, design, permitting, construction, reclamation, and monitoring, with potential implications for project cost, schedule, and execution.

This paper discusses the challenges encountered and solutions employed in preparing these plans for TMEP. Key challenges included the interpretation of critical habitat, particularly at varying scales and levels of specificity; the approach to baseline field work and development of mitigation; and the selection of measurable targets to evaluate the success of mitigation and habitat restoration measures in the absence of accepted thresholds or other guidance. Solutions explored will highlight the importance of (1) taking a practical approach to defining and interpreting critical habitat in various stages of development and review, (2) an understanding of potential project effects on the various biophysical attributes to develop practical measures to avoid, mitigate, and restore critical habitat, and (3) developing effective measurable targets by ensuring targets are quantifiable, practical, achievable, and biologically relevant.

The challenges and solutions presented are applicable to a broad range of species at risk; therefore, the lessons learned are valuable for helping project proponents understand and mitigate project effects to reduce uncertainties and risks related to project cost, schedule, and execution.

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INTRODUCTION

In recent years, a greater emphasis has been placed on the protection of species at risk and their critical habitat in Canada, with increasing regulatory requirements being placed on proponents whose projects may adversely affect these species and their critical habitat. The federal Species at Risk Act (SARA) provides legal protection for wildlife species and is intended to prevent the extinction or extirpation of threatened or endangered species and to manage species of special concern from becoming threatened or endangered. SARA requires that the federal government prepare recovery strategies for species listed as endangered or threatened on Schedule 1 of SARA. The recovery strategies identify the measures that are needed to halt or reverse the decline of a species at risk and identify critical habitat (to the extent possible) that is required for the survival and recovery of the species. The identification of critical habitat in Canada is the responsibility of the federal government under SARA, although provincial, territorial, and federal governments have an agreement to coordinate actions to protect and recover species at risk and their critical habitat within their respective jurisdictions under the Accord for the Protection of Species at Risk (Government of Canada 2014).

It is important for proponents to complete detailed project planning in consideration of potential project interactions with species at risk and their critical habitat as well as to implement mitigation and restoration measures to reduce adverse project effects. Although rare, project interaction with identified critical habitat has led to significant implications for proponents. For example, where the federal government determines species and critical habitat protection is inadequate and a species faces imminent threats to its survival and recovery, an Emergency Order under SARA may be issued to provide for the immediate protection of the species. The first Emergency Order was issued in November 2013 for the Protection of the Greater Sage-Grouse (*Centrocercus urophasianus urophasianus*). This Order identified and protected habitat that is necessary for the survival or recovery of greater sage-grouse and included prohibitions related to activities that result in the killing or moving of sagebrush plants and native grasses or forbs; installing or constructing fences; installing or constructing machines or structures that produce noise in excess of a defined intensity and duration; constructing new roads or widening an existing road; or installing or constructing a structure, machine, or pole that is greater than 1.2 meters (m) in height within the identified areas of critical habitat (Government of Canada 2013). These prohibitions have resulted in difficult challenges for the construction and operation of linear development projects and agriculture in the area covered under the Order.

A second Emergency Order was issued in July 2016 for the western chorus frog (*Pseudacris triseriata*) (Great Lakes / St. Lawrence–Canadian Shield Population) (Government of Canada 2016). It blocked the construction of 171 buildings of a residential development project in La Prairie, Quebec. The Order also requires utility companies to apply for SARA permits prior to constructing or maintaining infrastructure within the area covered by the Order.

For projects regulated by the National Energy Board (NEB) that intersect critical habitat for species at risk, recent approval conditions have included requirements for the preparation of detailed mitigation and habitat restoration plans (HRP). Examples for linear projects include TransCanada Pipeline Limited's Vaughan Mainline Expansion Project located in southern Ontario, and Trans Mountain Pipeline Corporation's (Trans Mountain) Trans Mountain Expansion Project (TMEP or the Project) located in western Canada.

The objective of this paper is to examine the potential challenges encountered and solutions that may be implemented when projects encounter federally identified critical habitat for species at risk. TMEP will be used as a case study to highlight the increased focus on species at risk and discuss the challenges faced when developing mitigation and habitat restoration strategies.

TMEP involves the construction of approximately 980 kilometers (km) of pipeline, twinning the existing Trans Mountain pipeline, located in Alberta and British Columbia (BC), Canada. The NEB issued 157 conditions for the Project, including a condition that required Trans Mountain to file with the NEB for approval at least four months prior to commencing construction, Wildlife Species at Risk Mitigation and HRP for each species whose draft, candidate, proposed, or final critical habitat is directly or indirectly affected by the Project. Key requirements of this condition included:

- Surveys to identify the location of the biophysical attributes of critical habitat that may be potentially affected by the Project
- The spatial location of each type of critical habitat affected as well as the total area of proposed and final critical habitat affected
- Detailed mitigation and habitat restoration measures to reduce direct and indirect Project effects on critical habitat
- Detailed descriptions of how selected mitigation and restoration measures address potential time lags between project impacts and the point at which the mitigation and restoration measures are functioning
- Detailed post-construction monitoring of mitigation and restoration measures (NEB 2016)

TMEP intersects federally identified critical habitat for 14 terrestrial wildlife species at risk.

How Critical Habitat Is Defined and Challenges to Identification In the Field

As part of SARA, critical habitat is described as the habitat that is necessary for the survival or recovery of a species listed on Schedule 1 as threatened, endangered, or extirpated (Environment and Climate Change Canada [ECCC] 2016a). A federal species recovery strategy or action plan identifies critical habitat geospatially and describes its constituent parts (i.e., biophysical attributes). ECCC considers critical habitat to be destroyed if part of it (i.e., a biophysical attribute) is degraded, either permanently or temporarily, such that it would not serve its function when needed by the species (ECCC 2016a). The process used by ECCC to identify critical habitat considers the best available information for a species (e.g., life history characteristics, habitat specificity, and known habitat attributes), and employs the most appropriate scale for critical habitat identification (e.g., site-level versus landscape-level) as well as the best method or approach to mapping the habitat (e.g., modelling) (ECCC 2016a).

Federal recovery strategies typically proceed through four stages of regulatory, species expert, and public review. Recovery practitioners (i.e., ECCC staff and contracted species experts) prepare an early draft stage of a federal recovery strategy for internal federal review; the resulting candidate stage is then vetted by provincial/territorial and other relevant agencies. Taking feedback into consideration, a proposed federal recovery strategy is then posted to the SARA Public Registry for a 60-day consultation period. It is only at this point which critical habitat information becomes publicly available; prior to this, it can only be obtained with written permission from ECCC, highlighting the importance of early consultation with ECCC to identify otherwise unknown potential project constraints. Following the public review period, any remaining revisions are completed and a final recovery strategy is posted to the *SARA* Public Registry.

The extent of critical habitat is primarily defined by the ecology and life history of a species, but its delineation may vary considerably across the stages of recovery plan development. In particular, early draft and candidate critical habitat mapping are often less refined than proposed and final. For species with a large geographic range and broad habitat usage, critical habitat identification at the landscape scale (1:100,000 to 1:1,000,000+) may be most appropriate. In such cases, the precise locations of critical habitat are not identified and instead mapping includes both occupied and suitable habitat as well as unoccupied or unsuitable habitat (ECCC 2016a). On the other hand, critical habitat for species with small geographic ranges and narrow habitat specificity are mapped at the site scale (1:1 to 1:15,000). This is habitat delineation at the scale of individuals or local populations, which includes occupied suitable habitat patches and sometimes additional contiguous suitable habitat that is unoccupied (ECCC 2016a). For species somewhere in the middle (i.e., large geographic range and narrow habitat specificity or small geographic range and broad habitat usage), critical habitat delineation may be best suited to an area scale (1:15,000 to 1:100,000). At this scale, in addition to occupied sites, necessary unoccupied suitable habitat may also be mapped to address threats like habitat fragmentation (ECCC 2016a). Geospatial identification of critical habitat can be presented in a variety of ways (e.g., through mapping of discrete polygons or standardized grid squares, or by listing in a table of coordinates) (ECCC 2016a). However, there are often knowledge gaps that prevent critical habitat from being fully or accurately described.

Along with geospatial identification of critical habitat, biophysical attributes that constitute critical habitat are defined by ECCC. They are intended to help in determining locations of critical habitat, particularly where critical habitat mapping includes both suitable and unsuitable habitat. Within mapped areas, critical habitat is only present wherever the biophysical attributes occur. Like considerations for the scale of critical habitat identification, the level of specificity of biophysical attributes is dependent on the habitat preferences of the species (e.g., habitat generalist versus specialist) and best available information on the ecology and life history of the species.

The overlay of mapped critical habitat onto a narrow, linear corridor presents challenges. This was the case for TMEP and was further complicated by inclusion of species with critical habitat ranging from early draft to final, which increased the complexity of determining the best approach to address the various species at risk and their critical habitat that overlapped the Project. As noted, Trans Mountain was required to provide the location, type, and area of critical habitat potentially affected by the Project, as well as the results of surveys for the biophysical attributes of critical habitat. Obtaining information on the presence of biophysical attributes within a project footprint is important for several reasons. It evaluates the actual occurrence of critical habitat (given critical habitat is only present where the biophysical attributes occur), informs mitigation and habitat restoration, and provides an accurate baseline condition for comparison during post-construction environmental monitoring. As such, field work is most efficient and cost effective when mitigation and post-construction environmental monitoring are considered at the same time. The process of developing mitigation and monitoring methods can be time consuming; therefore, it is important to recognize that substantial up-front work may be needed prior to conducting field work.

Examples of variations in scale and specificity are described below for two of the species at risk with critical habitat crossed by TMEP, demonstrating some of the challenges in planning and carrying out surveys of critical habitat.

Western Screech-owl

Critical habitat for western screech-owl (*Megascops kennicottii, macfarlanei* subspecies) is in the early draft stage of development and was provided by ECCC for TMEP. The draft biophysical attributes of critical habitat were provided by ECCC and describe three habitat types:

- **Nesting habitat**: all mature and old forest structural stages (including all known or potential nest trees) of the following ecosystems: cottonwood-snowberry-rose (Fm01) vegetation association, in middle-bench floodplains; sites with rich or very rich soil nutrient regime; and sub-hygric or hygric soil moisture regime.
- **Roosting habitat**: any type of young or mature forest areas with thick shrub cover; any site series/ecosystem type can serve as roosting habitat as long as sufficient cover occurs in the form of trees or shrubs; warmer aspects are preferred (i.e., south- or west-facing slopes).
- **Foraging habitat**: open forests and sparsely treed hillsides that provide perches from which owls can hunt, often on steep slopes or the edges of openings (e.g., riparian edges, fields, pastures); more secure, smaller openings; warmer aspects preferred (south or west-facing slopes) (Environment Canada 2015).

The early draft of critical habitat is mapped at an area scale (10 x 10 km grid squares) and the pipeline route crosses it for more than 250 km within interior BC, including areas that are unlikely to contain occupied or suitable habitat. The biophysical attributes are relatively specific for nesting habitat, and broader for roosting and foraging habitat. This posed challenges in identifying the Project's overlap with critical habitat, as determining the location of the biophysical attributes of critical habitat along a lengthy pipeline right-of-way (ROW) is costly and impractical. In addition, roosting and foraging habitat is likely to be relatively common along the pipeline route given the broad nature of the biophysical attributes. Avoidance of such broadly defined areas of critical habitat is not possible or practical as similar habitat would likely be present in adjacent areas. It would also not make sense to adapt mitigation in response to identification of roosting or foraging habitat, considering both the abundance of these features, and the expectation that both natural regeneration and planned seeding of native herbaceous and shrubby vegetation would restore functional habitat in a short time.

With the above considerations, there was little mitigative value in expending time and effort to inventory foraging and roosting critical habitat within the pipeline ROW. Instead, efforts were best spent on determining where nesting critical habitat was present since it is likely to be the more limiting habitat type for the species, and identification of its biophysical attributes in the field could lead to site-specific, effective mitigation. Equipped with this rationale, Project consultants reviewed available desktop and field information (i.e., previous occurrence records, Terrestrial Ecosystem Mapping, and aerial imagery for the Project) to narrow the area of focus to sections of the ROW that had the potential to support the biophysical attributes of nesting critical habitat. As a result, the more than 250 km of early draft critical habitat that overlapped with the Project was narrowed to a total of 18 km of refined areas of interest. This reduced length was much more feasible to survey. The areas excluded by this exercise included forested and unforested habitat that may support the biophysical attributes of roosting or foraging habitat as well as areas with unsuitable habitat (e.g., existing anthropogenic disturbance). The dramatic difference in the mapped early draft critical habitat versus the refined area of interest illustrates how common the broadly defined biophysical attributes and areas of unsuitable habitat can be and emphasizes the importance of scrutinizing areas of project overlap with critical habitat.

Lewis's Woodpecker

The federal recovery strategy for Lewis's Woodpecker (*Melanerpes lewis*) has been finalized and is publicly available. Critical habitat was defined using a habitat suitability model mapped as 400 m by 400 m cells (ECCC 2017) (Figure 1). Within the defined geospatial boundaries, critical habitat is present wherever the biophysical attributes required to support nesting or foraging by Lewis's woodpeckers occur:

- **Nesting**: known nest trees, alive or standing dead, occupied by Lewis's woodpecker at any time in the past (includes some utility poles), or potential nest trees, alive or standing dead, including:
  - Ponderosa pine (*Pinus ponderosa*), black cottonwood (*Populus trichocarpa*), or Douglas fir (burned or not burned) (*Pseudotsuga menziesii*), trembling aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), western larch (*Larix occidentalis*), or subalpine fir (*Abies lasiocarpa*)
  - Diameter at breast height (dbh) >30 centimeters (cm) in ponderosa pine or black cottonwood stands, or >24 cm in burned stands
  - With cavities five cm in diameter or greater, or classified as decay class 2 or higher, which are trees of a significantly advanced stage of decay to facilitate excavation by Lewis's woodpeckers
- **Foraging (within 400 m of a known or potential nest tree as defined above)**:
  - Standing trees not exceeding 35 percent canopy closure, to provide perching, foraging,

and food caching substrate

– Presence of at least one fruit-bearing shrub (e.g., saskatoon, currant, or chokecherry), or at least one 10 m² or larger patch with greater than 20 percent cover of perennial grasses (ECCC 2017)

ECCC's delineation of critical habitat for Lewis's woodpecker is on a smaller scale compared to western screech-owl, *macfarlanei* subspecies (i.e., 400 m grid cells versus 10 km grid cells), and overlaps the Project for approximately 25 km. Although identification of critical habitat is final and more refined, the habitat suitability model still captures some areas of unsuitable habitat, such as cultivation and residential areas, which were excluded from consideration via a desktop review of aerial imagery and Terrestrial Ecosystem Mapping. Through this desktop review, the area of interest was reduced to just under 19 km. Given the specificity of the biophysical attributes, their identification in the field is straight forward. However, the presence of foraging habitat is contingent on the presence of nesting habitat (i.e., foraging habitat only occurs within 400 m of a known or potential nest tree). Ideally, an inventory of biophysical attributes in the field should take this 400 m proximity criterion into consideration by surveying out to this distance to identify known or potential nest trees within 400 m of either side of the ROW. However, this can become a challenge when large areas need to be covered by survey crews and is not always possible when access to adjacent, privately owned land is not allowed.

To address this challenge, field efforts were focused on identifying and describing where the biophysical attributes of critical habitat were present within the Project footprint to allow for site-specific avoidance or mitigation instead of endeavouring to define what areas were and were not critical habitat through more complex mapping of biophysical attributes in consideration of the 400 m proximity criterion. In this way, suitable nest trees were assumed to be available within 400 m wherever the biophysical attributes of foraging habitat were present on the Project footprint (unless this was clearly not the case when reviewing aerial imagery or in the field). This approach was appropriate in this context because critical habitat for Lewis's woodpecker is final and largely refined, which, in combination with a desktop review, increased confidence in the assumption that suitable nesting habitat was likely present in proximity to foraging habitat identified on the Project footprint. Taking this conservative approach also avoids the risk of under-representing critical habitat presence when faced with limitations in inventorying biophysical attributes that are spatially dependent on one another. This approach may not work for species with more broadly defined critical habitat, but it was considered reasonable in this case.

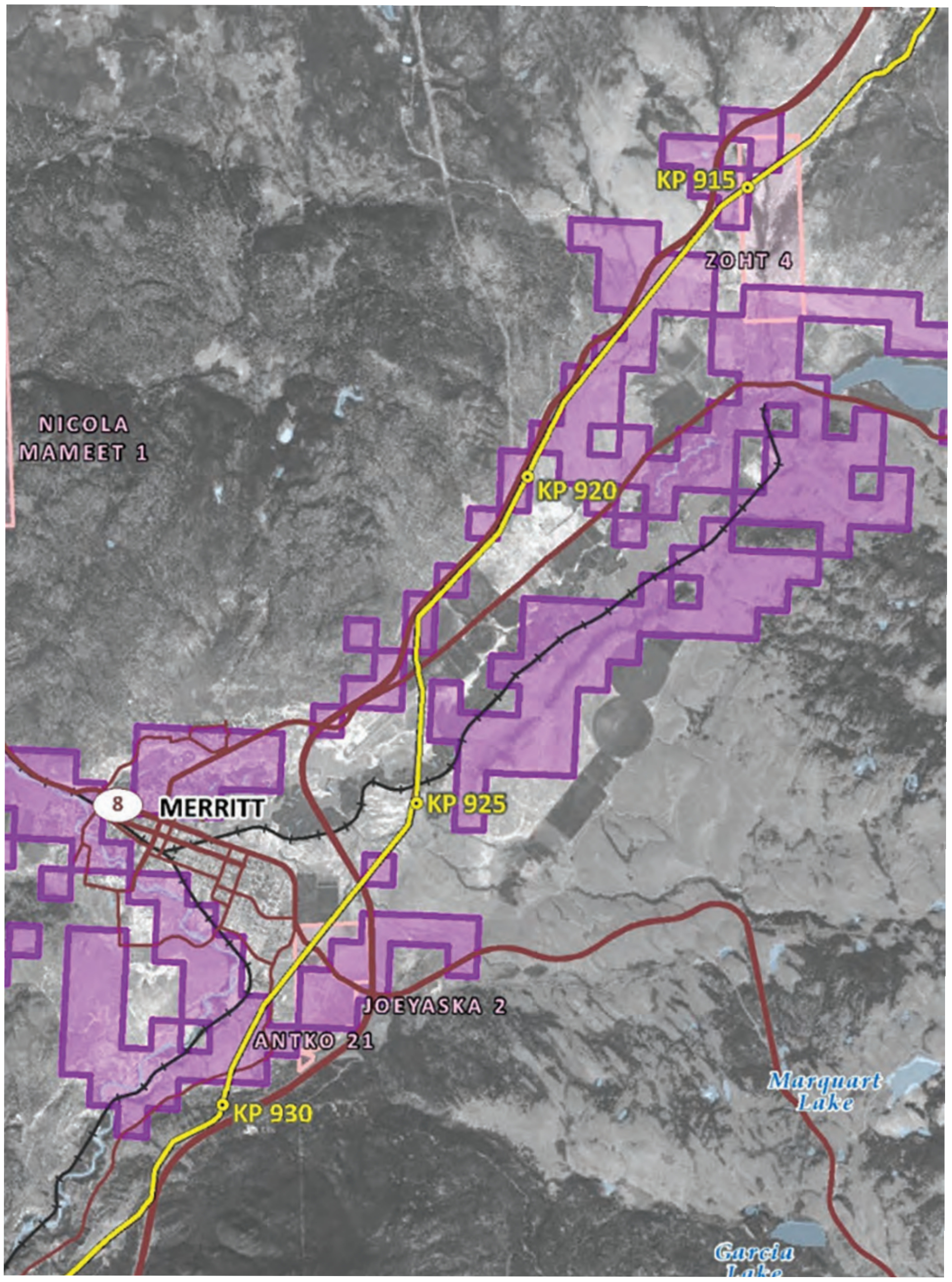

Figure 1. The Project (yellow line) Relative to ECCC's Identified Final Critical Habitat for Lewis's Woodpecker (purple polygons) near Merritt, BC

As illustrated by the above examples, it is important to take a practical approach when planning surveys of critical habitat to maximize cost-effectiveness and the value of data collected. Scrutinizing mapped critical habitat to identify and refine a narrowed area of interest reduces overall survey effort and can focus field effort on areas or habitat types that are most pertinent to project mitigation and monitoring. Effective field data collection of biophysical attributes is imperative to informing strong mitigation and habitat restoration recommendations.

Mitigation and Restoration

The planning and development of mitigation measures for the Wildlife Species at Risk Mitigation and HRP prepared for TMEP followed the hierarchy of (1) avoid, (2) minimize, and (3) restore onsite. As noted previously, the coarse scale of some ECCC-identified critical habitat presented challenges to the avoidance of critical habitat through routing and siting. Where direct avoidance was not practical, sensitive time periods for species at risk becomes an important consideration in Project scheduling to avoid impacts on biophysical attributes when these features are used by the species (e.g., nest sites and fruit-bearing shrubs for Lewis's woodpecker). However, scheduling construction to avoid these periods is not always practical, especially for species with sensitive life history phases that occur throughout the year or in light of other constraints to Project scheduling, such as conflicting least-risk windows for other sensitive species or environmental elements, landowner requests, and the nature of sequential linear construction methods. Dealing with multiple and conflicting timing windows can be complex and requires a delicate balance of valued priorities and project scheduling. In these situations, additional mitigation measures may be required to reduce the risk of mortality to species at risk or the destruction of an occupied habitat feature and can include measures such as salvage and relocation programs.

An important consideration during the initial development of avoidance, mitigation, and restoration measures was a thorough review and understanding of the defined biophysical attributes and the ways in which Project activities might affect each. In this way, specific mitigation could be developed to reduce Project impacts on each individual biophysical attribute, thereby reducing overall impacts on critical habitat for each species. Biophysical attributes related to discrete, well-defined habitat features presented practical opportunities for mitigation through site-specific avoidance or replacement. For example, nesting habitat for Lewis's woodpecker includes detailed attributes of suitable nest trees (e.g., preferred tree species, DBH, cavity sizes, and decay class). These features were identified during field surveys and allowed for opportunities to modify the construction footprint to avoid direct impacts (i.e., modifying the layout of temporary workspace to avoid clearing a potential nest tree). Where direct avoidance was not possible, measures to reduce impacts or replace discrete features were instead considered. For example, where a suitable nest tree is identified in the middle of the construction footprint and cannot be avoided, a commitment is made to provide a suitable replacement structure. This may include replacement with an artificial nest box or artificial cavity on a nearby suitable tree or girdling or topping of a suitable tree to encourage natural recruitment of cavity trees and snags in the future. The consideration of time lag is an important part of the development of mitigation and habitat restoration measures where a biophysical attribute must be restored in a shorter timeframe to be present for a species at risk. In the case of nest trees, the installation of artificial nest boxes or artificial cavities substantially reduces time lag associated with restoration of nesting habitat versus the longer-term creation of snags.

Where biophysical attributes are more general in nature and are not discrete features that can be avoided or directly replaced, recommended mitigation measures focused on reducing Project disturbance and restoring habitat onsite. Using western screech-owl and Lewis's woodpecker foraging habitat as an example, this will be accomplished by implementing reduced ground disturbance construction methods to facilitate natural revegetation, seeding areas with native grass mixes and short-lived cover crops, and planting trees and fruit-bearing shrubs (i.e., in the case of Lewis's woodpecker).

Measuring Success

Measurable targets for post-construction environmental monitoring were developed to evaluate the success of mitigation and critical habitat restoration. Measurable targets need to be quantifiable and practical in order to evaluate the success of mitigation and restoration measures in achieving their intended goals in the context of a project. They also need to be achievable within the timeframe they are to be monitored, which—for TMEP—is five years following final clean-up and reclamation. Finally, measurable targets need to be biologically relevant for the species within the relevant monitoring timeframe, supported by knowledge of species biology or results of reclamation efforts on other projects. Meeting these criteria is challenging in the absence of accepted thresholds or targets for species of interest or available literature to support the selection of targets.

Measurable targets for TMEP were aligned with potential Project effects on species at risk and their habitat, such as mortality risk and change in habitat, and considered the broader goals set out in the Mitigation and HRPs (e.g., avoidance of species mortality during Project activities, retaining or replacing site-specific habitat features, and restoring native vegetation consistent with the biophysical attributes of critical habitat). As part of these broad goals, specific performance indicators were selected to refine exactly what would be measured (e.g., the comprehensive components of the biophysical attributes). Measurable targets for each performance indicator that can be monitored during or following construction were then identified. These targets are intended to act as a trigger for the implementation of corrective actions if mitigation and restoration measures are found to be underperforming. Table 1 provides examples of some of the goals, performance indicators, and measurable targets developed for Lewis's woodpecker.

Each of the targets in Table 1 has a quantifiable component, such as the percent cover of regenerating native vegetation or number of suitable nest structures per hectare of the Project footprint within critical habitat. Published thresholds do not exist for all of the biophysical attributes of critical habitat for this species, so quantifiable targets were developed in consideration of the criteria outlined above, including practicality, achievability, and biological relevance.

The first goal in Table 1 relates to restoration of native vegetation, which is intended to target the general vegetation attributes of critical habitat for Lewis' woodpecker. Vegetation community composition and cover by layer are practical indicators because they can be easily measured and are consistent with post construction monitoring methods that are planned for other species at risk and environmental components of the Project, which allows for consistency and efficiency during post-construction environmental monitoring. Relevant best available information (e.g., baseline information collected for the Project and other projects in similar regions) and the professional experience of Trans Mountain's reclamation and vegetation experts was used to select a vegetation restoration target that would be achievable within the monitoring timeframe, while also being consistent with baseline vegetation cover conditions within the arid regions in which Lewis' woodpeckers occur.

Part of the second goal in Table 1 relates to retention and replacement of suitable nest structures, which include nest boxes, cavity trees, and artificial cavities. In initial iterations of this measurable target, retention or replacement of a percentage of the total potential nest trees identified within the Project footprint was considered. However, in some areas, the existing

Goal	Performance Indicator	Measurable Target
1. Restore disturbed vegetation to natural vegetation communities that will regenerate herbaceous and shrub layers	• Vegetation community composition and percent cover of: - native species - seeded non-native species (agronomic) - invasive non-native (weed) species - leaf litter - bare soil - rock - cryptogamic crust • Density/distribution of invasive non-native (weed) species	• Minimum 50 percent cover of regenerating native vegetation (natural regeneration, seeded, or planted) and maximum 20 percent cover bare soil, with seeded non-native (agronomic) vegetation, and litter, rock, and cryptogamic crust (where naturally occurring) making up the remaining percent cover. • No new introduced invasive species/noxious weeds; extent of weeds is maintained or reduced from pre-construction conditions.
2. Retain or replace habitat features that provide nesting or foraging requisites	• Large-diameter trees (≥ 30 cm dbh) with cavities • Density/distribution of fruit-bearing trees/shrubs	• An average of approximately 0.33 suitable nest structures per hectare of Project footprint in the refined areas of proposed critical habitat retained or replaced, with emphasis (75 percent) on nest boxes or artificial cavities to address immediate replacement. • Fruit-bearing shrubs regenerating in habitat where they were identified prior to construction with a density and distribution similar to pre-construction conditions.

Table 1. Example Performance Indicators and Measurables Targets for Lewis's Woodpecker

availability of nest structures may greatly exceed the typical density of Lewis' woodpeckers, and there is no biological relevance to maintaining such a high abundance of nest structures. Instead, inspiration was taken from a similar cavity-nesting bird species at risk, Williamson's sapsucker, whose biophysical attributes of nesting habitat included a criterion for the minimum number of suitable nest trees required per breeding territory (i.e., 5.6 per territory or 0.35 per hectare [ha]) (ECCC 2016b). Employing similar logic for Lewis's woodpecker, available literature describing the average breeding territory size and minimum number of suitable nest trees required within a territory was used to develop a specific, quantifiable target for nest retention and replacement. Basing this target on empirical information relevant to Lewis's woodpecker reduces uncertainties related to restoring habitat function within the Project footprint.

For other attributes where no information was available to guide selection of a quantifiable target (e.g., density/distribution of fruit-bearing trees/shrubs), reliance on professional judgment became more important for determining what would be relevant, practical, and achievable. Where the biophysical attributes were similar for different species at risk, common measurable targets were used. Alignment of measurable targets for critical habitat across the Project simplifies and increases the efficiency of post-construction environmental monitoring.

SUMMARY & RECOMMENDATIONS

The development of Wildlife Species at Risk Mitigation and HRP for TMEP yielded the following key lessons and recommendations for the development of similar plans:

- The scale, specificity, and stage of critical habitat is important to consider in the context of potential project interactions. Not all geospatially identified areas of critical habitat necessarily contain the required biophysical attributes of critical habitat and it is important to scrutinize critical habitat mapping to refine areas of interest. Refining areas of interest will focus surveys and result in a more efficient and effective field effort.
- Surveys for biophysical attributes are important for informing mitigation and habitat restoration measures and providing accurate baseline information for post-construction environmental monitoring. These should take a practical approach, considering what attributes may be affected, and whether standard construction mitigation will reduce Project effects or whether additional mitigation and site-specific information are needed.
- By developing mitigation and habitat restoration measures specific to each biophysical attribute, overall impacts on critical habitat for each species will be reduced.
- Where attributes may be affected in the long term, it is important to consider alternative methods to restore habitat function in a shorter timeframe.
- Measurable targets used in the evaluation of success of mitigation and habitat restoration measures are expected to be most effective when they are quantifiable, practical, achievable, and biologically relevant. Where existing targets or thresholds are not available, selection of measurable targets should be guided by relevant best available information and may need to include professional judgment or input from regulators and species experts.

An increased focus on the reporting, mitigation, and habitat restoration requirements for terrestrial wildlife species at risk and their critical habitat has become more evident in federally regulated projects in Canada. The importance of staying current with updates to the status of federal species at risk, the posting of recovery strategies, and the identification of critical habitat cannot be overstated. Proponents whose projects have the potential to directly or indirectly affect critical habitat for species at risk should anticipate approval conditions similar to those received for TMEP related to Wildlife Species at Risk Mitigation and HRP and be prepared for the effort required to respond. Changing regulatory expectations have implications for all levels of project development and execution. The early consideration of species at risk and their critical habitat is imperative and needs to occur throughout all stages of a project, including planning, design, permitting, construction, reclamation, and post-construction monitoring to reduce uncertainties and risks to a project.

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Dana Drumm is a professional biologist at Jacobs with more than eight years of professional consulting experience. She has expertise in environmental planning and assessment, design of wildlife field programs, and development of effective and innovative mitigation recommendations to protect wildlife and wildlife habitat. Drumm has contributed to numerous applications for federally and provincially regulated linear infrastructure and energy development projects in western Canada. Areas of interest include species at risk mitigation, habitat restoration, and cumulative effects assessment. Drumm is a member of the Alberta Society of Professional Biologists and the College of Applied Biology in BC.

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Trevor Friesen has more than eight years of wildlife biology and environmental consulting experience designing and leading wildlife field programs in BC, Alberta, and Saskatchewan, and preparing the associated technical reports and mitigation recommendations for provincially and federally regulated projects. Friesen's field experience includes amphibian surveys (diurnal and nocturnal), breeding bird surveys, aerial waterbird surveys (helicopter supported), sharp-tailed grouse surveys, call playback surveys (burrowing owl, common nighthawk, western screech-owl, woodpeckers, yellow rail), winter track surveys, and the field identification of the biophysical attributes of critical habitat for species at risk. He has been a key contributor to the development and preparation of wildlife species at risk mitigation and habitat restoration measures for various project-specific environmental protection plans and environmental effects assessments. Friesen is a member of the Alberta Society of Professional Biologists and the College of Applied Biology in BC.

Mitigation for ROW Impacts to Threatened and Endangered Bats and Migratory Birds Using Habitat Equivalency Analysis

Gordon Ferguson, David Trimm, and Katie Baker

A common challenge during linear project planning and development is the valuation of lost habitat (and those ecological services provided) when developing a compensatory mitigation approach for ecologically important habitat that supports sensitive species. Historically, the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Fish and Wildlife Service (USFWS) have used a Habitat Equivalency Analysis (HEA) to determine compensation for lost natural resources. The HEA program accepts input of parameters necessary to determine long-term service loss and long-term service gain based on the desired compensatory restoration action. The principal concept underlying the HEA method is that the loss of habitat resources and ecological services can be compensated through habitat replacement that provides for the same types of services.

This paper provides a case study where scientists and conservation managers calculated compensatory mitigation for the Indiana bat (IB; *Myotis sodalis*), northern long-eared bat (NLEB; *M. septentrionalis*), and migratory bird forested habitat impacted by tree clearing to establish a new, 200-foot (ft) right-of-way (ROW) for a planned electric power transmission project. In cooperation with the USFWS, Visual_HEA© software was used in conjunction with tree survey data and land valuations to categorize and rate affected forested habitat and to calculate the amount of compensatory mitigation (CM) that would be required to match ecological services lost following anticipated construction-related tree removal. The initial mitigation cost estimate using the software model was overly conservative because it was not based specifically on each woodlot's capacity to support the expected ecological services. The more rigorous subsequent analysis presented herein incorporated detailed tree assemblage and spatial coverage data to define forest class and composition for each affected woodlot, and ultimately provided a more realistic view of what would be required to replace the impacted habitat. Finally, land values were obtained to calculate mitigation costs representative of current economic conditions.

Keywords: Habitat Equivalency Assessment (HEA), Migratory Birds, Mitigation, Threatened and Endangered (T&E) Bats, Visual_HEA©.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

In the last few decades, regulatory agencies in the U.S., such as the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Fish and Wildlife Service (USFWS), have applied habitat functional analyses, including hydrogeomorphic methods (Smith et al. 1995), habitat evaluation procedure (USFWS 1980), indices of biotic integrity (Karr 1981), and habitat equivalency analysis (HEA) for quantifying lost services for biota where supporting habitat has been detrimentally impacted. HEA has commonly been used during natural resource damage assessments (NRDA) for predicting the amount of compensation needed for lost services after oil spills and other hazardous substance releases. Since service losses and gains occur at different times, their calculated monetary values must be adjusted in order to be directly compared. This adjustment is accomplished using a discount factor (i.e., net present value), which decreases the value of future services and increases the value of past services in order to reflect how much the public values future (or past) service benefits today. At a Superfund site in New England, the USFWS used HEA to determine compensation for lost services from metals' contaminated soil and sediment (USDOI 2007), and the U.S. Army Corps of Engineers (USACE) commonly uses HEA for determining the appropriate amount of compensation resulting from operational impacts under their jurisdiction, including impacts to and loss of soft- and hard-bottom habitats, including coral reefs (Ray 2009).

A requirement for mitigating habitat impacted by linear power projects is common practice, and various approaches have been used to determine appropriate replacement habitat. In conjunction with the USFWS and The Nature Conservancy, NiSource—one of the largest fully regulated utility companies in the U.S.—developed a strategic approach for addressing mitigation under a Multi-Species Habitat Conservation Plan for natural gas transmission facilities throughout their system. In a similar effort, the USFWS Region 3, in conjunction with Northern Indiana Public Service Company (NIPSCO; a subsidiary of NiSource) and other project proponents, developed a program for determining compensatory mitigation for loss of migratory bird habitat or for Endangered Species Act (ESA)-listed bat species habitat using HEA. HEA allows the determination of how many units (e.g., acres) of new habitat is required to compensate for each acre of lost habitat. For example, a calculated mitigation ratio of 5:1 indicates five units of replacement habitat are required for each unit of lost habitat. With this program, habitat requirements and land values are calculated and the developer is informed on how they can reduce costs by avoiding high-ratio habitat (i.e., habitat that can support high populations of sensitive or unique species), and co-locating new projects within existing rights-of-ways (ROWs). The program was so successful that it won a Presidential Migratory Bird Federal Stewardship Award in 2015.

In 2013, NIPSCO and Pioneer Transmission, LLC publicly announced construction of the proposed Greentown Reynolds Electric System Improvement Project (Project). This proposed Project included construction of a new 765-kilovolt (kV), single-circuit transmission line approximately 102.6 kilometers (km) long, with a 61-meter (m) ROW, using self-supporting 42.7-m steel lattice structures spanning lengths averaging 381 m. To operate and maintain the facilities and prevent encroachment on the new transmission line, the ROW would be cleared of trees and woody vegetation; however, woody shrubs compatible with the transmission line in wetland areas and adjacent to streams would not be removed. From the earliest stages, the Project was routed, designed, and developed to avoid much of the forested habitat along the proposed route.

To determine compensatory mitigation for the Project, the USFWS initially assessed impacts on woodlots that were affected by Project construction that could support ESA-listed bats and/or migratory birds, and then calculated the potential compensatory mitigation cost for predicted lost ecological services. Their analysis incorporated field data on woodlot tree types and sizes. They used the Visual_HEA© model to determine mitigation ratios. Visual_HEA© is a software tool created in 2006 by Nova Southeastern University's National Coral Reef Institute to facilitate the assessment of losses and gains in ecosystem services related to compensatory mitigation under the U.S. NRDA Act (Pioch et al. 2017). Mitigation ratios were then used to calculate the acreage required to replace lost ecological services.

For the purposes of developing Visual_HEA© ratios and, ultimately, mitigation fees, affected woodlots were initially divided by the USFWS into two categories: Intermediate Stage Forest and Mature Forest. Land values were then applied to determine the final compensation cost expected from the Project sponsors. It was believed that the initial mitigation cost estimate, which was determined using the software model, was overly conservative because it was not based specifically on each woodlot's capacity to support the expected ecological services. The USFWS's analysis considered each woodlot from a general perspective, but did not consider each lot's unique tree assemblage or spatial coverage. Ultimately, a subsequent analysis was conducted, which considered a more detailed understanding of each woodlot, and included consideration of tree species, ages, and spatial coverage.

On behalf of the Northern Indiana Public Service Company (NIPSCO) and Pioneer, the authors analyzed age, forest classification, and coverage of individual tracts, resulting in an alternative mitigation fee estimate. The purpose of this paper is to present the findings of the subsequent analysis through a detailed evaluation of the capacity for affected land tracts to provide support for the Indiana bat (IB; *Myotis sodalis*), northern long-eared bat (NLEB; *M. septentrionalis*), and migratory birds, as well as the compensatory mitigation required to account for lost ecological services.

METHODS

Compared to the approach applied by the USFWS, tree species and age were considered as the primary factors for use in assessing a woodlot's potential to provide bat maternity/roosting habitat and/or migratory bird habitat, thus providing a more comprehensive analysis of each woodlot's capacity to support sensitive species. Generally, woodlots that did not provide bat maternity and/or roosting habitat were deemed important as migratory bird habitat.

Woodlot tree size data considered the largest specimens identified during field surveys to predict the age structure of each lot. Age and species were determined for the three trees with the largest diameter within each woodlot, based on a review of diameter at breast height (dbh) measurements and the application of species-specific annual growth rates from publicly available sources. In concert with the tree data analysis, current and historical aerial photographs (1939 to the present) were reviewed for each woodlot identified by the USFWS as bat or migratory bird habitat. Woodlot historical photographs provided both spatial and temporal characteristics for forested and non-forested habitat as time passed. This allowed each woodlot to be temporally compared, and indicated the current (or, at least, the most recent per the date of the aerial) age of the trees on the lot (or on a portion of the lot). This method allowed for a critical evaluation and identification of age structure across a woodlot, and age variability within a lot, as compared to a single age structure for the entire lot.

Using the approach described above, this study further defined the forests' ages and structures into five classes to be more representative of existing woodlots. The five classes are as follows:

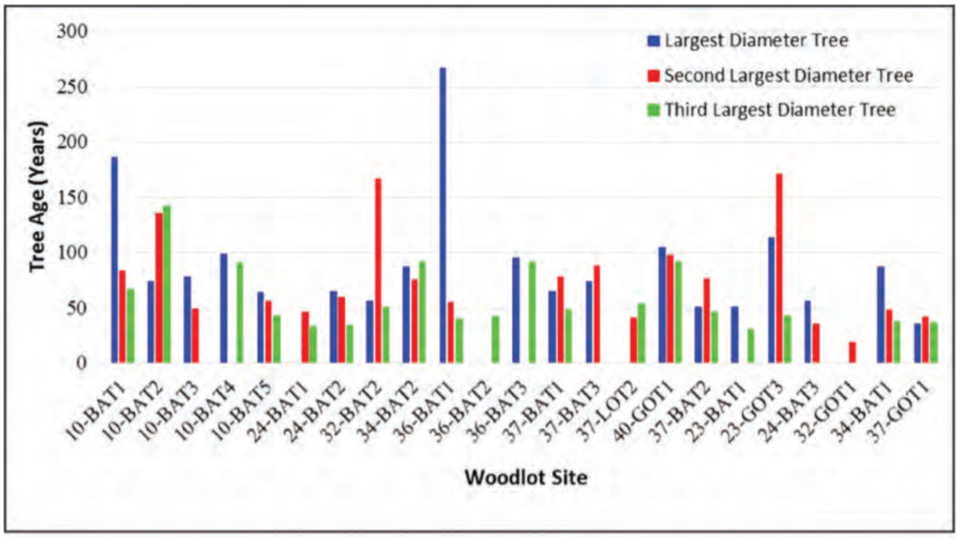

Figure 1. Indiana Bat and Northern Long-Eared Bat Maternity Habitat Tree Size (dbh) Comparison by Woodlot Site at the Greentown Reynolds 765-kV Electric System Improvement Project. *Note: Growth rates could not be calculated for some tree species and are shown as missing values in Figure 1.*

- **Early Stage Forest** (Migratory Bird Habitat)—Comprises trees up to 50 years old and includes replacement of eastern white pine (*Pinus strobus*) or other fast-growing tree species for migratory birds. At 26 years of growth, 22.86-centimeter (cm) dbh trees provide habitat for myriad of warbler, sparrow, and blackbird species.
- **Early Stage Forest** (Non-Maternity Bat Habitat)—Early Stage Forest with an approximately 50-year recovery period to provide non-maternity (roosting) IB and NLEB habitat. Recovery starts when fast-growing trees reach 7.62 cm dbh, which provides NLEB roosting habitat, and at 12.7 cm dbh, when trees provide IB roosting habitat (USFWS 2018).
- **Intermediate Stage Forest** (Maternity Bat Habitat)—Includes woodlots with 50- to 70 year-old dominant trees.
- **Late Stage Forest** (Maternity Bat Habitat)—Habitat with 71- to 85-year-old trees.
- **Mature Forest** (Maternity Bat Habitat)—Habitat providing bat maternity habitat with trees (e.g., shagbark hickory [*Carya ovata*]) 86 to 100 years old.

The overall goal in this exercise was to differentiate required compensatory time frames for the selected forest-age classes so that the applied mitigation would accurately reflect what was being lost and what compensatory recovery period would be appropriate. Visual_HEA© modeling curves for the five classes of forest providing IB/NLEB maternity, IB/NLEB non-maternity, and migratory bird habitat were then developed, and mitigation ratios determined for calculation of habitat replacement acreages. Finally, land values for Indiana agricultural land were determined based on Dobbins and Cook (2016), and a final compensatory value (including a six percent fiduciary fee, site preparation, and maintenance costs) was proposed.

RESULTS

The data for each woodlot were analyzed to determine which category was best represented by on-site forests (Figure 1). Based on aerial photography analysis, it was determined that discrete woodlot portions could represent more than one forest-age class. For example, the 1941/1951 historical information

Woodlot Name	Forest-Age – Percentage of Woodlot (hectares [ha])[1]: Early Stage 40-50 YO Migratory Bird	Early Stage 40-50 YO Bat	Intermediate Stage 50-70 YO	Late Stage 70-85 YO	Mature 86-100+ YO	Notes
Bat Maternity Habitat						
10-BAT1 (1.12)			100% (1.12)			
10-BAT2 (0.87)				65% (0.57)	35% (0.30)	
10-BAT3 (0.87)			80% (0.70)	20% (0.17)		
10-BAT4 (1.04)			85% (0.88)	15% (0.16)		
10-BAT5 (1.9)	39% (0.75)		55% (1.04)	6% (0.11)		
24-BAT1 (0.42)		90% (0.38)	10% (0.04)			
24-BAT2 (0.44)			40% (0.17)	60% (0.27)		
32-BAT2 (0.39)					100% (0.39)	8% of woodlot non-forested
34-BAT2 (1.34)					100% (1.34)	
36-BAT1 (1.93)					100% (1.93)	
36-BAT2 (0.3)			100% (0.3)			12% of woodlot non-forested
36-BAT3 (1.0)				100% (1.0)		
37-BAT1 (2.57)			100% (2.57)			
37-BAT3 (0.8)					100% (0.8)	
37-LOT2 (0.11)				100% (0.11)		
40-GOT1 (1.26)	32% (0.40)			68% (0.86)		
Bat Non-Maternity/Migratory Bird Habitat						
37-BAT2 (0.85)	100% (0.85)					Woodlot dominated by white pine – considered migratory bird habitat
23-BAT1 (0.23)		100% (0.23)				
23-GOT3 (0.04)		100% (0.04)				14% of woodlot non-forested
24-BAT3 (0.09)		100% (0.09)				
32-GOT1 (0.39)		100% (0.39)				61% forest coverage of woodlot
34-BAT1 (0.64)		100% (0.64)				
37-GOT1 (0.12)		100% (0.12)				98.4% forest coverage of woodlot
Total	**2**	**1.89**	**6.82**	**3.25**	**4.76**	

Note:
[1] Based on percentage of Mitigation Acreage.
Key:
YO=Years Old

Table 1. Evaluation of Greentown Reynolds Project Forest Woodlots for Bat and Migratory Bird Habitat

for one woodlot (10-BAT5) showed that there was a small portion (six percent) of the woodlot that had an established forest that was likely more than 70 years old, but subsequent aerial photography showed that relatively newer forests were not formed until the 1960s, suggesting that these areas were only 50+ years old. This latter forest occupied most of the woodlot (55 percent). In addition, 39 percent of the woodlot was identified as potential migratory bird habitat. Thus, the mitigation acreage was subsequently divided between the five forest-age classes on a percentage basis (Table 1).

The tree age structure and historical aerial photography indicated that many of the woodlots were highly likely to support IB and NLEB maternity habitat. Woodlots 10-BAT1, 10-BAT2, 10 BAT3, 10-BAT5, 24-BAT1, 24-BAT2, 34-BAT2, 36-BAT1, 37-BAT1, 37-BAT3, and 37 LOT2 (Table 1) were all assessed to have a tree size structure and historical forest spatial extent sufficient to support IB and NLEB maternity colonies. Each of these woodlots had resulting "IB/NLEB Acreage" values equal to the full size of the woodlot in question. Other woodlots, including 10-BAT4, 32-BAT2, 36-BAT2, 36-BAT3, and 40-GOT1, were identified as supporting IB and NLEB maternity colonies, but the "IB/NLEB Acreage" was reduced, primarily based on current aerial photographic evidence that showed that not all of the originally estimated woodlot area was forested. When this occurred, the original area size was reduced to reflect the actual forested area presently occurring on each woodlot. Table 2 provides a summary of the habitat areas by forest classification that were used to estimate the final compensatory mitigation fee.

Forest Classification	Hectares
Migratory Bird – Early Stage Forest	2
IB/NLEB Non-Maternity – Early Stage Forest	1.89
IB/NLEB Habitat – Intermediate Stage Forest	6.82
IB/NLEB Habitat – Late Stage Forest	3.25
IB/NLEB Habitat – Mature Forest	4.76
Total	**18.72**

Key:
IB=Indiana bat
NLEB=Northern long-eared bat

Table 2. Summary of Area for Mitigation Estimates

DISCUSSION

In 2015, prior to the current analysis, the USFWS identified 15.79 ha of affected forest as maternity roost habitat for IB and NLEB. This number was based on assumed optimal density of potential roost trees (≥ 22.86 cm dbh, alive or dead) at 27 trees per acre. Our subsequent response to the USFWS provided an alternative analysis for evaluating compensatory mitigation. We presented general data on the woodlots affected, but did not provide a detailed analysis of tree size and age structure for individual woodlots because these data were not available from pre-construction tree lot surveys conducted along the ROW. Discussions resulted in the current alternative approach for assessing the age structure of individual forest woodlots so that compensatory mitigation would accurately reflect value and replacement of "in kind" habitat.

In 2016, we developed a more robust evaluation of woodlots that would be affected and then proposed a modified approach for development and determination of a compensatory mitigation fee for lost bat and bird ecological services. The agreed-upon approach was to review tree size field data from individual woodlots, and, based on the largest specimens identified during field surveys, predict the age structure of each woodlot.

As stated, the overall goal of this exercise was to differentiate required compensatory time frames for the forest-age classes so that the applied mitigation would accurately reflect what was being lost and what recovery period would be appropriate. This approach required the addition of three Visual_HEA© model curves that estimated recovery and mitigation ratios based on the five forest classes listed above. For example, under this approach, a 40- to 50-year-old forest providing either bat roosting habitat or migratory bird habitat would be in one of the two early stage forest classes. Ultimately, all woodlots were re-assessed to more accurately reflect services lost and services gained when determining what the compensatory acreage should be (Tables 1 and 2).

The results of this analysis showed that the forest acreage proposed by the USFWS for supporting IB and NLEB maternity colonies was reduced from the original 15.79 ha to 15.21 ha. The analysis modified the IB and NLEB non-maternity habitat to 1.51 ha. The migratory bird habitat requiring mitigation was increased from the former 1.89 ha estimated by the USFWS to 2.00 ha. The total acreage of potential migratory bird and ESA-listed bat species habitat identified by the above analysis resulted in 18.72 ha that was used in calculations for the mitigation fee estimate.

Previous Visual_HEA© models used by the USFWS and our team for developing mitigation ratios employed only two periods for estimating recovery of forests for lost IB, NLEB, and migratory bird ecological services: 100 years and 70 years. The first predicted that a 100-year recovery period would be needed to replace Mature Forest habitat deemed appropriate for supporting IB and NLEB maternity colonies. The Visual_HEA© model curve that used the 100 year recovery period produced a mitigation ratio of 5.19. The 70-year recovery period for replacement of Intermediate Stage Forest for migratory birds (and non-maternity bat habitat) initially developed by the USFWS produced a mitigation ratio of 2.06. Both of these ratios were included in ratios developed for the five forest-age classes in developing overall mitigation size and cost (Figures 2 through 6). Again, our tree stand analysis indicated that five forest-age classes should be considered for woodlots expected to support IB and NLEB maternity colonies, non-maternity activities, and migratory bird habitat requisites (see "Methods" section above). The overall goal of this exercise was to differentiate required recovery time frames for the forest age classes so that the applied mitigation would accurately reflect what was being lost and what recovery period would be necessary to allow similar habitat to develop.

Table 3 presents the mitigation ratios calculated by the Visual_HEA© model for the USFWS and author developed habitat recovery curves. The initial analysis conducted by the USFWS in October 2015 assigned most of the impacted forested habitat to the Mature Forest category and applied a mitigation ration of 5.19 to 1 to the impacted habitat area, estimating a required replacement acreage of 82.11 ha. The remaining habitat was classified by the USFWS as Intermediate Stage Forest. The Intermediate Stage Forest mitigation ratio of 2.06 to 1 was used, resulting in an estimated replacement value of 7.53 ha. As such, the initial USFWS HEA analysis proposed that 89.64 ha of replacement habitat was required. Based on a more robust analysis of the forest-age data, and mitigation ratios based on HEA modeling curves, the replacement habitat area was reduced from the initial estimate of 89.64 ha to 64.98 ha. This was accomplished by dividing impacted habitat areas (woodlots) by a forest-age class that is more representative of the lost services (Tables 1 and 2). Then, we used the associated mitigation ratios below (ranging from 5.19 down to 1.65) instead of the USFWS baseline assumption that most of the impacted habitat was Mature Forest, and applied

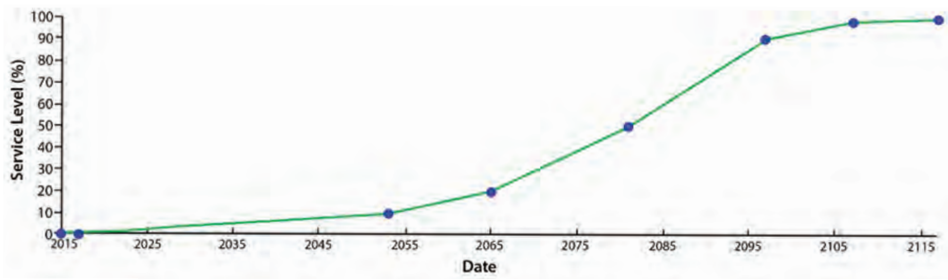

Figure 2. Indiana Bat/Northern Long-eared Bat Mature Forest Maternity/Roosting Habitat (USFWS Curve) – Permanent Loss – Mixed Species Planting – 100–Year Full Recovery. *Notes: Revised Visual_HEA© model curve for restoration of IB and NLEB maternity habitat. Recovery is based on time taken to grow 50.8 cm dbh trees of dominant species. Assumed a two year delay for land acquisition, planning, and planting. After 40 years, dominant species will reach 22.86 cm dbh and can begin to provide maternity roost habitat services. After 80 years, 90 percent of services will be restored. These services increase until full service is attained at 100 years. Mitigation ratio=5.19.*

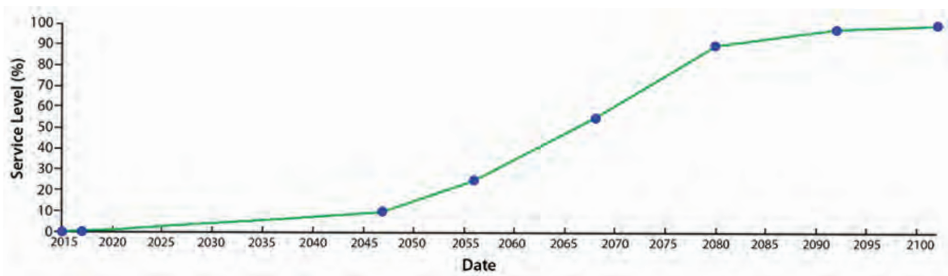

Figure 3. Indiana Bat/Northern Long-eared Bat Late Stage Forest – Maternity/Roosting Habitat (Authors' Curve) – Permanent Loss – Mixed Species Planting – 85–Year Full Recovery at Intermediate Rate of Gain. *Notes: Visual_HEA© model curve for restoration of IB and NLEB maternity habitat for Late Stage Forest woodlots: Recovery is based on time taken to grow 63.5 cm dbh trees of dominant species (green ash). Assumed a two–year delay for land acquisition, planning, and planting. After 32 years, dominant species will reach nine inches dbh and can begin to provide maternity habitat services. After 63 years of recovery, 90 percent of services will be restored. These services increase until full service is attained at 85 years. Mitigation ratio=3.82.*

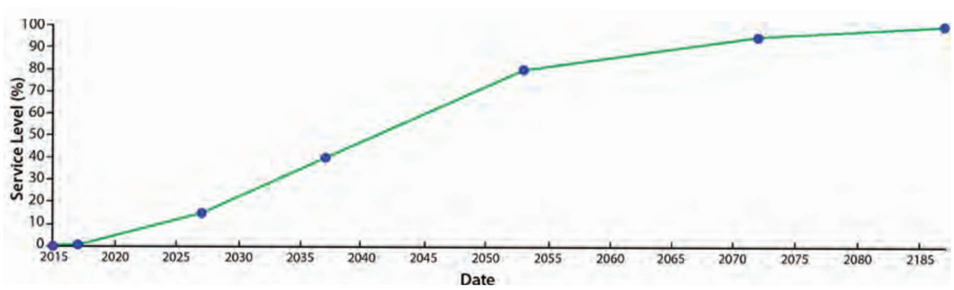

Figure 4. Migratory Bird and Bat Habitat – Permanent Loss – Intermediate Stage Forest (USFWS Curve) – 70–Year Restoration – Mixed Species Rapid Gain – Two–Year Delay – 100% Utility.
Note: Mitigation ratio=2.06.

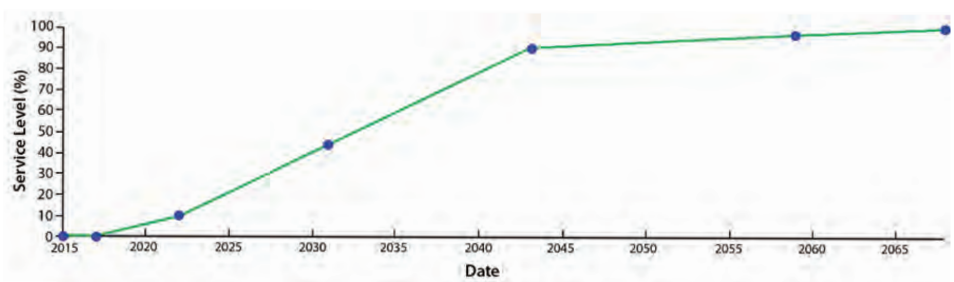

Figure 5. Migratory Bird Habitat Only – Permanent Loss – Early Stage Forest (Authors' Curve) – 51–Year Restoration to Replace 48.26 cm dbh White Pine and or 35.56 cm Green Ash – Rapid Gain – Two–Year Delay – 100% Utility. *Notes: Assume recovery begins (10 percent) after growth of 5.08 cm dbh white pine at five years; provides roosting, perching habitat for small passerine birds. Trees at 12.7 cm dbh. Mitigation ratio=1.65.*

the largest mitigation ratio of 5.19 to 1.

Finally, to determine the mitigation cost, land value was based on average farmland for the North, West Central, and Central regions of Indiana provided in the Purdue Agricultural Economics Report (P.A.E.R.) for August 2015 and August 2016 (Dobbins and Cook 2016). This report showed that land values for agricultural land decreased by an average of 5.5–9 percent since the USFWS had first estimated mitigation costs in July 2015. Dobbins and Cook (2016) also noted that farmland values and rental rates were expected to continue to decline within the next year across Indiana. The use of more current land value data that were more representative of current economic conditions reduced the agricultural land value unit costs from an assumed value of $10,028 per acre (that included a land value escalation factor of seven percent for a two-year period) to $7,341 per acre (a reduction of approximately 27 percent). Based on this information, a modified mitigation estimate was proposed. For this estimate, we applied (1) the adjusted acreages (hectares) for replacement of Early Stage Forest (Migratory Bird Habitat) and (2) Early Stage Forest (Non-Maternity Bat Habitat), Mature Forest, Late Stage Forest, and Intermediate Stage Forest and the changes in assumptions for land value estimates. Using the reduced values for required replacement habitat area and land values resulted in an alternative mitigation cost of $1.3 million for compensation of IB/NLEB maternity bat, IB/NLEB roosting bat, and migratory bird habitat—a savings of more than $1.4 million compared to the original proposed mitigation cost of $2.7 million.

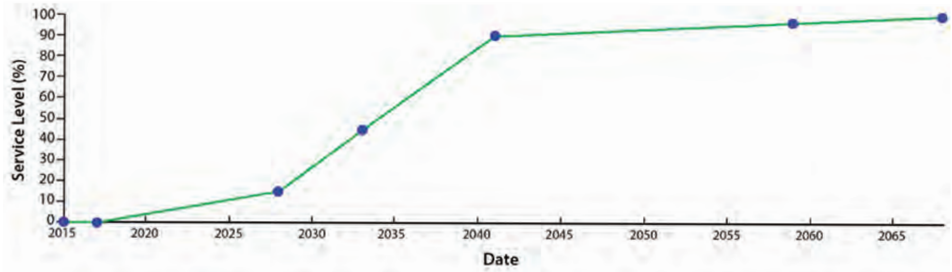

Figure 6. Migratory Bird and Bat Roosting Habitat – Permanent Loss – Early Stage Forest (Authors' Curve) – 51 Year Restoration to Replace 48.26 cm dbh White Pine, 35.56 cm dbh Green Ash, and Other Species – Rapid Gain – Two–Year Delay – 100 Percent Utility.
Note: Mitigation ratio=1.73.

Forest Classification	Mitigation Ratio
Migratory Bird – Early Stage Forest (Authors' Curve)	1.65
IB/NLEB Non-Maternity – Early Stage Forest (Authors' Curve)	1.73
IB/NLEB Habitat – Intermediate Stage Forest (USFWS Curve)	2.06
IB/NLEB Habitat – Late Stage Forest (Authors' Curve)	3.82
IB/NLEB Habitat – Mature Forest (USFWS Curve)	5.19

Key:
IB=Indiana bat
NLEB=Northern long-eared bat

Table 3. Summary of Mitigation Ratios by Forest Classification.

CONCLUSIONS

The results of this study revealed that a more robust analysis of the bat and migratory bird habitat affected during linear power projects may result in more realistic estimates of mitigation acreages and costs. Habitat timeframe recovery estimates and expected mitigation fees should reflect the actual ecological services lost in order to design a mitigation approach that is supportive of the affected species, but also appropriate for project planning and budgeting.

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AUTHOR PROFILES

Gordon Ferguson

Ferguson has more than 31 years' experience in environmental studies and pre-construction permitting of powerlines, pipelines, and power generation facilities. He has managed the development of mitigation plans to compensate for loss of wetlands and protected species habitat during permitting of linear projects, including the application of HEA modeling to quantify terrestrial habitat impacts. His ROW project experience includes ESA Section 10 permitting for electric transmission line construction through Karner blue butterfly (*Lycaeides melissa samuelis*) habitat.Ferguson is a Principal in Charge of natural resource permitting at NIPSCO.

David Trimm

Trimm, an American Fisheries Society (AFS) Certified Fisheries Professional, has more than 35 years' experience in terrestrial, aquatic and marine ecology, ecological risk, and natural resource damage assessment. He has used HEA methods for developing mitigation and compensation strategies for lost services associated with oil spills, mining events, and other habitat impacts. As a Principal Ecologist for 20 years, Trimm has led Ecology & Environment, Inc.'s global efforts for project-associated impact and mitigation in Kuwait, South America, and throughout the U.S. He has managed and conducted ecological assessments and implemented biological monitoring programs on behalf of federal and state agencies, completed wetland delineations and impact assessments, and applied the USFWS' habitat evaluation procedure. He has conducted natural resource damage assessments related to oil and hazardous waste spills throughout the U.S. and internationally.

Katie Baker

Baker, a Senior Biologist at Ecology and Environment, Inc., has more than 13 years' experience specializing in the evaluation of bats and other wildlife. As a USFWS-approved bat surveyor, she is permitted to survey and identify threatened or endangered bat species as part of ESA Section 7 and Section 10 consultation. Baker has conducted and managed pre-construction bat acoustic habitat and mist-net surveys as well as post-construction fatality monitoring surveys in 15 U.S. states. She applies the results of her investigations to evaluate project impacts and associated risks related to regional bat populations for existing and proposed gas and electric transmission projects, wind and solar energy sites, and military operations.

Mitigation of Effects to Mountain Beaver (*Aplodontia Rufa*) from a Run-of-River Hydropower ROW

Andy Smith

Keywords: Energy, Mitigation, Restoration.

The Hunter Creek Power Project is a 11-megawatt (MW) run-of-river hydropower project in the North Cascades Mountains of southern British Columbia (BC). Direct effects to occupied mountain beaver (*Aplodontia rufa*) habitat within the designed project right-of-way (ROW) were identified during the environmental assessment (EA). Efforts to mitigate project effects on mountain beaver through avoidance and translocation were unable to completely address residual effects, leaving off-setting in the form of habitat compensation as the remaining mitigation option. A 1.3-hectare (ha) closed-single-canopy stand with suitable mountain beaver habitat attributes, including presence of water and suitable soil for excavation, was selectively thinned and planted with native forage species. Retention patches with suitably developed understories were retained. This is the first known example of creating mountain beaver compensation habitat. The works were completed between 2016 and 2018; the results will continue to be monitored for five years' post-construction.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Resource development projects in British Columbia (BC) that meet certain thresholds require an assessment of the potential and residual effects on valued ecosystem components from project construction, operation, and decommissioning. The BC Ministry of Environment (MOE) has developed guidance documents that provide a framework for mitigating potential adverse effects of a project on the environment and provide guidance on the application of a hierarchical process for the identification and implementation of mitigation measures (British Columbia Ministry of Environment 2014b, a). The BC MOE mitigation hierarchy is described as follows:

- **Avoid:** Avoid project-related impacts by adjusting the site of an activity, using alternative methods, adjusting the timing or schedule of an activity, or by ceasing an activity altogether.
- **Minimize:** If avoidance is not possible, Project-related impacts can be minimized by adjusting the site of an activity, using alternative methods, or adjusting the timing or schedule of an activity.
- **Restore On-Site:** If disturbance cannot be avoided or minimized to an acceptable level, restoration of the value (e.g., habitat) in the Project area will be considered. Restoration aims to recover the function, integrity, resiliency, and self-sustainability of the disturbed value.
- **Offset (off-site or on-site):** If after measures to avoid, minimize, and restore on-site have been applied and residual impacts are predicted to remain, then offsets may be required. The provincial policy requires an assessment of ecological equivalency of any remaining impacts, and consideration and selection of measures to offset impacts on environmental values.

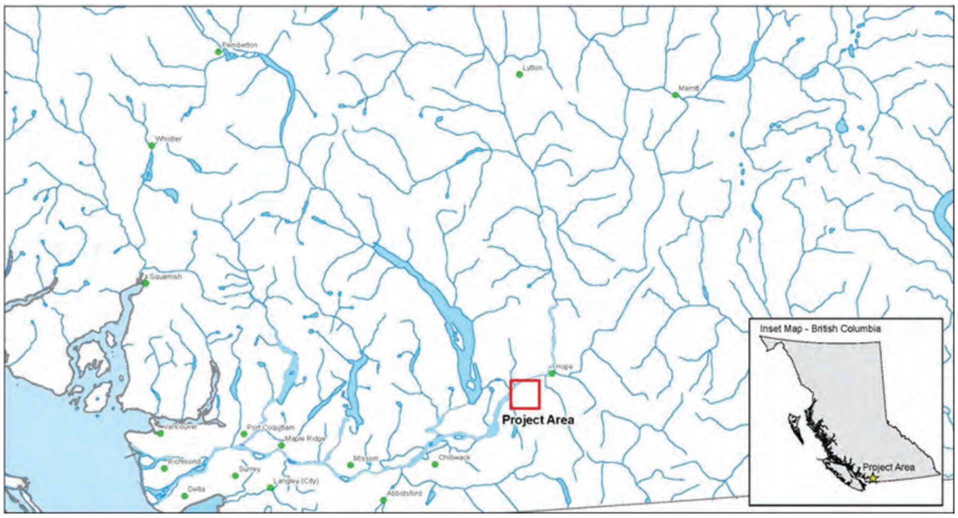

Figure 1. Project Location

The Hunter Creek Hydroelectric Project (the Project) is an 11-megawatt (MW) run-of-river hydroelectric project that began operations in June 2018. The environmental assessment (EA) completed for the Project in 2013 identified potential effects to occupied mountain beaver (*Aplodontia rufa*) habitat (Princeton Energy Inc. 2015). The Project was located and designed to avoid and minimize effects upon mountain beavers and their habitat wherever possible by minimizing the Project footprint, utilizing previous disturbed areas, and avoiding higher value habitat areas. However, project-related engineering constraints combined with widespread mountain beaver occurrence in the proposed development area resulted in a determination of residual effects requiring offsetting over and above prescribed restoration measures (Princeton Energy Inc. 2015). Identified Project residual effects based on the revised infrastructure footprint included a long-term effect on riparian habitat of 0.42 hectares (ha) and on aquatic habitat of 0.01 ha.

In order to further mitigate for effects on local populations of mountain beaver, a two-prong management approach was initially put in place to 1) complete pre-clearing surveys and buffer and avoid occupied habitat where possible, and 2) translocate individuals in the project footprint that could not be avoided. The combined efforts to mitigate Project effects on mountain beaver through avoidance and translocation were unable to completely address residual effects. High-quality mountain beaver habitat, some of it occupied, could not be avoided. While translocation likely reduced mortality among individuals relative to no action, mortality rates among those translocated were high (Smith & Ransome, in prep.). Since residual effects could not be entirely eliminated, off-setting in the form of habitat compensation for this species was the remaining mitigation option.

Thinning of dense conifer forests has been used as a tool to increase biodiversity of densely stocked regenerating forest stands (Suzuki and Hayes 2003) and has been shown to increase density or biomass of ground-dwelling small mammals. For example, variable density thinning in Douglas fir forests resulted in larger populations of deer mice (*Peromyscus maniculatus*) and creeping voles (*Microtus oregonz*) (Carey and Wilson 2001; Suzuki and Hayes 2003). Thinning Ponderosa pine (*Pinus ponderosa*) stands increased the biomass of small mammals such as deer mice, gray-collared chipmunks (*Tamias cinereicollis*), and least chipmunks (*T. minimus*) (Converse et al. 2006). To our knowledge, however, this is the first known example of creating mountain beaver compensation habitat through thinning and understory planting.

This paper describes the approach taken to compensate for habitat loss caused by the creation of the project right-of-way (ROW), some of the challenges faced during construction of the habitat compensation area, and outlines the compliance and effectiveness monitoring programs that have been implemented to gauge the effectiveness of the compensation works.

ROW Description

The Hunter Creek Hydroelectric Project is located approximately 10 kilometers (km) west of Hope, BC on the northern slopes of the North Cascade Mountains (Figure 1). Hunter Creek is a 4th order stream with a length of 11.4 km, a watershed area of 43 km2, and an elevation range of 30 meters (m) at the Fraser River to 1,900 m ASL at Mount Barr. The mid- and upper portions of the Hunter Creek watershed are a V-shape hanging valley located above the extended floodplain of the Fraser River, with the delineating elevation increase (100 m rise over 279 m distance) starting approximately 0.8 km upstream from the Fraser River in the form of a 100 m tall cascade-falls complex that poses a complete barrier to upstream fish passage. Hunter Creek splits into the West Branch and East Branch at 3.6 km upstream from the Fraser River; both branches are 3rd order streams.

The Project consists of a main headworks (intake, weir, and headpond) on the East Branch of Hunter Creek (main intake), secondary headworks on the West Branch (secondary intake), two water conveyance systems (main and secondary penstocks), and a main powerhouse with a turbine-generator (Figure 2). A 1.6-km, 25-kiloVolt (kV) transmission line that interconnects with an existing BC Hydro transmission line.

Occupied mountain beaver habitat was located primarily near the secondary intake; this area was the focus of the habitat compensation works.

Figure 2. Project ROW General Arrangement

Mountain Beaver Biology

The mountain beaver (*Aplodontia rufa*) is the only member of the family Aplodontiidae and possesses some of the most primitive anatomical and morphological characteristics of any living rodent worldwide (McGrew 1941; Hall 1973; Banfield 1974). There were two recognized subspecies in Canada (Hall 1973; Banfield 1974): *A. r. rufa* (Rafinesque 1817), located south of the Fraser River, and *A. r. rainieri* (Merriam 1899), located east of the Fraser River. However, recent DNA analyses across the species' range (n=383 samples, 16 from BC) indicated that mountain beaver in Washington and BC are one subspecies (Ransome unpub. data; Piaggio et al. 2013), and that there is no genetic basis for retaining the subspecies *A. r. rainieri*. Therefore, all samples from BC represent *A. r. rufa*. (Note: the current subspecies classification (*A. r. rufa*) has reverted to *A. r. olympica*, reflecting a prior classification suggested by Merriam (1899) (Piaggio pers. comm. 2010).

In Canada, mountain beavers are found in southwestern BC (Gyug 2000; Nagorsen 2005). The Canadian range exists as five populations, four of these as isolated populations (Figure 3). Two isolated populations are at the west edge of their range on Chilliwack (four km2) and Sumas (64 km2) mountains in the lower Fraser Valley. Two isolated populations are on the eastern edge of their range on Pike (128 km2) and Missezula (44 km2) mountains on the eastern side of the Cascade Mountains. Mountain beavers are also found throughout the mountains between these isolated populations (7,800 km2). Extensive surveys on the west side of the range since 1999 did not record mountain beavers north or west of the Fraser River (Ransome 2003; Keystone Wildlife Research, unpub. data).

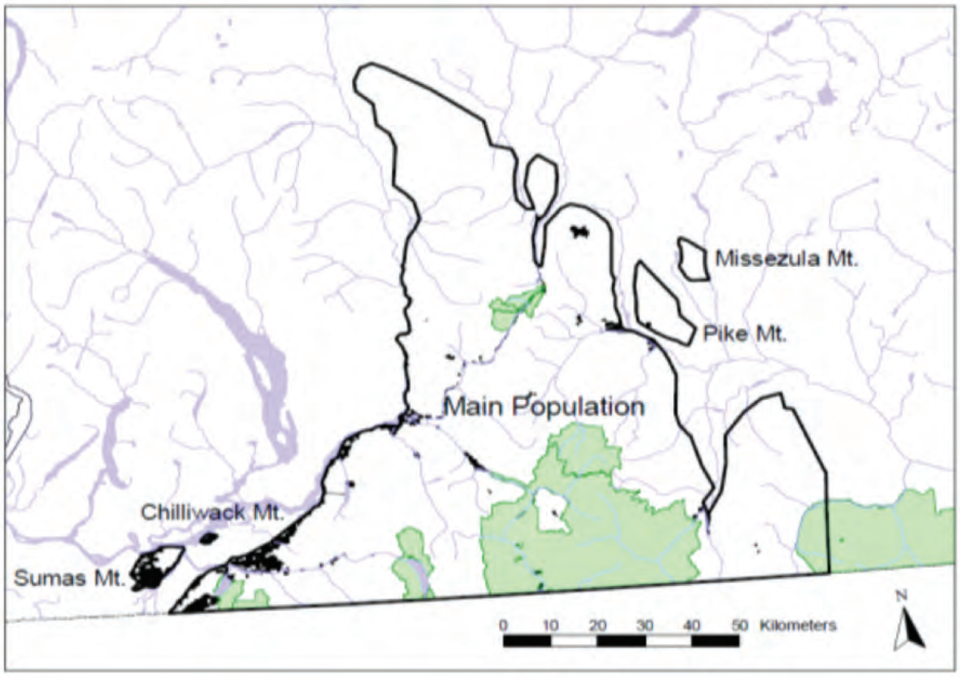

Figure 3. Mountain beaver (*Aplodontia rufa*) populations in Canada showing the main population and four isolated populations (Sumas, Chilliwack, Pike, and Missezula). Provincial parks are shown in green and the solid black lines indicate area of occupancy (from COSEWIC 2012).

Areas with high densities of mountain beavers are loosely referred to as colonies, but are recognized as being aggregations of solitary individuals (or an adult female with kits). These aggregations occur in high-quality habitat with inter-den spacing of at least 20 m maintained by territorial interactions (Martin 1971). Adults live alone in underground dens and are aggressive toward each other (Nolte et al. 1993).

Mountain beavers typically occur near streams or smaller drainages (i.e., seepage sites) because of their physical requirements for a cool thermal regime, abundant moisture, and adequate soil drainage (Beier 1989). They need soils that allow tunnel, runway, and burrow construction, a cool and moist microclimate, and suitable food within 50 m of the den (Martin 1971; Carraway and Verts 1993). Subsurface drainage that keeps most tunnels and burrows wet, even to the point of having water trickling through them, appears ideal (Beier 1989; Carraway and Verts 1993; Gyug 2000). While runways and tunnels may be quite wet, underground den sites must be dry and above the water table. Deep soils appear to be a prerequisite to establish dens and tunnel systems (Camp 1918).

Mountain beavers occur in forests of any age, but appear to prefer early to mid-seral stages where herbaceous food is abundant (Neal and Borrecco 1981; Carraway and Verts 1993). Within older seral stages, an important feature is the presence of permanent openings associated with streams and seepage zones (Gyug 2000). In forested portions of the lower Fraser Valley, mountain beavers commonly occur at sites ranging in age from recent clear-cuts to 20-year-old sites with either moist seepage areas or areas dominated by lush vegetation (Ransome unpub. data). Coastal populations (west of Hope, BC, previously identified as A. r. rufa) may attain peak densities in areas of early to mid-seral stages vegetated by young (i.e., <20-year-old) trees, shrubs, and forbs (Scheffer 1929; Dice 1932; Svihla and Svihla 1933; Hooven 1973, 1977).

Dens have been located immediately adjacent to seepage areas on lower slopes or alluvial fans where parent materials originated from moraines, but not in valleys of large streams or rivers with well-developed gravel or cobble floodplains dominated by coarse glacio-fluvial parent materials (e.g., the Skagit Valley of BC) (Gyug 2000, 2005). Mountain beavers tend to occur on smaller streams at higher elevations rather than in more flood-prone, higher order, lower elevation streams (Beier 1989; Gyug 2000). Dens have been found at elevations from sea level to 1,925 m (Gyug 2000; Ransome unpub. data), and on slopes up to 73 percent (Gyug 2000).

Mountain beavers eat a range of herbaceous and shrubby plant species. The shoots and cambium of shrubs and trees may be eaten in any season (Verts and Carraway 1998). A wide variety of herbaceous plant material is stored as “haypiles” in front of burrows (Gyug 2000). This “hay” is left above ground until wilted, possibly to decrease how quickly it will rot once the material is moved into burrows for storage and consumption (Voth 1968; Karban et al. 2007). Mountain beaver are prey for a number of predators, including hawks, owls, mustelids, bobcats (*Felis rufus*), and coyotes (*Canis latrans*) (Carraway and Verts 1993; Arjo et al. 2007).

OFF-SETTING APPROACH

The objective of the offsetting was to reduce the effects of identified residual effects on mountain beaver burrowing and foraging habitat. Mountain beaver were considered a good candidate species for habitat offsetting at Hunter Creek because: a) active burrows had been identified within the Project footprint; b) Hunter Creek has abundant riparian areas that are within a young forest structural stage dominated by closed-single-canopy (CSC) stands with poorly-developed understory; c) restoration of riparian CSC stands is seen as a viable and effective means of increasing habitat quality for mountain beaver; and d) habitat restoration within these stands is likely to benefit other species with a riparian association.

In the EA for the Project, mountain beaver colonies were found to be distributed through much of the wildlife local study area (LSA–the Project footprint plus a 500 m buffer) above 300-m elevation including the project footprint (Princeton Energy Inc. 2015). The highest density of mountain beaver colonies was encountered in the area around the proposed secondary headworks and the upper secondary penstock.

The Hunter Creek watershed is dominated by stands in the Young Forest structure class (approximately 41–80 years old); they comprised 66 percent of the wildlife LSA. Stands tend to have a relatively uniform cover of Young Forest (Photo 1a) with dense canopies (Photo 1b), poor understory growth (Photo 1c), and poor light penetration (Photo 1d).

Thinning of closed single-canopy stands is a common tool used to stimulate understory development by increasing light penetration to the forest floor (Thomas et al. 1999; Wilson and Puettmann 2007; Ares et al. 2010). Increased growth and biodiversity of forest understory is often the objective of these treatments, but prescriptions must be designed well to avoid unintended consequences such as the proliferation of non-native species (Franklin et al. 2002) or negative effects on the growth of tall shrubs (Chan et al. 2006). Selecting sites without non-native species and low cover of tall shrubs can help to avoid these effects.

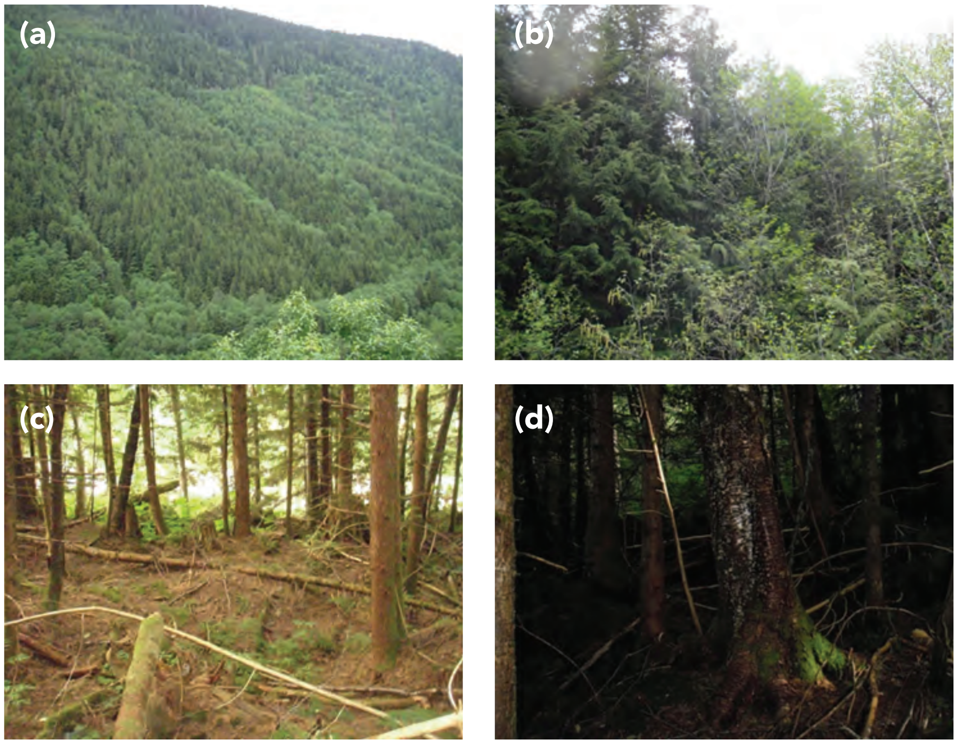

Figure 4. Representative photos of Young Forest structure within Hunter Creek

The Young Forest stands within the vicinity of the secondary headworks were estimated to have a stem density of 600 stems per ha (sph). Western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*) were the dominant tree species. The dominant tree layer was approximately 30 m tall with diameters at breast height (dbh) of 30–50 centimeters (cm). Crown closure was 75–90 percent. The understory was poorly developed, with regenerating western hemlock and abundant moss cover, but few herbs or shrubs.

Within the Hunter Creek watershed, active burrows were generally found within areas with well-developed understories, while burrows observed within dense Young Forest stands typically appeared to be inactive. A well-designed stand thinning and understory herb and shrub layer planting treatment was expected to re-create suitable foraging habitat for mountain beaver.

Location

The recommended location for habitat offsetting was within riparian areas adjacent to the proposed secondary headworks location. Forest structure in this area was primarily Young Forest (40–80 years old) and had a high canopy closure (generally ≥80 percent) and low herb and shrub cover (≤5 percent) (Figure 5). The majority of the area was within close vicinity to water and soils were deep and relatively fine grained. Interpretation of site conditions suggested that it was poor mountain beaver habitat, primarily due to the poor understory development, but that it should respond well to reclamation measures. The proximity of this area to the project footprint also facilitated access and tree removal while minimizing new disturbance.

Design

The thinning prescription was designed to achieve two objectives: stimulate the development of an herb and shrub understory layer and contribute downed wood resources for amphibians and small mammals. This was achieved by: a) reducing stand density from approximately 600 to 200 sph; b) removal of approximately 2/3 of felled trees; c) removal of regenerating coniferous trees in the understory where necessary to reduce competition with the herb and shrub layer (although some regenerating conifers were maintained in the understory as an overwintering food source for mountain beaver); d) planting of preferred mountain beaver browse species, including native ferns and shrubs at a density of approximately 600 sph; and e) placing remaining felled trees in both clumped and dispersed configurations to provide habitat attributes for amphibians and small mammals.

Specific harvesting techniques, tree and infill planting species, downed wood placement measures, and other necessary measures were clearly identified in a detailed design and implementation plan prior to any of the associated work taking place. A key priority was to develop practicable harvesting techniques/plans in order to minimize soil compaction within the restoration areas. This included restricting access of machinery to limited areas, directional falling, and—where possible—removal (yarding) of trees from roadside. As with any forest harvest operation, there were many constraints (terrain, safety, etc.) that had to be considered in finalizing the harvest plan.

According to this design, the measures described here will restore approximately 1.14 ha of riparian habitat for mountain beaver and other riparian species. This represented an overall ratio of offsetting to impact of 2.7:1.

Figure 5. Typical conditions in restoration area showing poor understory development

Construction Mitigation Measures

The mitigation measures prescribed for construction of the Project were also followed for the habitat offsetting works, thereby avoiding potential adverse impacts to other wildlife and wildlife habitat.

The offset areas were surveyed for active mountain beaver burrows (nest sites with stored food). One such site was documented. This location was mapped and the area was placed into a retention patch to avoid disturbance. It was maintained as a machine-free zone and all trees were felled away from the retention patch.

The final pre-construction site design was surveyed by Chartwell Consultants, Ltd. The cruise plots were completed to provide a distribution of tree sizes in the restoration area. Based on these results, it was estimated that retaining all trees 20 cm dbh or less (outside of all retention patches) should result in a density of approximately 100 sph. The site plan was further refined at this time to include general and site-specific measures primarily focused at minimizing soil compaction and damage to retained vegetation.

CONSTRUCTION OF HABITAT

Harvest operations commenced in late-September 2017, but most of the felling occurred within a two-day period on November 20-21, 2017. Though conditions were wet (combination of snow/rain), the ground was partially frozen and anticipated to be suitable for harvest activities

A rise in temperatures combined with rain on snow leading up to the early morning hours of November 23 resulted in a significant peak flow event on Hunter Creek estimated to have a return period of >200 years. Total precipitation at the Hope Airport weather station was 80.8 millimeters (mm) on November 23 and the temperature was 12.2˚Celsius (C) (Environment Canada 2018). This event caused a major shift of the Hunter Creek stream channel towards the right bank and major erosion to a portion of the restoration area. Roads and bridges were also washed out, preventing access to the restoration area for three months.

Harvesting of the remaining logs in the restoration site continued in February 2018 and was completed on February 26. The restoration site was

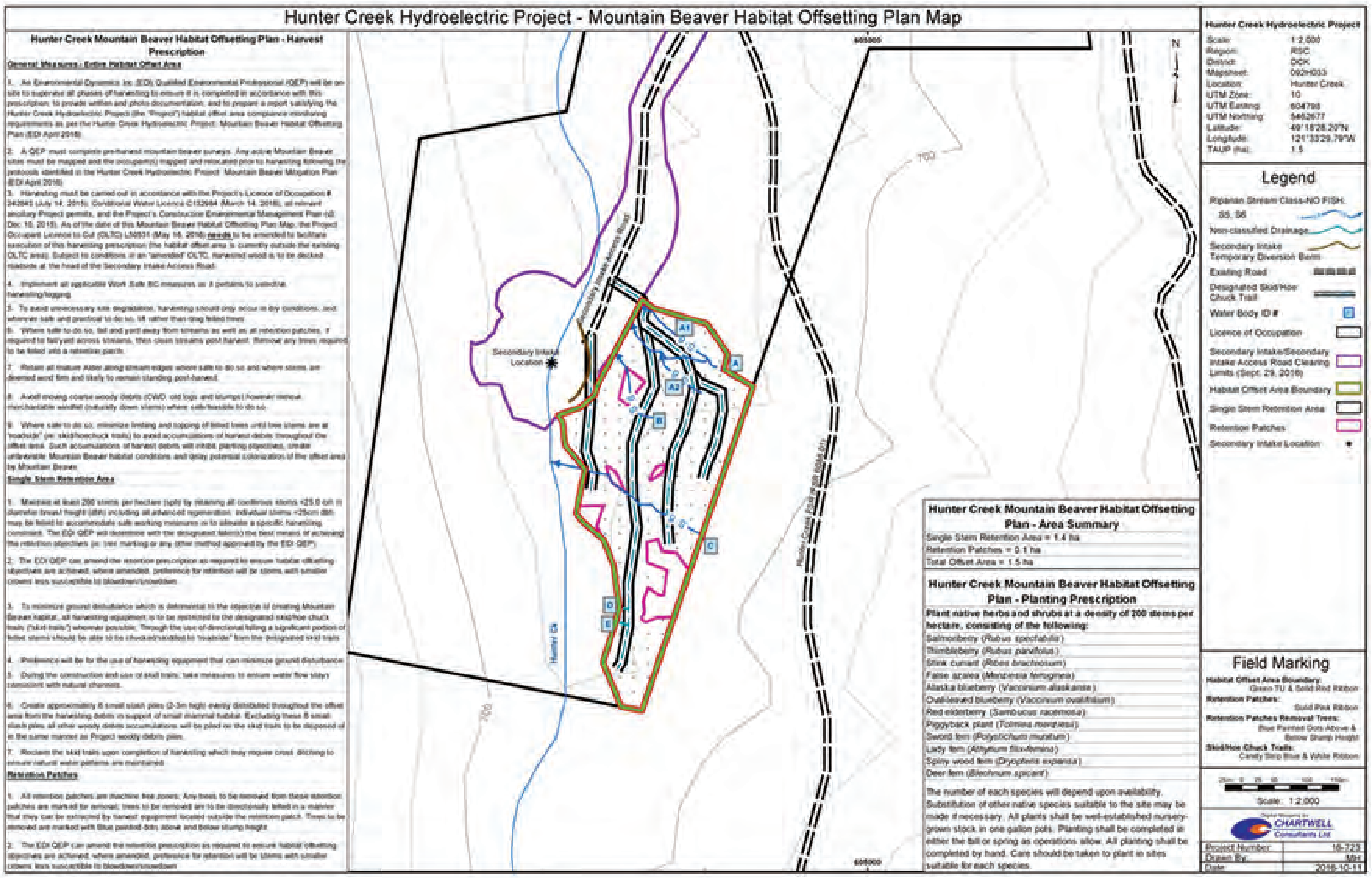

Figure 6. Pre-Construction Compensation Plan

assessed for damage from the November 23, 2017 flood event on February 19, 2018. Substantial erosion and deposition occurred in Hunter Creek, which jumped its banks and created a new channel adjacent to the restoration area above the secondary headworks and extending to immediately below the intake weir. The new channel caused substantial erosion on the southwest boundary of the restoration area (Figure 7, 8, 10). Previously, this boundary was located on top of a gentle slope leading down to riparian forest adjacent to Hunter Creek. A strip of trees had been left to provide bank stability and maintain forest structure. The flood event undermined this slope, causing all trees along the southwestern boundary, as well as some logs felled within the restoration area, to fall into the stream. The newly formed bank was 2–4 m tall with a slope of about 70 degrees. The top of the bank was up to approximately seven m inside the original restoration area boundary (Figure 7, 8, 10); thus, resulting in a small decrease in total area for the restoration site.

Weather was cold during project works in February, ranging from -2.0 to -11°C. A persistent layer of snow at least one m deep complicated retrieval of logs as all trees marked for removal from the restoration area were felled in the fall prior to the November 23, 2017 flood event, and any substantial snowfall. However, the snowpack combined with frozen ground conditions provided some protection to the ground surface during hoe-chucking. Log retrieval required sweeping through the snow with the excavator's grapple head because logs were not always visible. Log retrieval was closely monitored to ensure all areas were searched and to minimize any site disturbance while sweeping for logs. All areas were inspected on foot to search for logs that may have been missed with the excavator.

Planting of native plants and hand-cleaning woody debris from streams that were unable to be detected during winter harvest operations was conducted in May 2018. Wood debris remaining from falling and hoe-chucking operations was higher than intended, but not atypical for a conventional logging operation. Log recovery from hoe-chucking in snow conditions was better than anticipated, with only a handful of missed logs spread in the entire restoration area. Retention patches were intact and showed little-to-no apparent impact from falling and adjacent hoe-chucking activities. As anticipated, several retention trees were scarred from tree falling and hoe-chucking, but this was not a concern a general objective of the project was to create wildlife habitat.

The planting of the restoration area was planned for mid-May. This was anticipated to provide the best conditions following snowmelt, but prior to the onset of hot summer weather; however, May weather was relatively warm and dry compared to historical averages. The daily average temperature in May at the Hope Slide Weather Station from 1971 to 2000 was 9.1°C and average precipitation was 72.9 mm (Environment Canada 2018). In comparison, the average temperature for May 2018 was 13.3°C and total precipitation for the month was 8.4 mm.

Hot, dry weather was encountered during planting; temperatures for the month were 4.2°C warmer than average and total rainfall was about 12 percent of the average from 1971 to 2000. An informal survival survey on May 30 indicated that most plants were responding well to planting and mortality was low.

Figure 7. Erosion Caused by November 23, 2017 Flood That Created A New Channel and Undermined a Portion of the Compensation Habitat, As Seen On February 19, 2018

Figure 8. View of erosion caused by November 23, 2017 flood as seen on May 17, 2018

MONITORING PROGRAMS

A summary of compliance and effectiveness monitoring measures developed for the habitat compensation works is presented in Table 2. All compliance monitoring has been completed. Effectiveness monitoring will be implemented biennially between 2019 and 2023 with a final report completed in 2023.

CONCLUSIONS

Implementation of mitigation measures to compensate for residual effects to mountain beaver as a result of the construction of the Project was largely successful.

The objectives of the habitat compensation works were mostly met, but weather and operational challenges caused some difficulties. A >1-in-200-year flood in November 2017 created a three-month delay to compensation works and caused substantial erosion to a portion of the compensation habitat. Deep snow in February 2018 complicated removal of logs and caused greater-than-expected breakage of log tops and branches, resulting in the accumulation of substantial debris. Hot, dry weather during planting in May 2018 hindered establishment of plants planted in the compensation habitat and caused some mortality. Flexibility in approach allowed for adaptation to these issues so that project objectives could largely be met. Ongoing monitoring will help to measure the effectiveness of this methodology to create compensation habitat for mountain beaver.

Figure 9. Panorama of compensation habitat as seen on February 23, 2018

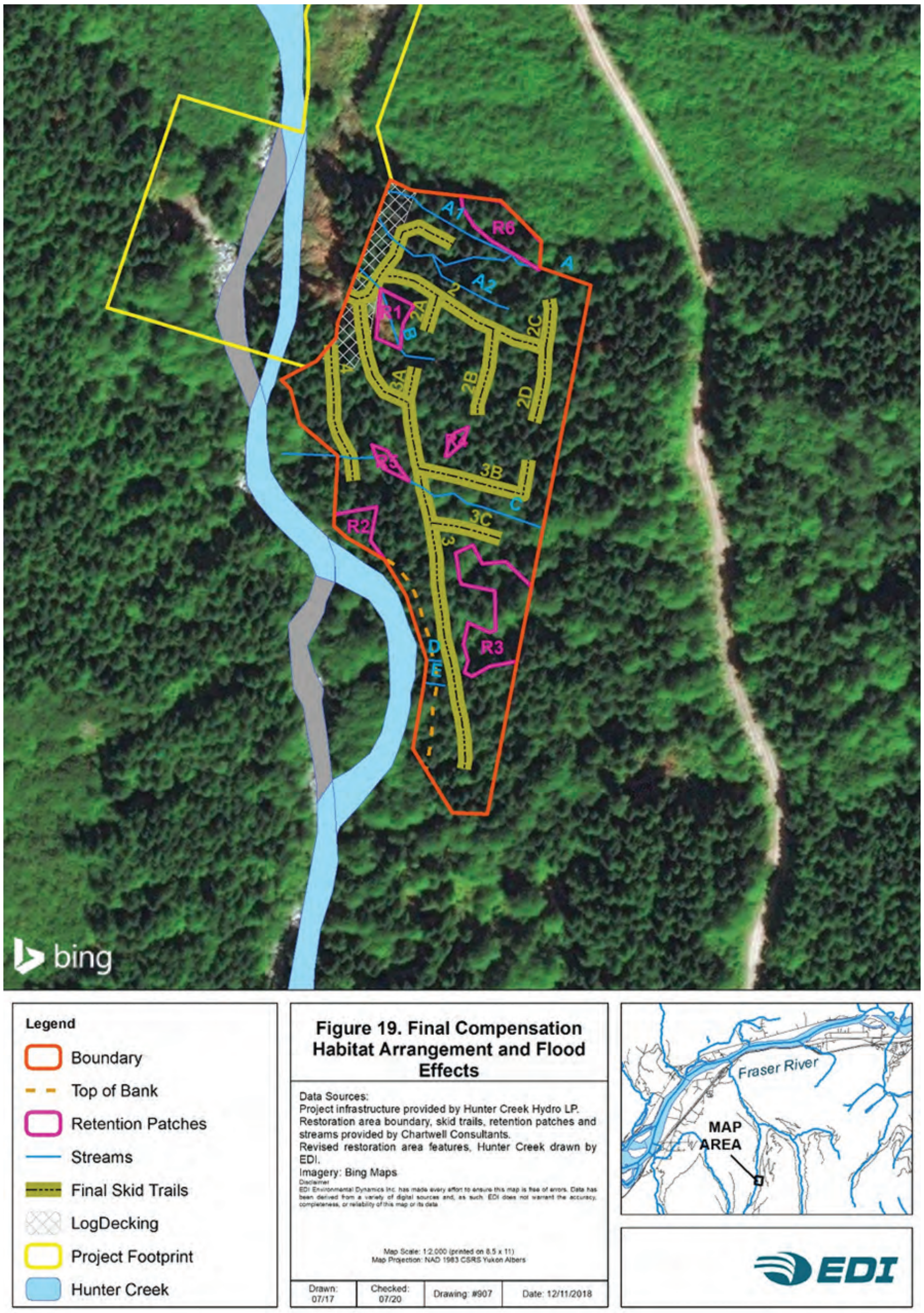

Figure 10. Final Compensation Habitat Arrangement and Flood Effects

Type	Offsetting Measure	Monitoring Question	Methodology	Timelines	Reporting	Completeness
Compliance	Stand Thinning	Was the work completed as authorized? Was the target density achieved?	Supervision by a QEP	Within 3 months post Project construction	Within 6 months post Project construction	Completed
	Downed Wood Placement	Was the work completed as authorized?	Supervision by a QEP	Within 3 months post Project construction	Within 6 months post Project construction	Completed
	Infill Planting	Was the target density achieved?	Supervision by a QEP	Within 3 months post Project construction	Within 6 months post Project construction	Completed
Effectiveness	Infill Planting	Is a minimum of 80% survival achieved?	Field plots to estimate survival of infill planting.	Years 1, 3, and 5 post completion of offsetting works	Annual progress reporting. Final report after year 5.	To be completed in 2019, 2021 and 2023.
	Habitat Enhancement	Are habitat restoration efforts responding as predicted? Has understory cover increased from prior to completion of works?	Qualitative assessment of understory development. Field plots to measure percent cover of understory herbs and shrubs.	Years 1, 3, and 5 post completion of offsetting works	Annual progress reporting. Final report after year 5.	To be completed in 2019, 2021 and 2023.

Table 1. Summary of the compliance and effectiveness monitoring proposed for the Hunter Creek Hydroelectric Project Habitat Offsetting plan

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AUTHOR PROFILE

Andy Smith

Andy Smith is a Senior Biologist with 23 years of experience in effects assessment, ecosystem interpretation, species at risk, and natural resource management. He has extensive experience leading and managing the terrestrial component of small to very large projects, including species occurrence and abundance, habitat assessment, Terrestrial Ecosystem Mapping, and wildlife habitat suitability modeling for numerous terrestrial species at risk. His broad range of experience also includes work on rare plants, forest ecology, and listed ecological communities. The bulk of Smith's work focuses on mitigating the effects of ROW development associated with run-of-river hydropower projects, transmission lines, and pipelines. Most recently, Smith was the vegetation and wetlands discipline lead for a 750-km long linear development project that included an assessment, mitigation, and management plans for potential effects to vegetation, ecological communities, wetlands, and wetland function.

Observations of White-Tailed Deer (*Odocoileus virginianus*) Crossing A Powerline ROW in the Winter: On the Issue of Habitat Fragmentation

G. Jean Doucet and
E. R. Thompson

In Quebec, wintering yards remain an important sensitive seasonal habitat for white-tailed deer (*Odocoileus virginianus*). The routing of a powerline right-of-way (ROW) in such yards often raises the issue of the ROW becoming a barrier leading to habitat fragmentation and possible isolation of local populations. We took advantage of an artificial feeding station located in the Rigaud deer yard to set up an in-field experimental design to address the deer-crossing issue. The objectives of the paper are two-fold: (1) it presents evidence that deer would readily cross the ROW if an attractor—in this case an artificial food source—was located across from another resource, namely cover provided by a cedar stand, and (2) take advantage of an in-field experimental design framework to obtain data to address the ROW deer-crossing question. We documented 1,208 white-tailed deer crossing a 30-meter (m), 120 kV powerline transmission ROW in winter throughout a seven-year period. Deer crossed under all conditions, including deep snow and strong winds. The overall average crossing time was 96.5 seconds (74.8–150.9 seconds). The winter with the least amount of browse (1999) presented the lowest average (74.8 seconds) per crossing for the winter. The data indicate that the ROW does not present a barrier to deer crossing in winter. Deer lingered longer in the ROW when horizontal cover and browse was higher. Since most powerline ROWs can be managed or operated at 30 m wide, these data put to rest the question that ROWs can become a barrier to white-tailed deer in winter yards.

Keywords: Experimental Design (in-field), Habitat Fragmentation, Powerline, Quebec, ROW, Snow, White-Tailed Deer, Winter Yard.

Environmental Concerns in Rights-of-Way Management
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INTRODUCTION

In southern Québec—except for some areas south of the St. Lawrence River and in recent years—the majority of white-tailed deer (Odocoileus virginianus) migrate to traditional habitats called winter yards to spend the winter. These deer yards provide habitat conditions of cover and browse and protection against cold temperatures, wind, and snow. Some yards harbor several thousand deer, but many contain a few hundred. In Quebec, deer yards are sensitive habitats protected by law on public lands, although not protected by law on private land, landowners are encouraged to protect cover stands in yards on their lands.

Deer yards are usually avoided in the planning of new powerline ROW routes. When no alternative exists, however, ROWs end up bisecting deer winter yards. In such cases, environmental impact analyses must address the issue of possible habitat fragmentation of sensitive habitats. The major preoccupation lies in the fact that ROWs could create a barrier effect, thus, isolating habitat patches during the winter if deer refuse to cross a given ROW. With time, mitigation measures have been put in place (Doucet et al., 1997), sometimes in a speculative manner to facilitate ROW crossing by deer. From the wildlife point of view, a pivotal question is what makes deer cross or refuse to cross a ROW. We assume that an attractor must be present on the other side, for instance to cover food, in order to encourage a deer to cross.

STUDY AREA

The deer yard under study is located on the Rigaud Mountain, approximately 100 km west of Montreal, QC, and covers an area of approximately 25 km2. Biologists responsible for the management of the Rigaud yard estimated the deer population at approximately 150 animals. The forest habitat near the ROW is characterized by deciduous or mixed stands interspersed with small islands of hemlock (Tsuga canadensis) and Balsam fir (Abies balsamea). The following lists the other species present in this area:

- Hawthorn (*Crataegus spp.*)
- Sumac (*Rhus typhina*)
- Red-osier dogwood (*Cornus stolonifera*)
- Trembling aspen (*Populus tremuloides*)
- Balsam poplar (*Populus balsamifera*)
- American elm (*Ulmus americana*)
- Ashes (*Fraxinus spp.*)
- Choke-cherry (*Prunus virginiana*)
- Sugar maple (*Acer saccharum*)
- Red maple (*Acer rubrum*)
- Willows (*Salix spp.*)

The forest stands attractive for deer in the Rigaud yard are those provided by white cedars (*Thuja occidentalis*)—an excellent cover for wintering deer in the northeast. The section of the 120 kV ROW studied was 30 meters (m) wide and approximately 1 km long, located on a gentle south-facing slope. It is noteworthy to mention that during the ice storm of January 1998, the 120 kV line collapsed and reconstruction took place in the summer 1998 (Doucet and Thompson 2002).

OBJECTIVES

A primary objection raised when a ROW route is considered through a yard is the barrier effect. In other words, the postulate that deer will not cross the ROW (or cross much less frequently) and, thus, some winter habitat will remain unused or less used. From the habitat fragmentation perspective, the impact would be greatest if food became isolated from cover. Our objective was two-fold: (1) to document that deer will readily cross a 30-meter wide ROW in a deer yard in winter under a variety of winter conditions, and (2) determine if we could achieve that by means of a simple in-field experimental design. Our hypothesis stated that white-tailed deer would readily cross a 30-meter wide powerline ROW in winter if a sufficient attractor, such as a food patch, was

Figure 1. The ROW Study Area in the Rigaud Deer Yard (120 kV)

located on the other side from an area of cover.

METHODS

Throughout the years, several ROW deer studies were conducted in the Rigaud yard (e.g., Doucet et al., 79, Brown and Doucet, 1991; Doucet and Brown 2002; Vickery et al. 2011). During those studies, we often observed deer crossing the ROW at dusk in a westerly direction headed for an artificial feeding station. This created an ideal situation to document deer crossing the ROW under various winter conditions. From a methods point of view, it is often difficult to set up a dependable experimental design in ROWs, mainly from a width to linearity perspective (Tripp 2016). Of note is the difficulty to obtain good data to test hypotheses or answer questions. The set-up to collect data was provided by a landowner/innkeeper who has been feeding deer in the winter at the same site for more than 15 years. The feeding site is approximately 500 meters to the west of the 30-meter wide 120 kV powerline ROW under study. The feeding site consisted of two to four troughs filled every day with special ungulate feed mix purchased at the local farm coop. In winter, the feeding site represented a strong attractor for deer to cross the ROW from two cedar stands located on its east side.

During the period 1996–2003, we observed from distant vantage points for seven winters, which represented a complete vegetation control cycle in the ROW. In addition, the line fell and was rebuilt following the January 1998 ice storm, thus, no data exists for the 1998 winter (Doucet and Thompson 2002). To observe deer, we stood behind trees, power poles, or snowbanks, mainly at dusk as deer crossed the ROW and headed for the feeding troughs located near the inn. We recorded when and where deer crossed, and recorded the direction and exact times. At the same time, we recorded any other observations of interest or relevance, for instance, if a deer did some browsing as it crossed the ROW or if a doe was accompanied by its young. Individual deer which seemed to act oddly, such as disturbances by snowmobiles or other spoofed animals, were excluded from the sample. The length of the ROW sampled was about 1 km long.

RESULTS & DISCUSSION

From 1996 to 2003, we observed a total of 1,208 deer crossing the 30-meter wide ROW in the Rigaud deer yard in winter. Crossing sites were not distributed evenly in the ROW. The majority of deer crossed in runways rather than make their own path through the snow. This was especially true when the snow was deep, for instance after a storm. Runways were reused within 24 hours after a snow storm. Some runways were established at the same sites, year after year. Doucet and Brown (1987, 2002) showed that there was more activity in the ROW when cedar stands occupied at least one side than when deciduous stands occupied both sides of the ROW. For example, a preferred site to cross was between poles 1133–39 and 1133–41(approximately 200-m long). This

Figure 2. Deer trails across the 120 kV Row

Figure 3. Single Deer Crossing the kV ROW

Figure 4. Deer crossing and browsing in the 30-m 120 kV ROW

span cuts through a cedar stand and was closest to the feeding troughs, which were approximately 500 m away. Most of the activity observed across the ROW occurred at dusk, when most deer were travelling in a westward direction toward the feeding site. No data were obtained in 1998 because the line was being rebuilt following a major ice storm.

The average (mean) time taken by a deer to cross the ROW was 96.5 seconds and the yearly averages for the seven winters ranged from 150.9–74.8 seconds (Table 1). Several factors can be invoked to explain these differences. During the winter seasons, snow conditions, temperature, and wind varied on a daily basis, and some winters were harsher than others. Finally, browse and cover availability differed from year to year due to the vegetation control cycle in the ROW. The fastest crossings lasted five seconds or less, and those were likely deer in flight, which jumped all the way across the ROW without changing gait or stopping. The fastest crossing by a deer that did not appear pursued was less than 20 seconds and did not involve browsing or stopping (alert stance). The longest crossing was 42 minutes, in which the deer did a lot of browsing in a small area in late winter of 2003 when the snow cover was disappearing. However, this animal was not included in the data base.

We find it more useful to present the data as categories of crossings, as it reveals more information about interactions between deer and the ROW in relation to the food source to the west of the ROW. A total of 96 (7.95%) deer crossed in less than 30 seconds or less (Table 2), which means traveling roughly at one m per second. Thus, those deer had to jump at least in part during the crossing. A trotting gait, including perhaps a short stop, all the way across could be done also within 30 seconds.

The largest number of deer (494: 40.89%) crossed between 31 and 60 seconds. Typically, such crossing meant walking through in an established runway, sometimes making one or two short stops (not to browse) on the way across. The longer the crossing time, the higher the probability that browsing occurred. Many deer crossed in 50–60 seconds, stopped but no browsing occurred. A total of 266 (22.02%) deer crossed in 61–90 seconds, which usually included short stops with short amounts of browsing if it occurred (Table 2). A total of 130 (10.76%) deer crossed in 91–120 seconds, and most deer made a definite stop in the ROW. A total of 59 (4.88%) deer crossed in 121–150 seconds; all of them stopped for a while possibly for browsing. A total of 67 (5.55%) deer crossed in 151–180 seconds. The almost three-minute crossing meant that all these deer had to have stopped while crossing. The longer the crossing time, the higher probability that some browsing occurred; usually a longer than three-minute crossing involved some browsing. Only 22 (1,82%) deer crossed in 181–210 seconds. Practically all deer which crossed from 211 seconds to more than 480 seconds did some browsing. Finally, 24 (1.99%) deer took more than 480 seconds to cross the ROW (Table 2), browsed, and seemed to lose interest for a while about the feeders.Most deer crossed the ROW with a specific purpose, to reach an artificial feeding site located on the other side. Thus, if the attraction is sufficient, deer will cross.

Year	Number of Deer n/year	Number of Seconds to Cross
1996	53	93.5
1997	91	128
1998	0	0
1999	201	74.8
2000	140	150.9
2001	174	92.4
2002	27	133
2003	522	84.5
Total	1,208	96.5

Table 1. Number of deer and annual average time taken to cross the ROW

Seconds	Number of Deer	%
0–30	96	7.95
31–60	494	40.89
61–90	266	22.02
91–120	130	10.76
121–150	59	4.88
151–180	67	5.55
181–210	22	1.82
211–240	8	0.66
241–270	10	0.83
271–300	8	0.66
301–330	2	0.17
331–360	7	0.58
361–390	4	0.33
391–420	3	0.25
421–450	4	0.33
451–480	4	0.33
481+	24	1.99

Table 2. Time categories and overall deer crossings during seven winters

CONCLUSION & MANAGEMENT IMPLICATIONS

We showed that it was possible to take advantage of local features to set up an in-field experimental design to obtain good data on deer activity in relation to ROW crossing and habitat fragmentation. Our data provide evidence that deer will readily cross a 30-m wide powerline ROW in winter under all snow conditions observed during the study (snow depth 20 cm to >1m). Most deer crossed the ROW with a specific purpose, to reach an artificial feeding site located on the other side. We consider the feeding station to be a significant attractor for the deer studied. Thus, a 30-m wide ROW does not represent a barrier to deer movement in winter. Most powerline ROWs (e.g., 735 kV) can be managed to a 30-m wide corridor for a short distance (e.g., in deer yards). This enables construction and operation of lines while keeping significant cover. There is no barrier effect and habitat isolation from the ROW.

We conclude that it is possible to manage a ROW at 30-m wide to address the fragmentation issue related to deer and probably most other large ungulates. It is noteworthy, that from a technical perspective in the boreal forest, the 30-m width option may not be available because of the wildfire concerns (Alex Beauchemin, pers. comm). A vegetation management approach towards optimal browse production in ROWs could be an added benefit for deer in yards in winter.

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Plant Biodiversity Dynamics in IVM-Converted ROW Areas and Population Dynamics of Pollinators and Other Invertebrates in ROW Areas Managed by VM and IVM Tactics

Anand B. Persad, Rebekah Sara Hall, and Anna De Toro

This study describes soil biological activity, plant diversity, and invertebrate fauna dynamics in areas along rights-of-way (ROW) managed using exclusively mowing and mechanical cutting tactics in plant management (vegetation management, VM) and integrated tactics (integrated VM, IVM) that incorporate selected herbicides as needed in undesirable plant management. The study explores the natural shift in plants and associated fauna when converting from VM to IVM. These biological parameters were investigated in utility transmission and distribution (T&D) corridors in the eastern U.S. in spring 2017 through early summer 2018. Plant diversity was higher in recently converted ROWs, compared to ROWs that were maintained for a period of seven or more years and ROWs that were managed using VM strategies alone. Soil biological activity (SBA) was similar in the areas managed by IVM versus VM. Diversity of ground-dwelling and above-ground invertebrates (including some pollinator species) was higher in IVM-managed ROWs. In ROWs that were recently converted to IVM (within the last three years), the invertebrate population of soil-dwellings was lower; however, above-ground invertebrate populations were similar. Hymenopteran-specific surveys revealed that converted and recently converted ROWs had higher bee populations compared to VM-managed ROWs, while ant populations were higher in VM-managed ROWs compared to those managed by IVM.

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INTRODUCTION

Trees, and vegetation in general, are often synonymous with rights-of-way (ROW) and utility corridors; to effectively manage ROWs sustainably—while keeping utility assets clear and providing safe worker access—prudent plant management becomes routine. While vegetation management (VM) strategies are straightforward and focus on the primary objectives of safety, reliability, access, and sight distance, these may still provide management challenges. Secondary objectives such as biodiversity, aesthetics, wildlife refuge, and invasive plant management do feature as integral targets, but may more often enjoy a wider audience in terms of community perspective, greenspace responsibility, and environmental stewardship.

Wildlife value, along with the added aspect of foraging and overwintering by pollinators on ROW vegetation and adjacent areas, are now an ever-increasing responsibility to our VM teams. With the uptick in pollinator welfare, public concern has transcended into our utility corridors and as we continue to enhance our VM strategies (Mader et al. 2011), the incorporation of pollinator health in our ROW VM policies is now becoming more focal. While the pollinator value of each of these methodologies either separately or integrated may be hard to quantify (O'Toole 1999; Vaughan 2006), the fact that we often have populations of various pollinators in and around our ROWs may mean that we are moving in the right direction. The rise of secondary objectives to greater prominence in utility VM (UVM) provides an opportunity for us to reboot our overall assessment of utility trees and vegetation as a resource worthy of management for generations to come. This study investigates biological parameters, including soil biological activity (SBA), plant diversity and soil, and above-ground dwelling invertebrates in ROWs managed by mowing and mechanical cutting alone (VM), recently converted ROWs from VM to IVM, and ROWs that were managed by IVM strategies for at least seven years.

METHODS

This study evaluated SBA, plant diversity, invertebrate populations in soil, and above ground, foliage feeding, and incidental organisms that were present. Various techniques were employed at utility ROW corridors in the eastern U.S.

Transect lines are straight lines (may be segmented if access is obstructed) that span a length of 100 meters at random sites to estimate flora and invertebrate fauna within a one-meter swath of the line center. Transect lines were established in VM, recently converted from VM to IVM, and IVM-managed ROW areas in Pennsylvania and Maryland. Transects lines were marked using towers and/or poles as markers and were backed up with soil and ground-level flagging, which was renewed as needed. Ten (10) 1m2 quadrants were installed every 10 meters on each transect line. The transect lines represented the areas that were sampled for SBA, plants, and invertebrates.

Soil samples were collected from three quadrants on each transect for processing and analysis.

The Solvita Respiration test is a measure of the carbon dioxide (CO^2) in the soil. CO^2 is produced from biological or microbial activity (the activity of living organisms in the soil). High microbial activity results in a high Solvita test number as a sign of good soil health. Low microbial activity results in a low Solvita test number as an indicator of poor soil health. The Solvita analysis was conducted at Spectrum Analytical Laboratory in Ohio.

Plants within each quadrant were identified to family; representative plants were collected by clipping at the base or uprooting, transported, dried, and stored (and identified if unknown) at the Davey Diagnostic Clinic (DDC) in Kent, Ohio. A population estimate was made of each component plant for each quadrant. Plant diversity was thus evaluated in each of the 10 quadrants for all transect lines.

Pitfall traps are favored in the extended period analysis. A small container (Figure 1) is filled up three-fourths with soapy water solution, which serves to preserve the sample. The container is buried in the ground with the rim at surface level and five were placed along each transect line at increments of 20 meters (m). Traps were placed in the early morning, collected, and drained 24 hours later the following morning. All invertebrates that were collected were placed in labelled Ziploc© bags, sealed, and transported to the DDC laboratory for identification.

The pitfall trap affords a longer term (24-hour sampling window) of soil and soil surface dwelling and incidental invertebrates. Sweep nets were used to collect insects that are not easily seen, but may be incidental. Twenty sweep samples were taken on each line, each consisting of seven sweeps per linear swath and extending to one meter on either side of the line. Sweep net sampling was done between 10:00 a.m. and 4:00 p.m. Invertebrates and plant material were also sampled using videography; video footage was analyzed and identified at the Davey Institute Bio-Ecological Laboratory in Kent, Ohio.

Figure 1.

STATISTICAL METHODS

All analyses were conducted in SAS (version 9.1 SAS Institute, Cary, North Carolina). Statistical comparison of means between tree groups were made using the Scheffes test (alpha value = 0.05).

RESULTS & DISCUSSION

SBA was generally similar in the areas managed by IVM versus VM and for the newly converted areas (Figure 2).

Plant diversity (number of species) was higher in recently converted ROWs compared to ROWs that were maintained by VM and by IVM. The higher species diversity in recently converted areas can be described as several opportunistic, invasive, and transition species, such as weeds and clover, which may have capitalized on the open ground created after recent herbicide application. The number of plant species is reduced significantly in ROWs maintained by IVM in established areas (but still more diverse compared to VM alone) as equilibrium may be achieved by some species, eventually out-competing the transition species through natural succession (Figure 3).

Invertebrate species counts were significantly higher in ROWs treated by IVM tactics compared to all other treatments. This may be because of an ecosystem climax from years of plant material coexisting together in a habitat (USDA Nectar Corridors 2001). Organisms that utilize this type of habitat can better align their life cycles with suitable plants and/or site conditions (USDAARS 2002) (Figure 4).

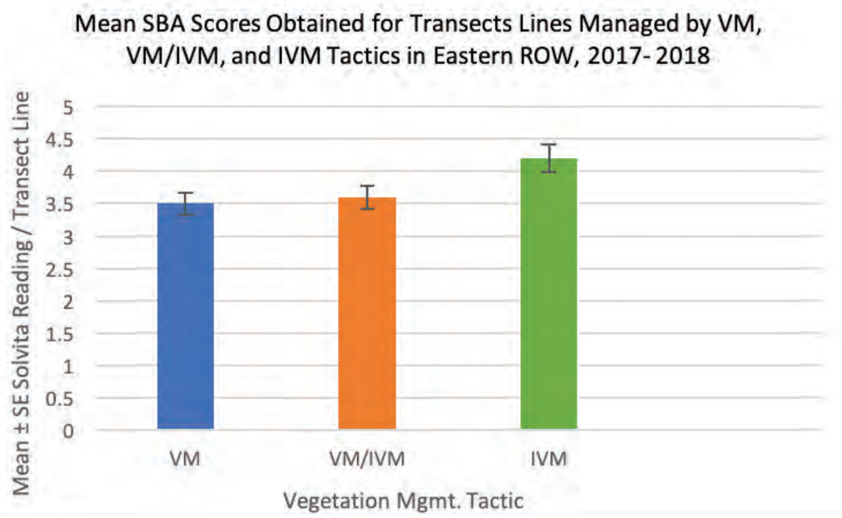

Figure 2. Mean SBA Scores Obtained for Transects Lines Managed by VM, VM/IVM, and IVM Tactics in Eastern ROW, 2017- 2018. P=0.24 aaa

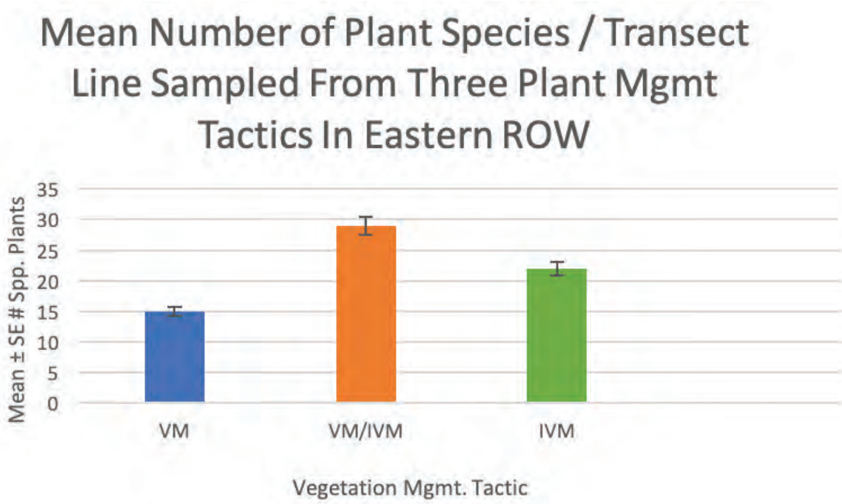

Figure 3. Mean Number of Plant Species / Transect Line Sampled From Three Plant Management Tactics In Eastern ROW, 2017-2018 P=0.014 abc

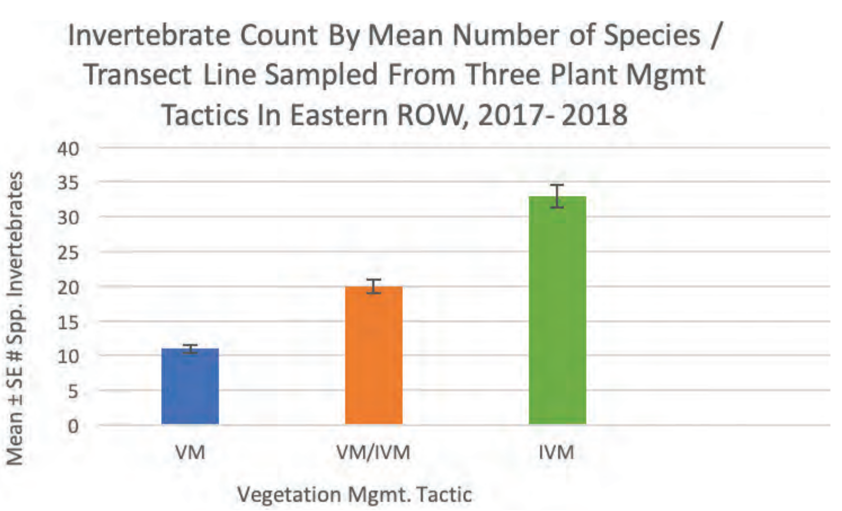

Figure 4. Mean Number of Invertebrate Species / Transect Line Sampled From Three Plant Management Tactics In Eastern ROW, 2017-2018 P=0.001 abc

Hymenopteran-specific surveys revealed that VM areas had the highest ant populations, which may have occurred as several grassy areas had openness, which allowed for ant mounds to be readily built. Ant tracks or pathways were more noticeable in VM areas, bee populations were higher in VM/IVM ROWs compared to VM ROWs, and those managed by IVM (Figure 5). Higher bee populations likely occurred in the VM/IVM ROWs as transition plants, including weeds and clover, were in high abundance and probably attracted larger numbers of bees. Bee composition was, however, skewed between sites, with VM sites having the lowest populations of the main bee groups collected, including mining bees (*adrenidae*), honey bees (*apidae*), and sweat bees (*halicitidae*); VM/IVM sites had the highest number of honey bees, while IVM sites had the highest population of bumble bees (*Megachilidae*). Native bees were collected in higher numbers in sites managed by IVM or that were converted to IVM. Sites that provide overwintering habitat and foraging for bumble bees and other native bees act as a natural resource and may be more stable environments (Buchman 1996; Williams, P. et al. 2014). The presence of bumble bees in significantly higher populations at IVM sites thus may help validate the tactics associated with IVM in ROW. Overall analysis of invertebrates in this study (Figure 7) indicate that the highest populations of invertebrates sampled were the orders hymenoptera, represented by ants, bees, and wasps; lepidoptera represented by butterflies and moths, and acarina represented by ticks in this study.

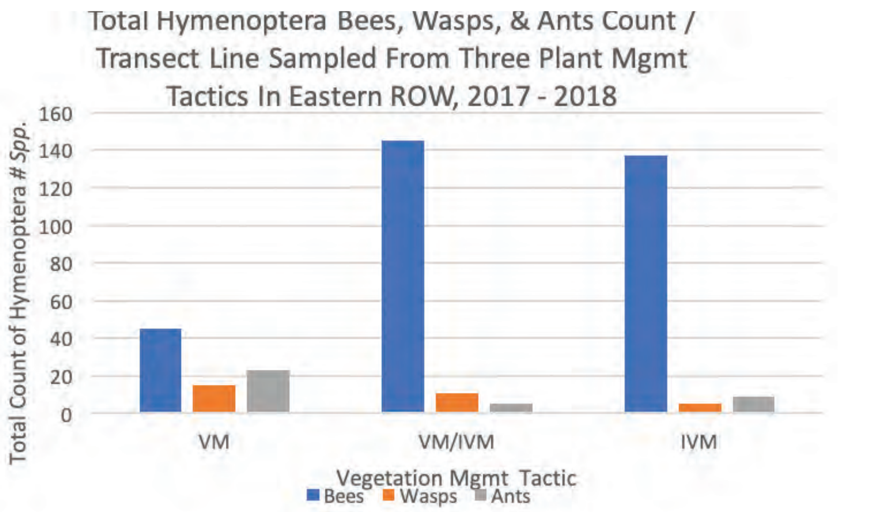

Figure 5. Hymenoptera: Bees, Wasps, & Ants Count / Transect Line Sampled From Three Plant Management Tactics In Eastern ROW, 2017–2018 (P=0.001 Bees abb, Wasps aaa, Ants abb)

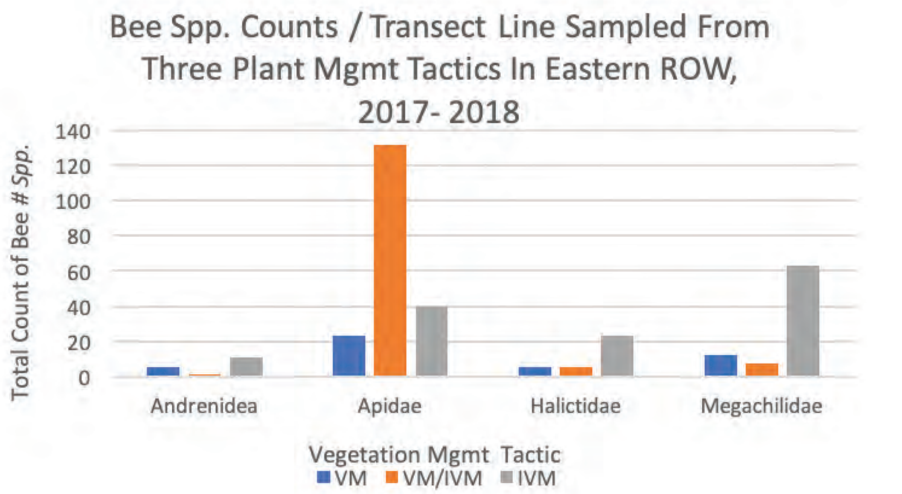

Figure 6. Bee Spp. Counts / Transect Line Sampled from Three Plant Management Tactics in Eastern ROW, 2017-2018 (P=0.001 An-aab, Ap-abc, Ha-aab, Me-abc)

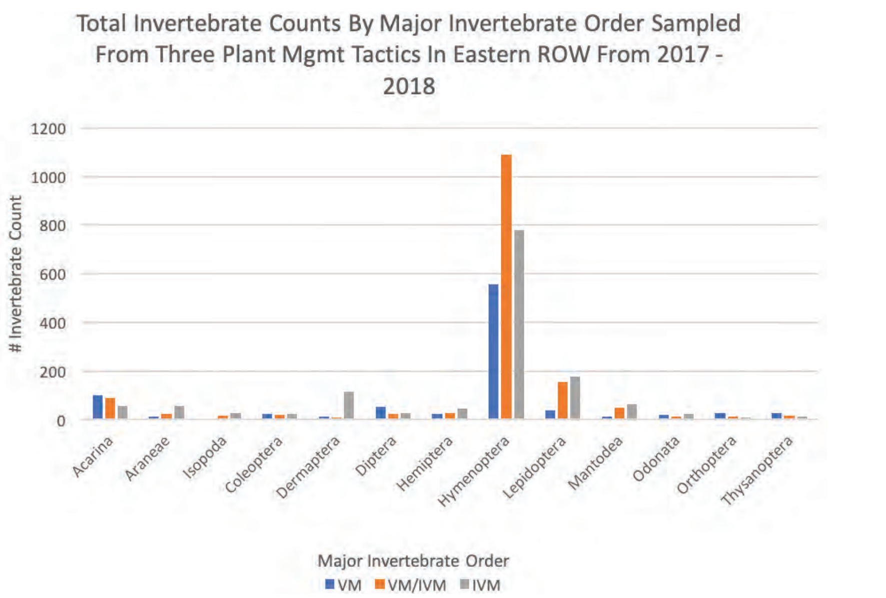

Figure 7. Total Invertebrate Counts by Major Invertebrate Order Sampled from Three Plant Management Tactics in Eastern ROW from 2017–2018

CONCLUSIONS

This study demonstrates that as VM techniques migrate to hybrid VM/ IVM to IVM, plant diversity and succession, and invertebrate fauna improves.

The growing emphasis of plant management in utility ROWs to the secondary benefits of wildlife value (including pollinators) represents opportunity for plant vegetation managers to embrace integrated technologies as IVM strategies are advanced.

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Response of Amphibian and Reptile Populations to VM and Edge Habitat Enhancement Along Utica-Marcellus Pipelines In Eastern Ohio

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Keywords: Habitat, Herpetofauna, Pipeline, Vegetation Management (VM), Wildlife.

Pipeline rights-of-way (ROWs) constitute the majority footprint of Marcellus-Utica shale gas development. We examined snake and salamander response to ROWs vegetation management (VM) and ROWs/forest edge habitat manipulations in eastern Ohio. Study plots (*n*=16) were assigned to treatment: mowing-maintained ROWs, herbicide-maintained ROWS, mowing-maintained + modified edge ROWs, and herbicide-maintained + modified edge ROWs. Two transects of artificial cover objects were placed at each plot (24/plot): along the ROWs/forest edge and perpendicular into adjacent forest. Cover objects were checked after treatments periodically between May 2017–July 2018. Basal area, canopy openness, and natural cover were surveyed pre- and post-treatment. Downed, coarse, woody debris and canopy openness increased and basal area decreased in edge zones post-treatment. In total, we observed six different salamander species and five snake species with 84 observations in total. Northern slimy salamander (*Plethodon glutinosus*), eastern gartersnake (*Thamnophis sirtalis*), and ringneck snake (*Diadophis punctatus*) were most common. Salamander captures were higher in forested transects, and no treatment effects for salamanders were detected. Snake observations increased for ROWs maintained by mowing and occurred almost exclusively within the ROWs itself. No differences were observed between plots with and without edge zone modifications; snake observations more than doubled in the second year post-treatment though reasons as to why were uncertain.

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INTRODUCTION

Amphibians and reptiles (hereafter herpetofauna) are the world's most imperiled groups of vertebrate organisms (Collen et al. 2014; IUCN 2014; Pimm et al. 2014). The array of threats facing herpetofauna are diverse, and habitat loss and degradation is consistently the number one threat to be recognized (Sala et al. 2000; Collins and Storfer 2003; Gardner et al. 2007). Wildlife exploitation, climate change, biological invasions, and pollution are just a few of the other factors posing serious threats to herpetofauna globally (Leclerc et al. 2018). Despite near-universal agreement on the relative plight of these taxonomic groups, they continue to be the least researched—though progress has been made (Di Marco et al. 2017) of vertebrate organisms and are underrepresented by any different number of evaluative metrics for conservation (Butchart et al. 2015; Rios et al. 2018).

In the eastern U.S., the Appalachian Mountains and surrounding foothills have long been recognized as a biodiversity hotspot for amphibians—namely, salamanders (Williams et al. 2017), and the region harbors important populations of reptiles as well. Dating back several centuries, the Appalachians have a legacy of habitat change and degradation (Hicks and Pearson 2003). Most recently, surface coal mining has been the leading cause of deforestation in the region (Drummond and Loveland 2010; Brady 2015). Notwithstanding, in portions of Ohio, Pennsylvania, and West Virginia underlain by the subsurface Marcellus and Utica shale plays, shale gas development utilizing hydraulic fracturing has likely assumed the lead role of disturbance since the early- to mid-2000s (Drohan et al. 2012; Dunscomb et al. 2014; Trainor et al. 2016).

Within areas of concentrated extraction, the unique and pervasive nature of land cover change and habitat alteration due to hydraulic fracturing in the northcentral Appalachians is gradually being understood (Evans and Kiesecker 2014; Slonecker and Milheim 2015). The net sum of direct (e.g., infrastructure construction, habitat loss) (Adams et al. 2011; Evans and Kiesecker 2014; Young et al. 2018) and indirect (e.g., habitat fragmentation, edge effects, noise pollution) (Bayne et al. 2008; Northrup and Wittemyer 2012; Moran et al. 2015; Donnelly et al. 2017) impacts of shale gas development have led several researchers to pinpoint particular taxonomic groups as being more susceptible to precipitated impacts than others (Fahrig and Rytwinski 2009; Gillen and Kiviat 2012). Many amphibian and reptile species would likely be included in a long list of taxa sensitive to energy-related disturbance (Cushman 2006; Brand et al. 2014); however—that herpetofauna are universally negatively impacted—would be a gross mischaracterization. Examples are included below to highlight conservation opportunities as well as challenges presented to herpetofaunal communities in relation to unconventional shale gas development.

As pipeline rights-of-way (ROWs) represent by far the largest proportion of the direct footprint of Marcellus-Utica shale gas development (Langlois et al. 2017), for better or worse, potential for post-construction revegetation and management is abundant and widespread. Thinking broadly about ROWs across sectors (e.g., transportation, overhead, and underground utility), the conservation community has broadly recognized both the serious challenges as well as opportunities for wildlife (Willyard et al. 2004; King and Schlossberg 2014). In particular, the epidemic-level decline in early successional habitat throughout much of the central and eastern U.S. (Lanham and Whitehead 2011) has thrust ROWs' potential into the forefront of many habitat-centric discussions and in a positive light. Key to this phenomenon is that, while early successional habitat is, by nature, ephemeral and short lived, the regulatory and safety constraints which exist across ROWs sectors mandate habitat stays in a continually "arrested" state of succession (Niering and Goodwin 1974). Important sector-level distinctions between what characterizes compatible vegetation should not be dismissed, and vegetation management (VM) is informed by sector-specific best management practices (BMPs) to achieve desirable vegetation/plant communities and habitat (Nowak and Ballard 2005).

However, for most taxa, the net contribution of ROWs to conservation is a simple equation—if all the positive effects of ROWs outweigh all the negative impacts, then compatibility with ROWs is at least possible via the net positive contributions to the species' well-being. If not, then the opposite is true. Indeed, certain researchers have acknowledged, even praised, the potential conservation role of ROWs (Gardiner et al. 2018): early successional songbirds (Bulluck and Buehler 2006; Confer and Pascoe 2003), certain rare plants (Smallidge et al. 1996), and different classes of invertebrates (Russell et al. 2005; Silverman et al. 2006; Wojcik and Buchmann 2012); however, not without reservation (e.g., predation risk along edges) (DeGregorio et al. 2014). Others have lamented the impact ROWs have had on certain types of habitats and other groups of wildlife (Rich et al. 1994; Farwell et al. 2016).

Considered at a wider scale, a broad conceptualization of tradeoffs likely applies to herpetofauna as well. While exceptions most obviously apply, a forest opening caused by a pipeline ROWs and revegetated by grasses and forbs may provide quality habitat for a snake species' preferred prey species and abundant basking habitat amidst an otherwise closed canopy of mature second-growth forest. The exact same ROWs disturbance may simultaneously pose a serious barrier to terrestrial salamander movement and negatively influence micro-habitat and climate factors (e.g., detrital moisture, soil temperature) necessary for survival. In exhaustive review of the literature and consistent with patterns pointed out early in the Introduction, no field-based studies have considered the effects of shale gas infrastructure, specifically pipeline ROWs (Richardson et al. 2017), on herpetofauna in the Marcellus-Utica region.

We sought to examine whether snake and salamander populations differed under varying ROWs VM treatments as well as potential response to transitional habitat zones created along otherwise hard ROWs/forest edges. More specifically, we tested for differences in relative abundance between ROWs managed via mechanical versus chemical techniques and between ROWs paralleled by hard forest edges versus softened transitional habitat edge zones. Because the study only spanned two years, long-term effects of full-cycle VM are not identified.

METHODS

The study occurred on 16 plots (eight sites) in four eastern Ohio counties (Belmont, Guernsey, Harrison, Jefferson) within the unglaciated Appalachian Plateau physiographic province. The maximum straight-line distance between study site location extremes is 90 kilometers (km). The general landscape is moderately fragmented by human land use and has a recent history of strip-mining and agriculture. Though some of the habitat remains open, second-growth forest has reclaimed much of the previously disturbed ground and forest communities occupying the moderately dissected topography are classified as mixed mesophytic (Braun 1950). Xeric forests characterize ridgetops (dominant species—*Quercus, Carya* spp.) before transitioning downslope to mesic upland forests (*Acer rubrum, Acer saccharum, Fagus grandifolia, Prunus serotina*) and bottomland forest stand types under more hydric conditions (*Liriodendron tulipifera, Ulmus americana*). Isolated conifer plantations occur across much of the landscape. Well-documented mesophytic transitions of the mid- and understory are occurring in the study area's forests (Albright 2017), and invasive woody shrub species (e.g., *Rosa multiflora, Elaeagnus* spp.) dominate many sites' low-growth vegetative community. Elevation between sites range from 278 to 385 meters (m), and mean annual precipitation is 104 centimeters (cm) (approximate center of study area, Cadiz, Ohio).

Almost without exception, pipeline corridors were established between three and five years prior to the study's initiation in association with Marcellus-Utica shale gas development. Each study plot was carefully selected using strict criteria. All ROWs study plots are bordered by contiguous forest (advanced to pole stage or beyond) on each side and are located >100 m from the nearest non-forested land cover type (e.g., pasture) or major anthropogenic disturbance (e.g., road). Canopy disruption overtop each ROW was complete and corridor width varies between eight and 43 m depending on plot (mean=30 m; 13 plots > 24 m width). Overall plot dimensions are 200 m x ROWs width, and all but one plot is located on privately-owned property. Reclamation plantings following initial construction established cool season grasses supplemented by legumes (*Lotus corniculatus, Trifolium* spp.). Up until study initiation, plots were maintained by yearly mid-late growing season mowing, which occurred between mid-July and early-September.

Study design included a pair of treatments (2x2 factorial design) such that plots would be designated as control, treatment 1, 2, or 3. The first factor in the study design addressed VM within the pipeline ROWs corridor, and the second factor targeted the edge zone along the ROWs/forest border. The ROW vegetation treatment was selective herbicide application by backpack crew to target incompatible vegetation. The selective herbicide treatment was modeled after integrated VM (IVM) (Nowak and Ballard 2005) principles, and we hired contractors active within the industry to implement our treatments. Mowing reduction or cessation and implementing a multi-year herbicide cycle is known to be an effective means for allowing forbs and other native vegetation to flourish, which may create higher quality habitat conditions for various taxa (Entsminger et al. 2017), while still effectively meet safety and regulatory specifications (Nowak and Ballard 2005).

Figure 1. Treatments 1 and 3 plots controlled incompatible invasive species and woody encroachment via backpack sprayer foliar application of selective herbicides—September 2016, Ohio.

A consultant tailored herbicide applications to plot-specific needs. Initial backpack application of herbicides occurred in September 2016 and used foliar spray technique to target incompatible plant species using products Rodeo and Arsenal (Figure 1). For plots scheduled to receive the edge treatment the following spring, hack-and-squirt with machetes was used to control unwanted woody invasives and small-diameter woody regeneration within the designated edge zone. The edge treatment was conducted March 2017 by ground crews using chainsaws to remove marked trees from 10-m wide zone of forest which paralleled the ROW edge and along entire 200-m plot length (Figure 2). The treatment targeted one side of each selected plot to remove >75 percent basal area to increase canopy openness and allow light to stimulate understory growth. Cut stem and stump treatments with herbicides prevented re-sprouting (Milestone and Arsenal in dilutions to cut surface immediately after felling and as specified on the herbicide label). Felled material was left in place and distributed throughout the edge zone. Desirable midstory native species such as *Cornus florida* and *Cercis canadensis* were retained when possible, and remaining residual trees (0-3/plot) were high timber and/or wildlife value (e.g., *Quercus alba, Prunus serotina*). In September 2017, a follow-up herbicide application completed the selective herbicide treatments and targeted any residual incompatible vegetation left growing within ROWs corridors as well as woody invasive encroachment persistent within the modified edge zones.

Control plots (*n*=4) were maintained by annual mowing and retained abrupt edges between the ROWs corridor and the adjacent forested habitat. Treatment 1 (*n*=3) retained hard ROWs/forest edges but managed corridor vegetation utilizing selective herbicides. Treatment 2 (*n*=4) utilized annual mowing and created a transitional habitat ecotone along one ROWs/forest edge, and Treatment 3 (*n*=5) incorporated both ROWs and edge treatments. Researchers worked

Figure 2. Modified edge habitat zones were created along Treatment 2 and 3 plots. Trees were removed from 10-m wide zone adjacent to ROWs to create an ecotone transition, and stumps were treated with herbicide to prevent re-sprouting. Foliar herbicide application was used to control invasive species within treatment zone, and native vegetation was encouraged to re-colonize the site. Pictured is three months post-treatment—June 2017, Ohio.

with energy companies responsible for ROWs VM as well as property owners prior to study initiation to choose treatments for each plot, and established written and signed memorandums of understanding (MOU) specifying both the nature of each plot and duration of the study.

A spherical densitometer was used to estimate canopy openness (%) pre- and post-treatment at each cover board location. Basal area (m^2/hectare [ha]; point-center quarter method) and coarse woody debris (m^3) were measured in plot edges before and after edge habitat manipulation. Coarse woody debris was measured within three-m radius of each cover board pair location, and all wood material contacting the ground and measuring a minimum of 10-cm diameter (Harmon and Sexton 1996). There was no minimum length to be considered coarse woody debris.

Herpetofauna were sampled by artificial cover boards (CBs) placed at all 16 plots. At each plot (dimensions 200 m x ROWs width), a CBs array with two primary transects was installed in July 2016. One transect paralleled the pipeline corridor and was installed one-m interior to the ROW and along the ROW/forest edge receiving greater daily amounts of solar exposure. This transect was spaced at 30-m intervals (six locations/transect), and each 30-m spaced location consisted of one metal (galvanized ribbed sheet metal, 60 x 90 cm) and one wooden cover board (untreated ½” plyboard, 40 x 60 cm) roughly 0.5-m apart. The other transect originated at a random parallel transect location and entered the adjacent contiguous forest patch perpendicularly, and six CB pairs were located systematically from 10 to 60 m interior spaced by 10-m intervals. Twenty-four cover boards were placed at each of the 16 study plots totaling 384 in all.

Cover boards were checked once every three weeks from May–October 2017 and from May–July 2018. Checks were scheduled within 24-48 hours of a precipitation event (rainfall > 0.25 cm) when possible. All cover boards at a single plot were checked the same day, but plot checks occurred on multiple days throughout each sampling period. Date, time, cloud cover, ambient temperature, start- and end-time for sampling, species, board type (wood, metal), and board location (edge, interior) were recorded.

Observations of snakes and salamanders were pooled separately across years. Fisher's exact test was used to test for differences in salamander counts between treatments, and chi-square (2x2) with Yates correction was used for snake counts. Proportional differences in snake and salamander observations between ROWs maintained via mechanical (control and Treatment 2) versus chemical means (Treatment 1 and Treatment 3) and edges with (Treatment 2 and Treatment 3) and without manipulation (control and Treatment 1) were examined using two-sample test for equality of proportions. Slight differences in sampling effort between treatment groups were accounted for in our analyses. An exact binomial test was used to test whether or not snake and salamander use of ROWs versus interior forest and cover board type (wood, tin) was random. Alpha level was 0.05. Scientific and common names attributed to Pfingsten et al. (2013).

RESULTS

Plots were checked 9.8 times on average (+ 0.22; 1 SE), with slight variability in 2017 due to weather and other constraints, and four times per plot in 2018. A total of 3,792 artificial cover objects were flipped in the span of the two-year study. Snakes (n=61) comprised the majority of herpetofaunal captures, and total number of observations numbered 84. Salamander captures were distributed evenly between years, 12 and 11 respectively; snake observations doubled from 2017 (n=19) to 2018 (n=42). Six salamander species and five snake species were observed in the course of the study with northern slimy salamander (*Plethodon glutinosis; n*=14), eastern gartersnake (*Thamnophis sirtalis; n*=29), and ringneck snake (*Diadophis punctatus; n*=20) occurring most often. Other salamander species captured included eastern red-backed salamander (*Plethodon cinereus; n*=3), Jefferson's salamander (*Ambystoma jeffersonianum; n*=2), red-spotted newt (*Notophthalmus viridescens; n*=2), marbled salamander (*Ambystoma opacum; n*=1), and spotted salamander (*Ambystoma maculatum; n*=1). Other snakes species included eastern milksnake (*Lampropeltis triangulum; n*=8), black racer (*Coluber constrictor; n*=3), and northern brownsnake (*Storeria dekayi; n*=1).

Across plots, canopy openness measured 44.7 percent (+ 5.7 percent; 1 SE) prior to treatments. Canopy openness measured in plots receiving edge modifications (Treatment 2 and 3) increased to 72.7 percent (+ 8.0 percent; 1 SE). Basal area was reduced 74.3 percent on average for Treatment 2 and 3 plots (+ 7.8%; 1 SE), and coarse woody debris increased within three-m radius of the ROWs/edge cover board transect as well as at the 10-m interior forest board locations (average increase=0.10 and 0.21 m^3/cover board pair, respectively). For salamanders (pooling observations across species), no treatment effect was detected (p=0.596). An effect of treatment was detected for snakes (χ^2=4.001, df=1, p=0.045), though significance was marginal. Snake observations did not differ between plots with and without the edge habitat manipulation (χ^2=0.663, df=1, p=0.416); however, snakes were captured more frequently in plots maintained with mowing than with selective herbicides (χ^2=4.673, df=1, p=0.031).

Disproportionately, more salamanders were detected on forested transects (n=18) than ROWs transects (n=5; p=0.011), and snakes almost exclusively (95 percent) utilized ROWs and were seldom observed at forested cover board locations ($p < 0.001$). Though assessing cover object type preference was not a stated study objective, salamanders did not show a preference (p=0.678) between wood and metal boards, and snakes utilized metal objects 87 percent of the time ($p <$ 0.001).

DISCUSSION

Herpetofaunal communities varied in their relative abundance within pipeline ROWs and adjacent forest stands as well as in response to ROWs VM. Although salamanders did not display selection for different treatments, limited captures resulted in extremely small sample sizes. Given the amount of sampling effort invested, low salamander capture rates could suggest that effects of canopy disruption (e.g., altered microclimate, loss of natural cover) following initial site disturbance may still be compromising habitat quality for those species. Other studies suggest reductions in salamander abundance may last upwards of a decade or more post-disturbance, and recovery may not even begin within a severely disturbed site for four to seven years (Ash 1997; Ross et al. 2000; Hocking et al. 2013). That northern slimy salamander were the most common salamander species observed in our study is another possible indication that the initial site clearing disturbance for pipeline installation is still exerting an influence on our study plots. Other studies have noted the northern slimy salamander's comparative resilience to various silvicultural-related disturbances when compared to other woodland salamander species which are more profoundly affected (Petranka et al. 1993; Mahoney et al. 2016).

Pipeline ROWs appear to be more compatible with certain species of snakes, likely due to increased basking habitat in a landscape otherwise characterized by closed-canopy, maturing forest. A positive response by snake populations to forest disturbances resulting in canopy openings is well documented by other studies (Ross et al. 2000; Greenberg 2001). In other ROWs and related studies, a similar overwhelming difference was noted in snake use of ROWs versus forest (Yahner et al. 2001; Moseley et al. 2010). Snake relative abundance was higher in plots maintained by mechanical versus selective herbicides. While it is possible, this was an unmeasured side effect; longer term monitoring of sites may provide clues as to why this pattern was observed.

The number of snake captures also provided an opportunity to investigate the role of ROWs width with respect to snake utilization of pipeline corridors. Though not a statistically significant relationship, evidence hints that wider ROWs may provide higher quality snake habitat (t=1.723, df=14, p=0.107). Caution is warned in interpreting this result, given the small sample size, but this pattern does warrant further exploration. Greater sunlight penetration into wider linear forest openings would not only provide increased opportunity for basking, but increased primary productivity and plant growth borne out by the vegetative community within the ROWs itself. Not only this—corridor width affects the distance thresholds at which deleterious edge effects curtail within adjacent habitat (Kroodsma 1984). As such, the importance of ROWs width is important to consider with regards to a specific species' needs.

A point worth clarifying is that the study's counts of salamanders and snakes do not reflect actual population numbers of individual organisms at plots, but rather, it is a relative frequency of number of snakes and salamanders observed per sampling occasion. Low capture rates limited our overall ability to examine species-specific responses to treatments and relationships to environmental and habitat variables. Additionally, unequal detectability likely occurs across numerous spatiotemporal gradients (e.g., temperature, time of day) (Grant et al. 1992; Marsh and Goicochea 2003; Joppa et al. 2009; MacNeil and Williams 2013; O'Donnell et al. 2014). For instance, earlier sampling periods (March, April) would likely have increased the number of salamander detections, whereas the warmer weather months of June, July, and August were likely biased towards snake observations. Other research objectives (beyond the scope of this research and manuscript) likely compounded our ability to optimally allocate sampling effort and mitigate such biases.

Unique to the organisms themselves, another potential source of bias arises from the fact that species- and individual-level detection probability varies by factors ranging from life history to body size to reproductive status (e.g., snakes) (Cox et al. 2009). Some studies have suggested natural cover object searches or night surveys are more effective sampling methods for certain herpetofauna (Hyde and Simons 2001), and many of the factors hinted at above also influence an individual's probability of object utilization at any given point in time. Yahner et al. (2001) noted equal use of adjacent forest and ROWs corridor by woodland salamanders, but differed in methodology by sampling both during day and night, and this result was corroborated by another overhead utility study (Brannon et al. 2014). In the case of both Yahner et al. (2001) and Brannon et al. (2014), the ROWs were decades old—and an important distinction with our study where the direct impact of disturbance was much more recent. Intrinsic to the ROWs/forest edge treatment was the corresponding creation of increased coarse woody debris and natural cover objects. Though the outcome of creating additional cover was one of the primary intents of the treatment, differences in natural cover object abundance between plots could create differential usage rates of the artificial CB placed to standardize search effort.

Snake observations more than doubled between 2017 and 2018, and the increase was even more pronounced when accounting for differences in sampling effort between years. Multiple reasons could be at work here, and a couple seems likely. First, cover boards are increasingly attractive through time as small mammals and other small organisms occupy and burrow under artificial cover objects. Second, the time from initial construction and/or time from treatment (particularly for edge modification) was likely a factor in disturbance-sensitive species' colonization and use of artificial cover objects. Because the study was short-term, these data do not likely represent a full response on behalf of the herpetofaunal community to the in-corridor VM or ROWs/forest edge treatments. Further long-term studies are required.

CONCLUSIONS

Though data was limited on salamanders, this study is the first of its kind in examining the effects of underground pipeline corridors on salamander populations. For pipeline infrastructure associated with Marcellus-Utica shale gas development, ROWs appear to be compatible with at least some snake species. Snakes may favor the habitat provided by maintained ROWs as they provide open-canopy areas for basking and may provide higher densities of small mammals used for prey by larger-bodied snakes. Given the pervasive and substantial nature of disturbances by ROWs, additional research is needed long-term to ascertain effects of linear utility corridors on herpetofaunal populations in the region.

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Setting Up a Long-Term Research Study of Pollinators on ROWs: Experience From Literature and the Field

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Landscape-level changes have contributed to loss and fragmentation of pollinator habitat. The 2014 Presidential Memorandum, "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators," addresses enhancement and creation of pollinator habitat as a top priority. Electrical powerline rights-of-way (ROWs), and the approximately 3.8 million hectares (ha) (9.6 million acres) of early successional habitat they provide in the U.S., offer an opportunity to address this need. Determining baseline data, trends, and best management practices (BMPs) require long-term monitoring and research. This paper addresses three key elements of initiating long-term pollinator projects on ROWs: 1) experimental design and site selection, 2) vegetation and insect pollinator monitoring techniques, and 3) obtaining appropriate baseline information. Each component is addressed through literature, the authors' experience, and data obtained from the first year of a long-term study in Upstate New York. Importance of partnerships between utilities and scientists are emphasized as the "glue" holding research and development of adaptive management for pollinator habitat together.

Keywords: Long-term Study, Bees, Butterflies, Integrated Vegetation Management (IVM), Pollinators, Rights-of-Way (ROW), Vegetation Management (VM).

Environmental Concerns in Rights-of-Way Management
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INTRODUCTION

The definition of a long-term study can be highly variable and dependent on several factors (e.g., the system or organism you are working with, standard practices in the field of research, or background processes contributing to the ecology of the system you are studying). Strayer et al. (1986) provided two concise definitions: 1) "A study is long term if it continues for as long as the generation time of the dominant organism or long enough to include examples of the important processes that structure the ecosystem under study," or 2) "A study has continued for a longer length of time than most ecological studies in that field, revealing attributes of the system that were not obvious from a short-term study."

A literature review conducted in 2018 found that, of 36 studies performed on rights-of-way (ROW) on pollinators, 80 percent were conducted for two years or less, and 60 percent were carried out for only a single field season (see Van Splinter et al. for these proceedings). Very few studies were carried out for the entire length of a treatment cycle; the most important process was the shaping the environment within a ROW (with the exception of annual mowing), which created a desperate need for long-term manipulative field research of pollinators on ROWs.

Long-term research studies have the ability to improve ecosystem management by providing important ecological insights not readily apparent through short-term studies. However, Lindenmayer and Likens (2009) found many fail due to poor planning or lack of focus. They also found that the inclusion of a few key factors could make a project more likely to succeed:

- Dedicated guidance by one or a few project leaders
- Simple study design with room to address short-term questions
- Clear definition of the function of the project and when it will be complete
- Data management plan

Our research group has taken these key factors into account within the last three years, along with research into existing literature and methodology, to work toward developing a consistent protocol for sampling pollinators on powerline ROWs within the context of a long-term manipulative field experiment. We have done so at the request of the Electric Power Research Institute (EPRI) as part of a larger experiment to examine the effects of various vegetation management (VM) treatments on pollinators within a ROW ecosystem. A technical report, which provides more detail than this document, is available through EPRI (Ballard et al. 2018). Much of the work presented within this document is based upon the protocols reported in that document.

OBJECTIVE

The objective for this document was to provide suggestions for developing field research protocols promoting consistent design, installation, implementation, and monitoring of insect pollinators on electrical transmission line ROWs. This was done by addressing three key characteristics: 1) site selection, 2) vegetation and pollinator monitoring techniques, and 3) analyzing initial starting conditions.

Site Selection

Site selection is one of the most critical aspects of establishing and conducting field experiments. If suitable sites are not selected, then subsequent work will be compromised. It is for this reason that we recommend including a statistician in your research team. The goal is to select sites within blocks with homogenous conditions, and create blocks that vary ecologically, but remain consistent in regard to other variables. The following section is a set of guidelines to assist the researcher in achieving this goal.

It is highly recommended that a preliminary site selection be conducted prior to field visits. This can be done

Three sites/blocks (preferably in three different ecoregions [USDA Keys et al. 1995] and in ROWs approaching the end of a treatment cycle/scheduled for treatment in the next year)

Three treatment plots per site (3–4 acres each, depending on ROW width)

Consistent off-ROW conditions within (and among) blocks

- e.g., forested conditions (for >500 ft on both sides of ROW), or other uniform conditions off-ROW (i.e., forest cover is not a requirement, but conditions should be consistent)

Consistent on-ROW conditions within a block;

- Consistent life form assemblages; e.g., shrub/short tree communities with 25–75 percent cover and similar species mix
- Consistent stream/wetland conditions (if present)
- Soils reasonably consistent (e.g., see Web Soil Survey, Soil Survey Staff 2017)
- Consistent vegetation management prescribed treatments (if applicable/available)

No known landowner issues

Suitable, safe access and parking

Other issues noted?

Approximately five full transmission line tower spans at each site are needed with these conditions to allow for 2-3 acre plots and adequate buffer (tower span) between plots.

ROW width can affect length of plots required; e.g., a 300-ft wide ROW (two adjacent powerlines) may permit half-span sections (~400 ft long) to establish 2.75-acre treatment plots; narrow ROWs will require adjustment to treatment and measurement plot sizes.

Reasonable travel distance to sites (e.g., within ~one hour drive from researchers' primary work location/university campus)

Table 1. Outline: Guidelines for Site Selection

remotely using free resources including Google Earth/Google Maps, the U.S. Department of Agriculture (USDA) NRCS soil survey website, the geographic information system (GIS) Clearinghouse, etc. Additionally, current map books may be available from your participating utility company. These books may provide useful span-by-span information on vegetation conditions, treatment prescriptions (past or present), delineated wetlands and streams, landowner issues, and information on powerline infrastructure (e.g., number of towers and corridor dimensions).

It is recommended that a minimum of 2–4 times as many candidate sites be chosen as are needed in the final selection (e.g., 6–12 candidate sites for three final locations). It is also useful to include utility personnel in site selection, as they may have site-specific information not documented in other sources. Even with all the following considerations taken into account, when working on private lands, the unexpected may happen (e.g., land may change hands and new owner does not want to participate). Therefore, it is important to include more than the minimum number (three) of replications in your design to prepare for the unexpected.

1. Plot Characteristics and ROW Conditions

Plot size should be between 1.21 and 1.61 hectares (ha) (three and four acres). This is consistent with the average plot size for published ROW literature (see Van Splinter et al. for these proceedings). Between each plot, we recommend a buffer of 304.8 meters (m) (1,000 feet [ft]), or approximately one tower-span on a high voltage transmission line ROW. This distance will allow for two analysis groups. Short-flighted bees, whose flight distance can be as little as 91.44 to 182.88 m (300 to 600 ft) (Greenleaf et al. 2007), will show how resource availability can change community composition with time. Meanwhile, larger bees are able to fly more than a mile and will be able to decide between plots, showing use preference. Sites must be selected to allow for one replication of each treatment and the allotted buffer space between them, within an area containing consistent on- and off-ROW conditions.

Off-ROW conditions should be held constant both within and among blocks for >152.4 m (>500 ft) on both sites of the ROW. This includes conditions such as adjacent land use, which may impact pollinator communities, but does not necessarily vary with ecoregion. On-ROW conditions should be held constant within blocks. This includes, shrub/short tree communities with consistent cover and similar species mix, consistent stream/wetland conditions (if present), and same stage of treatment cycle—if initiating treatment, preferably end-of-treatment cycle. Additionally, sites should be selected that are representative of the ROW conditions at large. For more specific guidelines on site selection, see Table 1.

2. Additional Considerations

Communication between researchers and stakeholders is the key to minimizing disruption in research. ROW managers in particular provide an invaluable resource to researchers implementing a study. They often possess intimate knowledge of the powerline corridor, including treatment cycle (i.e., when was the line last treated and the next treatment scheduled), vegetation conditions, site access, landowner issues, etc. They will also likely be responsible for coordinating treatments later on in the process.

ROW managers may have also built a rapport with landowners and may be able to explain and gain their support for a project. Landowners must be understanding of the process and willing to participate through minimal vegetation disturbance throughout the course of the study. Landowners may have concerns about plot placement, especially during hunting season. Additionally, they may have concerns about their privacy and intrusion into personal space. A single disgruntled landowner can cause the loss of an entire site. The best way to avoid this issue is to select sites with amenable landowners who are willing to participate.

At minimum, communication with utility personnel to confirm/finalize study site and plot locations is critical to avoid inadvertent treatment/disturbance of study plots by routine (or emergency) utility activities both in the short and long term. If possible, the utility company should add the study locations to their database(s) maps, etc. to avoid miscommunication when decisions within the company are made (this does happen; e.g., study plots have been compromised/destroyed by tower/line crews accessing the site for repairs without consulting the utility forester responsible for regular VM).

Along with good communication, safety should be of key concern in site selection. This includes safe parking locations and access to plots, along with limiting travel distance. Since the sites and plots will need to be accessed regularly by a number of researchers, project partners, utility personnel, and occasional visitors, suitable access to a site is important for both safety and convenience. Safe parking locations for vehicles should avoid parking on the shoulder of the main roadway, especially if it is a heavily traveled road. While this type of field research necessitates hiking between plots on uneven/rugged terrain, consideration should be given for safe ingress and egress during the site selection process.

Selecting sites within a reasonable driving distance is certainly an important practical consideration, since field work will need to be conducted at regular intervals and it is desirable/necessary to complete a round of sampling at all sites in a 1-2 days period (especially insect sampling). Reasonable travel distance to sites is defined as within approximately a one-hour drive from researchers' primary work locations/university campuses.

As a precaution, signs may be used to demark boundaries of plots in an effort to avoid accidental disturbance to the study plots. Signs should indicate the location of research plots and contact information. However, this may also draw unwanted attention to plots. In each case, researchers must decide whether the risks outweigh the benefits.

Vegetation and Pollinator Sampling Techniques

Vegetation methods have been well established within the previous 20 years to describe ROW ecosystems (see Nowak et al. 2016 for recent EPRI-supported use of this type of measurement for ROW vegetation). ROW pollinator sampling, however—apart from butterflies (diurnal Lepidoptera)—has been precarious and inconsistent (see Van Splinter et al. for these proceedings). The following sampling methods are designed as a preliminary attempt to establish a concise, reproducible, and effective sampling method for pollinators on powerline ROWs. These methods should allow comparisons of results between research groups across the country.

It is important to consider that these methods are designed to be foundational investigations, allowing ample time for pursuing additional questions that arise throughout the course of the experiment. On average, 20–50 percent of a research group's time should be set aside for addressing these questions. This allows flexibility to address questions important to each specific project, while maintaining a study's ability for comparison with other research groups (Lindenmayer & Likens 2009).

1. Vegetation Sampling

Understanding how alterations in vegetation affect pollinators is a key component to discovering how to manage for pollinators on ROWs. Several ROW studies have found correlation between floral abundance and diversity, woody cover, and bare ground with pollinator population metrics (see Van Splinter et al. for these proceedings). Therefore, we recommend a minimum of three vegetation sampling periods throughout the experiment: 1) one-year pre-treatment, 2) one-year post-treatment, and 3) three to four years (end-of-treatment cycle) post-treatment.

Sampling should be conducted mid-summer of each of these years, utilizing 9–12 six-foot radius, circular sampling points (quadrats). The number of sampling points needed will depend on the variability of the vegetation within plots. The following data should be collected within each quadrat:

- Stem density of all incompatible trees and compatible trees and shrubs ≥1 inch (in) diameter at breast height (dbh) (diameter at 1.37 m [4.5 ft] above ground), by species and by height class: <3 ft, 3–6 ft, or >6 ft.
- Percent cover of plant life form (tree, shrub, herb/forb, fern, graminoid, vine, nonvascular) by height class: <3ft, 3-6ft, or >6ft.
- Dominant species/genera for each life form.
- Density of woody plants (stem ≥1in dbh should be measured as well, using a set of strip/belt transects or using a 100 percent inventory if density is very low).

In addition to these standard vegetation measurements, additional floral sampling is recommended. During each period of pollinator sampling, floral abundance and species diversity should be measured. We recommend Braun Blanquet-style categories for abundance. Plots are divided into four quarters (between transect lines) and systematically wandered, recording species presence and estimating floral abundance using the following categories: trace (0 to 10), 10–100; 100–1,000; 1,000–10,000; 10,000–50,000; and >50,000 inflorescences for each species. A 1.21-ha (three-acre) plot can be completed in approximately 45 to 60 minutes during peak bloom. This information can provide important corollaries relating to pollinator metrics and floral species presence and abundance.

2. Pollinator Sampling

Our lab has chosen to base our methodology for pollinator sampling primarily on bee protocol (*Hymenoptera Anthophila*), with consideration for alternate taxa (e.g. Diptera, Coleoptera, and Lepidoptera). This decision was based on two considerations: bees are often considered the most important pollinating group (Wojcik & Buchmann 2012) and bee sampling methods are well studied and documented. However, many studies examining bees focus on cataloging species richness and may inaccurately reflect other pollinator community metrics, such as abundance (Cane et al. 2000; Popic et al. 2013) (i.e., there may be no overall change in the species present within an area, but a significant change in the abundance of a group of pollinators that may be missed when focusing on richness alone). Therefore, researchers are cautioned against following the methodology presented in this paper without careful scrutiny of what these methods are describing. Our group is working toward verification. These methods measure overall changes in pollinator communities in response to vegetation treatments in the field over the coming years and would welcome the input of other research groups.

It is recommended that insect sampling be conducted at least three times (May, June, and late August) throughout the growing season, and take place between 9 a.m. and 5 p.m. on favorable weather days (LeBuhn et al. 2003). Measurements of insects must occur one year pre-treatment, one year post-treatment, and 3–4 years post-treatment. Date, time of day, temperature, and general weather conditions should be recorded at the start and end of the insect surveys. Insects should be identified down to the family level at minimum. When possible, they should be taken down to the species level. Representative voucher specimens of all insects collected should be archived. A minimum of two sampling methods are recommended to combat inherent bias within individual sampling methods.

Pan traps, or bee bowls, serve as a good baseline. They are user friendly and easily comparable between research sites and groups. Generally, three-ounce (oz) painted plastic fluorescent blue, fluorescent yellow, and white bowls are recommended for bee sampling (LeBuhn et al. 2003; Droege 2015). However, larger bowls may be advisable for sampling butterflies (Lepidoptera) or other larger pollinators (Campbell & Hanula 2007). Bee bowls are secured to metal brackets with plastic cable ties and supported by fiberglass rods placed securely into the ground (Wagner et al. 2014). Traps are placed with alternating colors, and bowls are filled with water and a drop of dish detergent to break surface tension. Samples are collected within 24–26 hours of deployment. Disposable paint strainers (large mesh size to avoid clogging) are an effective method of filtering insects from pan traps in the field (Droege 2015).

> *Note:* Droege (2015) suggests that Dawn© dishwashing liquid performs well, compared to other brands or additives, such as sugar, floral scents, etc. and that 30 pan traps per site are required to adequately sample bee fauna in observational studies.

Sweep netting, another highly utilized and useful sampling method (Popic et al. 2013), is recommended in conjunction with pan traps. Sweep nets will yield additional pollinators not collected in bee bowls (LeBuhn et al. 2003). Random sweeping will yield small, inconspicuous insects, while targeting specific pollinators along transects will capture sensitive, strong-flying insects, along with providing floral utilization data (Laroca & Orth 2002). Typically, a minimum of two people per plot for a total of 60 effort-minutes during each sweeping session (e.g., two people sweep for a total of 30 minutes), alternating sides halfway through the timed session to account for differences in sweeping proficiency, are used to sample a site (LeBuhn et al. 2003). Sweep netting is ideally done both during the morning (9:00 a.m. to 11:30 a.m.) and the afternoon (1:00 p.m. to 3:00 p.m.), to capture different pollinator populations occurring during the two time periods.

3. Surrounding Land Use

Many pollinators—e.g., butterflies and hoverflies—move across habitats for their entire adult lives. Bees, however, are central-place foragers, meaning once they establish a nest, they must forage around that nest, and their foraging distance is limited by body size (Greenleaf et al. 2007). Several studies have emphasized the importance of surrounding landscape on pollinator populations and on butterflies and hoverflies in particular (see Van Splinter et al. for these proceedings). Therefore, the land use on and surrounding a treatment plot should be accounted for by discerning the proportion of that landscape in different land use types using GIS. Land use categories should include the following:

- Agriculture: cropland
- Agriculture: pasture
- Commercial/industrial
- Residential
- Early-successional/shrub
- Forest
- Wetland
- Open water
- ROW (powerline, gas line, roadway, rail)

Measurement of land use categories can occur any year, but is best completed in the same years as VM treatments. No consistent methodology has been established regarding distances to be examined (see Van Splinter et al. for these proceedings). We recommend successive concentric circles at 152.4, 304.8, 609.6, and 1,219.12 m (500, 1000, 2000, and 4000 ft).

Analyzing Initial Starting Conditions

Consistent analysis and reporting of results between research groups is key to understanding how landscape and treatment affect pollinator habitat. This section provides general guidelines and rationale for performing and reporting analysis of results. Additionally, examples of pre-treatment analyses are provided for the New York case study to provide templates for result tables and figures. Finally, a section on data management is included as a primer for data storage and preparation for analysis.

1. Data Management

A data management plan is one of the key elements in designing a long-term study. Long-term research requires that your data be accessible, well documented, and organized. This is so your database can be built upon in subsequent years. Having a well-designed database will allow your group to avoid losing or changing original data that may be vital to the success of your project. Additionally, with good documentation and storage of your data, alternate research groups may be able to use the raw data to conduct additional analyses and address questions not intended in the original design. As Marcia McNutt (Editor-in-Chief, Science Journals) says, "Interpretations come and go, but data are forever."

DataOne.org provides a good primer on data management: "Primer on Data Management: What You Always Wanted to Know." This primer is a good introduction to data management practices and is recommended for any research group embarking on any type of project. Long-term studies in particular need proper storage and documentation for data to be available for analysis throughout projects changing hands or lengthy time intervals in which researchers may not remember specifics of data sets.

The first step to data management is quality assurance/quality control (QA/QC). It is good practice to have active QA/QC measures in place before beginning data collection. This is true for all aspects of the research program, and it is especially relevant to data entry and data management. Some examples of QA/QC include:

- Recording field data on hard copy data sheets, which are reliable in all field conditions, and backing up this data with electronic copies of field sheets. The Rocketbook application is a useful tool for this process.
- Using two different people for data entry: one to input and one to verify the data is correct, therefore catching potential entry errors.
- Using Microsoft Access to retain data integrity and exporting data to Excel for manipulation.

In conjunction with QA/QC procedures, naming schemes, which help quickly locate and identify data, are essential when dealing with multiple data sets. A naming and filing scheme should be decided on for all data types (e.g., field data sheets, photographs, Excel sheets, etc.), as well as a timeline for short- and long-term storage of these items. These names should include a location and date, as well as a unique identifier. They should be consistent and descriptive. This includes specimens, especially insects, where thousands can be collected in a single field season. We suggest a naming system that relates to taxonomic classification (e.g., HYM-API-0001 for a honey bee—*Hymenoptera Apidae*), and storage according to naming.

Within each data type, a consistent documentation should be established (e.g. data should be documented for someone—a stranger—who will discover the information decades from now). Good documentation allows for transition between researchers—e.g., when a graduate student has completed their studies and is handing the data off to the principal investigator, as well as public or agency transparency, depending on funding source, or to verify the reproducibility of analysis methods. Metadata, at a minimum, should include:

- Data collection methods
- Locations and dates
- Field crew names and contact information
- Any field notes taken

2. Analysis of Variance

Analysis of variance (ANOVA) is a statistical method used to test differences between two or more means, by using the variation between means in the same group (within group variance), and variation between means in alternate groups (between group variance). It is the basic statistical analysis that should be conducted for the randomized complete block experimental design outlined and recommended in the previous sections. Using a block acknowledges that there will be similarities between plots located proximal to one another in comparison with plots located in another ecoregion, but says we are not interested in this effect; we instead choose to focus on the treatment effect. This allows us to make assertions about treatment effects over a larger area than if all plots were located in one ecoregion.

If the main effect of TREATMENT is statistically significant in the ANOVA (e.g., a p-value less than 0.10, or more stringent, $p < 0.05$), then we can follow up with a mean separation procedure (equivalent to a t-test between treatments). For example, we might use Fisher's Protected LSD for these "post-hoc" comparisons between treatment means. Post-hoc comparisons should only be done if the overall F-test is statistically significant—that's the "protection" for Fisher's LSD against increased Type 1 error rate (Type 1 error occurs when incorrectly rejecting the hypothesis of no difference, when there is no difference) due to multiple post-hoc comparisons.

The analysis of pre-treatment vegetation conditions is useful to verify that starting conditions among treatments is not different. We do expect some variability within and between sites (blocks), since it is often difficult to find large areas of uniform vegetation conditions on ROWs at the scale needed to study pollinators. Note that a "no difference" among treatments result could be either/both: the result of no actual difference (vegetation is all the same), and/or high variability among treatment plots within and across sites that obscures inherent differences. There are methods to (partially) address non-uniform pre-treatment conditions, such as "paired difference" tests (see post-treatment section) and covariate analysis (ANOVA with a pre-treatment covariate).

The same ANOVA approach should be used for post-treatment data analysis as used for pre-treatment data. However, for post-treatment analyses, it is often useful to analyze both post-treatment conditions and the difference (change) between pre- and post-treatment conditions (i.e., a "paired difference," where the pair is the plot pre- and post-treatment). For a paired-difference analysis, the same type of main effects ANOVA is run on the plot-level *mean difference* values (e.g., percent shrub cover post-treatment minus percent shrub cover pre-treatment, with positive values indicating an increase and negative values indicating a decrease), which will test if the *change* in vegetation condition differs among treatment. As noted above, the "paired difference" approach can be especially useful if there are initial differences among experimental units. The paired difference allows for testing the magnitude of change rather than total quantities.

Another possible approach to deal with high variability in initial starting conditions is covariate analysis. For example, if we found a strong correlation between glossy buckthorn density prior to treatment (especially if buckthorn was highly variable between treatment plots) and response in pollinator abundance post-treatment, we could potentially use pre-treatment glossy buckthorn density as a covariate in the ANOVA of pollinator abundance (i.e., add glossy buckthorn as an "effect" in the model for ANOVA).

At a minimum, the following should be included in the reporting of results for vegetation and insect/pollinator data:

- Table(s) of treatment means and standard errors (Table 2)
- ANOVA tables (Table 3)
- Figures/graphs of important results (Figures 1 & 2)

For both tables and figures, the captions should be adequately detailed to "stand alone" (i.e., one should be able to read the caption for just that figure or table, independent of the report narrative, and have adequate context to interpret the figure or table). For examples/templates for reporting results in these formats, please see Tables 2 and 3 along with Figures 1 and 2.

Height: <3 ft.

Treatment	Tree	Shrub/Short Tree	Rubus	Vine	Graminoid	Forb/herb	Fern	Nonvascular
Blue	2.1 (1.1)	16.7 (4.9)a	2.3 (1.1)	1.1 (0.2)	26.7 (4.8)	38.3 (5.0)	5.3 (2.0)	1.9 (1.1)
Pink	2.3 (1.0)	25.4 (6.1)a	3.3 (1.0)	1.6 (1.4)	16.4 (1.7)	36.8 (7.3)	5.6 (0.2)	4.4 (2.3)
Orange	3.8 (1.3)	29.5 (11.2)a	2.1 (1.0)	2.8 (1.5)	26.9 (13.5)	25.4 (5.2)	3.9 (0.9)	1.7 (0.8)

Height: 3-6 ft.

Treatment	Tree	Shrub/Short Tree	Rubus	Vine	Graminoid	Forb/herb	Fern	Nonvascular
Blue	1.0 (0.5)	17.8 (5.8)	0.3 (0.1)	0.3 (0.2)	10.9 (4.5)	19.7 (3.2)	1.2 (0.9)	0 (0)
Pink	1.3 (0.6)	31.9 (6.3)	1.1 (0.5)	1.0 (0.8)	4.2 (1.4)	19.9 (9)	0.4 (0.1)	0 (0)
Orange	1.7 (0.7)	27.6 (9.8)	0.5 (0.3)	1.1 (0.7)	11.9 (9.6)	12.1 (1.6)	0.2 (0.1)	0 (0)

Height: >6 ft.

Treatment	Tree	Shrub/Short Tree	Rubus	Vine	Graminoid	Forb/herb	Fern	Nonvascular
Blue	0.6 (0.2)	7.1 (5.5)	0 (0)	0 (0)	1.3 (0.8)	0.1 (0.1)	0 (0)	0 (0)
Pink	0.9 (0.6)	19.6 (7.9)	0 (0)	0.1 (0.1)	0.2 (0.2)	0.2 (0.2)	0 (0)	0 (0)
Orange	1.3 (0.4)	9.3 (2.3)	0 (0)	1.3 (1.3)	1.6 (1.6)	0.3 (0.2)	0 (0)	0 (0)

Table 2. Example of treatment mean and standard error (in parentheses) of percent cover by life form category prior to treatment (2017) in the NY case study (n=3 blocks). Height classes correspond to the strata sampled on quadrats within treatment plots. Treatments are designated by flagging color used in the field: Orange (operational treatment only removing incompatible trees using selective individual tree application of glyphosate-based herbicides), Pink (same as orange, plus mowing under the conductors), and Blue (mowing of entire plot). Note: if treatment differences were detected in ANOVA and post-hoc comparison, they can be designating using different letters.

Cover %: Shrubs/Short Trees <3 ft. height — ANOVA, Year: 2017

Effect	df	MS	F	p
Block	2	482	0.46	0.66
Treatment	2	129	0.12	0.89
Error	5	1,055		
Total	9	1,666		

Cover %: Graminoids <3 ft. height — ANOVA, Year: 2017

Effect	df	MS	F	p
Block	2	326	0.30	0.76
Treatment	2	107	0.10	0.91
Error	5	1,097		
Total	9	1,530		

Cover %: Forbs/herbs <3 ft. height — ANOVA, Year: 2017

Effect	df	MS	F	p
Block	2	49	0.02	0.98
Treatment	2	149	0.07	0.93
Error	5	2,129		
Total	9	2,327		

Cover %: Shrubs/Short Trees 3-6 ft. height — ANOVA, Year: 2017

Effect	df	MS	F	p
Block	2	416	0.34	0.73
Treatment	2	157	0.13	0.88
Error	5	1,233		
Total	9	1,807		

Cover %: Graminoids 3-6 ft. height — ANOVA, Year: 2017

Effect	df	MS	F	p
Block	2	210	1.06	0.41
Treatment	2	53	0.27	0.78
Error	5	197		
Total	9	460		

Cover %: Forbs/herbs 3-6 ft. height — ANOVA, Year: 2017

Effect	df	MS	F	p
Block	2	109	0.18	0.84
Treatment	2	59	0.10	0.91
Error	5	605		
Total	9	773		

Cover %: Shrubs/Short Trees >6 ft. height — ANOVA, Year: 2017

Effect	df	MS	F	p
Block	2	74	0.21	0.81
Treatment	2	133	0.38	0.70
Error	5	346		
Total	9	553		

Table 3. Example of ANOVA results for percent cover by life form category prior to treatment (2017) in the NY case study. Height classes correspond to the strata sampled on quadrats within treatment plots. Treatments were: Orange (operational treatment only removing incompatible trees using selective individual tree application of glyphosate-based herbicides), Pink (same as orange, plus mowing under the conductors), and Blue (mowing of entire plot).

CONCLUSIONS

We would like to remind readers that though these pollinator protocols have been based on the literature and implemented in two projects, they are still preliminary in nature. A full description of our preliminary protocol is available through the EPRI, with a final protocol to come out in fall of 2020.

The lack of consistent methodology for sampling across invertebrate pollinator taxa has led to a limited ability to make broad-scale conclusions. This document, and the protocol provided by EPRI, seek to generate conversation and standardization between ROW pollinator researchers in hopes of reaching a larger understanding of pollinator's response to ROW vegetation treatment across multiple habitats. In the same vein, we welcome inquiries, comments, and suggestions for improving our methodology as we seek to develop it within the coming years.

ACKNOWLEDGMENTS

We would like to thank the EPRI for funding our project—specifically, John Acklen and John Goodrich-Mahoney. We would also like to thank the New York Power Authority for their support and feedback—particularly Lewis Payne, Christopher Sherwood, and John Gwozdz. Finally, we would like to thank our outstanding undergraduate techs who have provided much appreciated support through this project.

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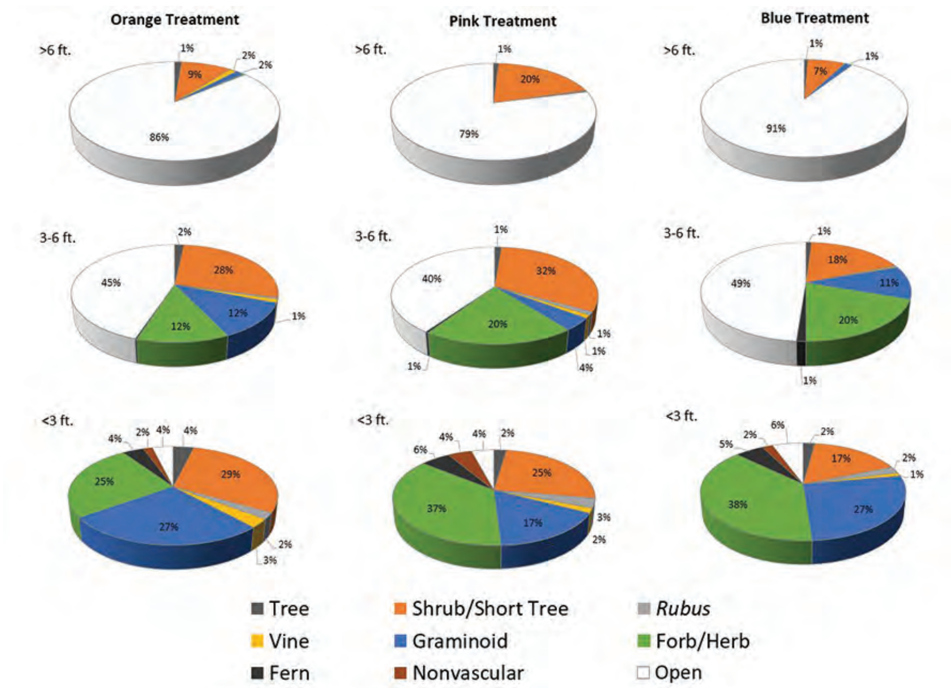

Figure 1. Example of average treatment percent cover by life form category prior to treatment (2017) in the NY case study (n=3 blocks). Height classes correspond to the strata sampled on quadrats within treatment plots. Treatments are designated by flagging color used in the field: Orange (operational treatment only removing incompatible trees using selective individual tree application of glyphosate-based herbicides), Pink (same as orange, plus mowing under the conductors), and Blue (mowing of entire plot).

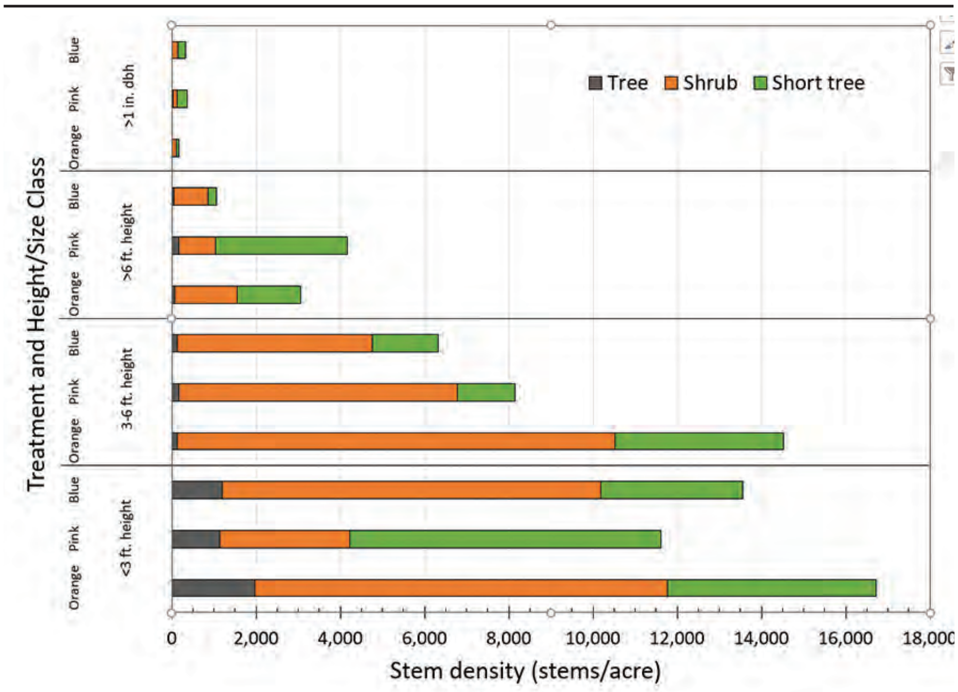

Figure 2. Example of average treatment stem density of woody plants, including shrubs, short-stature trees, and tall-growing trees by size class, prior to treatment in the NY case study (n=3 blocks). Size classes by height correspond to the strata sampled on quadrats within treatment plots. The >1-inch dbh (diameter at 4.5 ft above the ground) correspond to larger woody plants inventoried on transects. Treatments are designated by flagging color used in the field: Orange (operational treatment only removing incompatible trees using selective individual tree application of glyphosate-based herbicides), Pink (same as orange, plus mowing under the conductors), and Blue (mowing of entire plot).

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AUTHOR PROFILES

Jessica L. Van Splinter

Jessica L. Van Splinter is a graduate student at SUNY ESF pursuing a PhD in Conservation Biology. She is currently conducting research on pollinator promotion on powerline ROWs through VM with the support of a research grant from EPRI. She has been working in the labs of Dr. Nowak and Dr. Fierke for the past three years, contributing to research findings, technical reports, and fact sheets along the way.

Benjamin Ballard

Dr. Benjamin Ballard, is currently an Associate Professor of Renewable Energy at State University of New York (SUNY) Morrisville. Dr. Ballard has conducted research on ROWs for nearly 20 years with an emphasis on plant ecology and VM, including chemical and mechanical treatment efficacy and effectiveness, herbicide deposition patterns, and long-term effects of VM on plant community development, as well as contributed to the ongoing development of IVM. Recently, in addition to teaching in the renewable energy program at SUNY Morrisville, he has conducted research on exotic invasive species management on ROWs in Ohio and developed research protocols for pollinator research on ROWs in partnership with SUNY-ESF and EPRI.

Chris Nowak

Dr. Chris Nowak holds a PhD in Forest Resources Management from the State University of New York College of Environmental Science and Forestry, has been a Professor there for over 20 years, and recently became Department Chair. He currently teaches courses in forest ecology, silviculture, VM, and natural resources management, and has an active research program under all. Issues under his current study include: invasive species control; promoting pollinators on ROWs; regeneration ecology of woody plants; ecophysiology of American chestnut seedlings; ROW plant community dynamics; IVM systems; forest certification; and ROW Stewardship.

Melissa K. Fierke

Dr. Melissa K. Fierke, is an Associate Professor at SUNY ESF and has a PhD from the University of Arkansas in Entomology. She has previously conducted research, published on pollinators, and has successfully mentored 19 graduate students through MS and PhD programs. She has been collaborating with Dr. Chris Nowak on ROWs for two years, including this long-term study on pollinators for EPRI. She is also serving as Associate Chair of her department as well as Academic Governance Executive Chair.

sUAS Facilitate Cost-Effective Assessment Of Entanglement Hazards in Osprey (*Pandion haliaetus*) Nest Platforms

James F. Dwyer and
Michael C. Tincher

Keywords: Utility Lines, Human Use/Impact, Unmanned Aerial Systems (UAS), Drones.

Osprey (*Pandion haliaetus*) regularly incorporate synthetic polypropylene baling twine in their nests. This can create entanglement hazards, particularly for nestlings. When carried to power poles, this can lead to power outages, equipment damage, fires, and Osprey electrocutions. Removing baling twine could alleviate these concerns, but assessment of the presence of baling twine within nest cups where entanglement hazards are greatest is precluded by the difficulty of viewing nest contents from below. To evaluate a new technique potentially useful in identifying baling twine in nest cups, in 2017 and 2018, we used a small unmanned aircraft system (sUAS) to document the presence or absence of baling twine in 11 active and four inactive Osprey nests around Fort Collins, Colorado. Baling twine was visible in most nests (13 of 15; 87 percent) during at least one of our four surveys. In one nest, where an Osprey died of an entanglement-caused injury the year prior to our work, we observed twine inside the nest cup during every single survey. To minimize entanglement hazards for Osprey, users of baling twine (and of other sources of trash Osprey incorporate into nests) should be encouraged to collect and appropriately recycle or dispose of waste materials. Electric utilities could also consider annual removal from or cutting of baling twine in Osprey nests. Using a sUAS to check nest contents prior to accessing nests may make this more feasible by reducing time associated with accessing nests where no twine entanglement hazards exist.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

Osprey (*Pandion haliaetus*) routinely nest on man-made structures, including electric transmission structures, electric distribution poles, and nest platforms installed to redirect nesting away from power poles and equipment (Figure 1; APLIC 2006; Bierregaard et al. 2016; Dwyer and Tincher 2018). When constructing their nests, Osprey readily incorporate trash generated by humans living, working, or recreating within the bird's territories. Trash incorporated into nests includes baling twine, bait bags, beach toys, fishing line, nylon mesh, paper, plastic bags, and rope (Bierregaard et al. 2016; Blem et al. 2002; Houston and Scott 2006). We focus here on baling twine because twine's characteristics of synthetic polypropylene fibers woven together to create a durable, UV-resistant, high-strength, non-elastic cord designed to resist wear and weathering in natural conditions (Seacor et al. 2014) make it particularly dangerous to nesting and nestling Ospreys. When twine embedded in a nest entangles an Osprey, the engineered strength and wear characteristics prevent the bird from breaking free. The bird's subsequent movements within the nest cause the baling twine to increasingly constrict, binding the bird to nest if it cannot fly, leading to the bird hanging below the nest if it can fly, and cutting off blood flow to the entangled appendage.

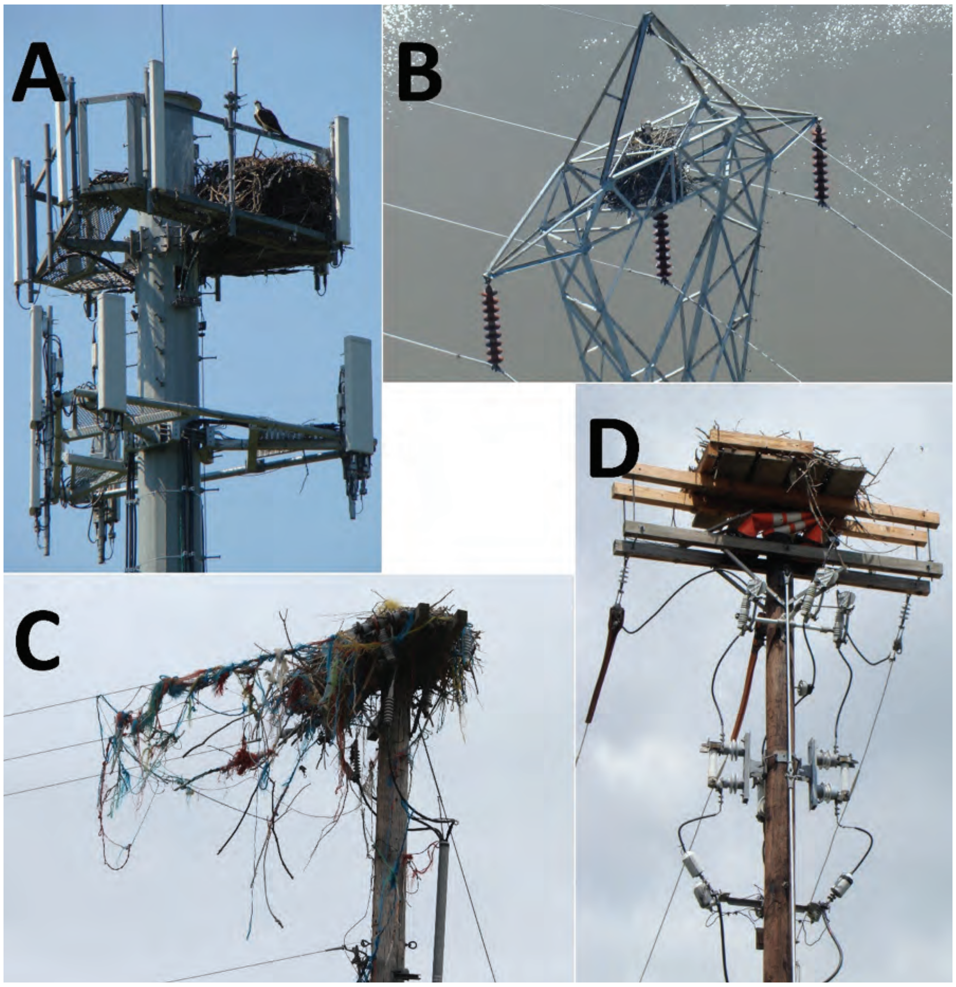

Figure 1. A) Osprey nest on cell tower. B) Osprey nest on lattice transmission tower. C) Osprey nest on distribution pole. D) Osprey nest on platform on distribution pole.

Baling twine entanglements of Osprey have been previously reported in scientific literature. For example, Montana Blem et al. (2002) observed 12 baling twine entanglements in 260 Osprey nests (five percent), including at least five entanglements resulting in mortalities. Seacor et al. (2014) found four of 120 Osprey nestlings (three percent) entangled in baling twine, also in Montana. Two entangled nestlings were extricated, but two died of baling twine-induced injuries. Houston and Scott (2006) found nine of 77 (12 percent) Osprey nestlings entangled in baling twine in a study in Saskatchewan. Houston and Scott (2006) extricated all entangled nestlings, but noted two nestlings likely died later of their injuries, as did one adult Osprey that was entangled and strangled by baling twine.

M.C. Tincher (unpub. data) removed two baling twine-entangled nestling Osprey from nests around Fort Collins, Colorado in 2016, and removed another in 2018. One of the 2016 birds had to be euthanized due to the extent of the injuries. The other was rehabilitated and released. In the 2018 case, the bird was an adult entangled by a single toe and found hanging below the nest (Figure 2). That bird was also rehabilitated and released, though both rehabilitated and released Osprey would have died without the intervention of the Rocky Mountain Raptor Program (Fort Collins, CO).

In our work using small unmanned aircraft systems (sUAS) for the electric industry (Gomez et al. 2018), and particularly in support of bird conservation within the electric industry (Lobermeier et al. 2015; Dwyer and Tincher 2018), we realized that sUAS may facilitate cost-effective assessment of entanglement hazards in Osprey nest platforms. We hypothesized that using sUAS may be useful because, although baling twine is readily observed from the ground around the outside of Osprey nests, the twine presumed most likely to entangle a bird (Dwyer and Tincher 2018) is inside the nest, not visible from the ground. Identifying the presence of baling twine inside the nest may not be practical if doing so requires the cost and labor investment of climbing poles or positioning a bucket truck. In the absence of knowledge of the presence of baling twine in nests, entanglement hazards to Osprey may persist even in situations where if the twine were known, it might be removed or cut to eliminate dangerous loops. To evaluate whether baling twine was present in the Osprey nests around Fort Collins, Colorado, we used a sUAS to view nest contents before and after the 2017 and 2018 breeding seasons.

Field Site Description

We identified 11 active and four inactive Osprey nests (collectively, "sites") in and around Fort Collins, Colorado from Wellington in the north, to Loveland in the south. Our study area included a mix of urban and rural habitats. For example, Fort Collins included 167,500 human residents within an area of 148 kilometers $(km)^2$ served by nearly 900 km of roads (City of Fort Collins 2017), but also included numerous natural areas used for conservation and recreation, and included agricultural fields used in commercial crop production. Of the 15 sites we studied, 14 were constructed supplemental platforms installed to redirect Osprey from nesting on nearby power poles. One nest was on a de-energized power pole. We did not find any Osprey nests on natural substrates (trees).

METHODS

The study reported here follows and builds on Dwyer and Tincher (2018), who in 2017 used a sUAS to survey 11 of the 15 sites described here. This study expands on the previous report by adding an additional year of observations, by adding four more sites, by adding a time series showing the presence and absence of twine in each nest over the course of four surveys, and by making the information more accessible to electric utility personnel. Dwyer and Tincher (2018) visited the sites on February 18, 2017 and 2018, prior to the spring arrival of Osprey in our study area, and again on September 9, 2017 and 2018 after Osprey dispersed from nesting territories (Dwyer and Tincher 2018). This survey timing ensured that Osprey were not present at the nest sites during sUAS missions prior to breeding seasons, and so could not be disturbed or displaced by our surveys, and ensured that if Osprey were present following the breeding seasons, they were no longer dependent on nest locations.

At each nest, we used a DJI Mavic or a DJI Phantom 4 Pro+ (Dà-Jiāng Innovations Science and Technology Co., Ltd., Shenzen, China) sUAS to fly 1-3 meters (m) directly above the nest, and used the aircraft's integrated camera to record multiple high-resolution photographs of the inside of the nest cup. We examined the images we collected to identify whether any baling twine was present within the nest cup, and for context, to also identify whether baling twine was present anywhere in or on the convex exterior of each nest, or on the nearest power pole to the nest. We defined nests as active if we could see changes throughout the upper surface of the nest, indicating that Osprey were regularly and consistently bringing new materials to the nest; The presence of a single new piece of twine was not sufficient to define a nest as active. This differs from a typical definition of nests as active if they contain eggs or young because we specifically avoided accessing nests while breeding was ongoing.

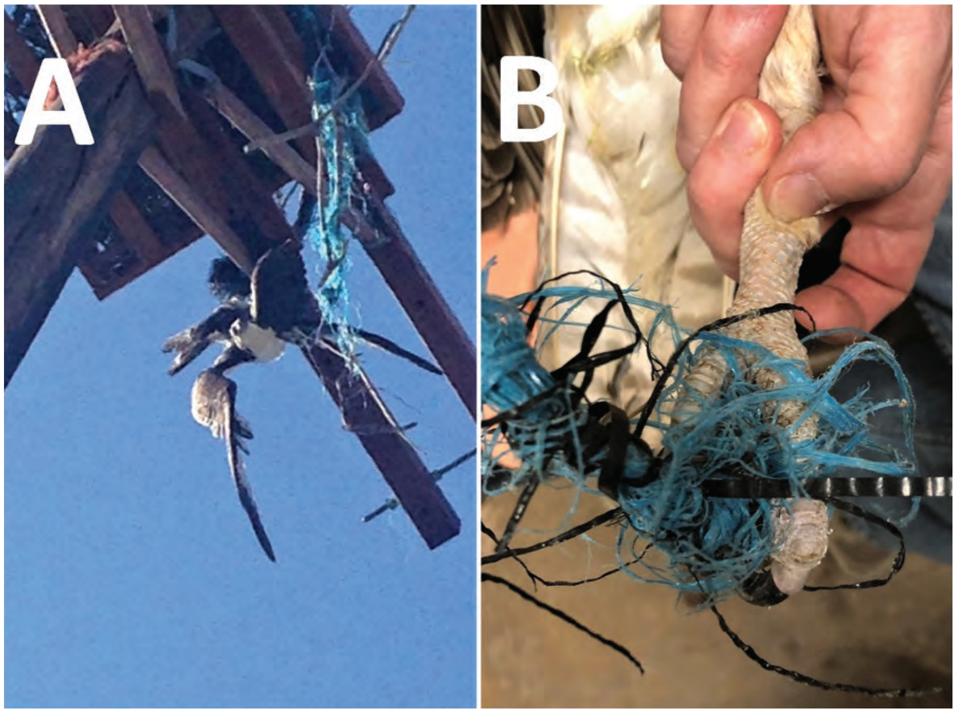

Figure 2. A) An Osprey entangled in baling twine at its nest near Fort Collins, CO (photo credit Frederick- Firestone Fire Protection District). B) Close view of baling twine wrapped around the foot of the bird in Figure 2A.

RESULTS

We visited 15 sites before and after the 2018 Osprey breeding season, including four sites that were not active during the 2018 season or during previous observations by Dwyer and Tincher (2018). In February, prior to the 2018 breeding season, we found three (20 percent) nests that included baling twine within the nest cup, 12 (80 percent) nests included baling twine outside the nest cup, and at three (20 percent), nests baling twine was present on the nearest power pole (Figure 3), though in no case was the twine in contact with energized equipment. In September, after the breeding season, five (33 percent) nests included baling twine within the nest cup, 12 (80 percent) nests included baling twine

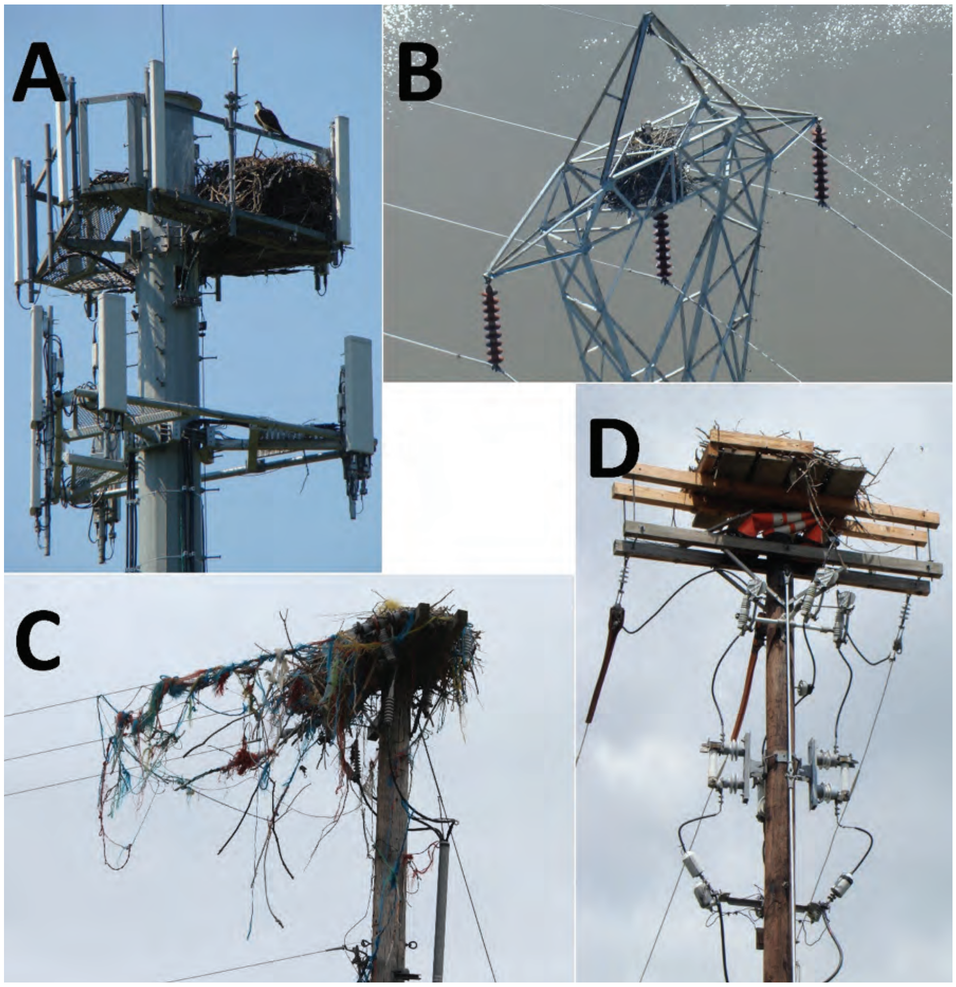

Figure 3. A) Active Osprey nest on nest platform with abundant baling twine incorporated throughout the nest. B) Active Osprey nest on deenergized power pole with baling twine suspended from transformers. C) Inactive Osprey nest with no baling twine. D) Active Osprey nest with small amounts of baling twine on the nest and on the adjacent energized power pole.

outside the nest cup, and at three (20 percent), nests baling twine was present on the nearest power pole.

We did not consistently observe twine in the same nests during all surveys. Rather, we observed increasing levels of twine in or on nests from the start of 2017 surveys through 2018 surveys (Table 1). Only some inactive nests lacked any twine during any survey; all active nests (and some inactive nests) included twine during at least one survey. Considering only twine observed inside nest cups, we only observed twine during every survey for a single nest, but we also observed twine within the nest cups during at least one survey in seven other nests. In 8 nests, we never observed twine inside the nest cup during any survey, though some of these nests had twine on the outside.

DISCUSSION

We used a sUAS to quickly and cost-effectively identify baling twine inside the nest cup of 40 percent of Osprey nests in and around the Fort Collins area. We also identified twine on the outside of additional Osprey nests (87 percent) in our study area, and on power poles adjacent to nests. This twine, particularly the twine inside the nest cup, poses entanglement hazards to nesting Osprey and to nestlings in the nests (Blem et al. 2002; Seacor et al. 2014; Tincher unpub. data). Osprey add nest materials to their nest throughout each breeding season and nestlings sometimes re-arrange nest materials either deliberately or by walking around in the nest (Bierregaard et al. 2016). We believe this explains why twine disappeared in some nests between surveys, as twine was brought to nests in some cases, or covered with other materials in other cases.

Ideally, the responsibility for addressing potential twine-related impacts to Osprey populations and electric utility reliability should be borne by twine users who should actively collect and recycle or dispose of used twine. Though electric utilities are unlikely to introduce twine into the environment, electric utilities may be perceived by the public as responsible for Osprey entanglements, twine-induced outages, and twine-caused electrical fires if any of these situations occur on power poles or on nest platforms installed to divert Osprey from nesting on power poles. Consequently, electric utilities with Ospreys in their service areas should consider implementing programs focused on actively identifying twine in Osprey nests and on adjacent poles, and cutting or removing that twine so it cannot create problems. Such a program is likely to be prohibitively time and resource intensive if it requires climbing a pole or using a bucket truck to look inside each Osprey nest, particularly given that most nests do not have twine within the nest cup—at least in our study area. Using a sUAS to conduct surveys may alter the cost-benefit ratio sufficiently to support a business case in which the costs of a single scheduled day of surveys, followed by targeted access to nests to remove or cut twine, may be less than the costs associated with waiting for an unscheduled callout to address a twine-caused emergency. Cutting loops of baling twine may be more effective than removal because cutting is likely more time and cost efficient and less likely to impact the overall structure of the nest within which baling twine is embedded (Dwyer and Tincher 2018). If organizations other than electric utilities installed a nest platform, those organizations could consider similar processes for taking responsibility for

Nest Number	Twine present anywhere in or on nest				Twine present inside nest cup			
	2017		2018		2017		2018	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
1	Present	Present	Present	Present	Present	–	–	–
2*	–	–	–	–	–	–	–	–
3	Present	Present	Present	Present	–	–	Present	Present
4	Present	Present	Present	Present	Present	–	Present	Present
5*	–	–	Present	–	–	–	–	–
6	–	Present	Present	Present	–	–	–	–
7	–	Present	Present	Present	–	Present	–	Present
8	Present	Present	Present	Present	Present	–	–	Present
9	Present	Present	Present	Present	Present	Present	Present	Present
10	Present	Present	Present	Present	–	Present	–	–
11	–	–	Present	Present	–	–	–	–
12	Present	Present	Present	Present	–	–	–	–
13	Present	Present	Present	Present	–	–	–	–
14*	–	–	–	–	–	–	–	–
15*	–	–	–	Present	–	–	–	–

*Indicates the nest has not been active during this study.

Table 1. History of small Unmanned Aircraft Systems (sUAS) records of baling twine anywhere in or on the nest (left) and only inside the nest cup (right) of 15 Osprey nests in and around Fort Collins, CO. Twine inside the nest is a subset of twine anywhere in or on the nest. Dashes indicate no twine observed during the survey indicated.

the potential unintended consequences of providing a nest platform.

We used a sUAS to collect photos which served as the foundation for this project, but we were unable to use the sUAS to solve the problem of twine in nests. Elsewhere in the electric industry, sUAS are transitioning from passive photo-platforms (Gomez et al. 2018) to active tools (Lobermeier et al. 2015). For example, sUAS are now capable of installing line markers on powerlines to reduce the risk of bird collisions with suspended wires (Figure 4). Given these developments, it may be possible to equip a small sUAS with an extension that could be used to cut loops of twine in nests without ever needing a person to physically enter the space. Such a solution could increase the time and cost efficiency of twine maintenance, and could enable twine maintenance of nest platforms isolated in wetlands where foot and vehicle access is impractical or impossible.

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AUTHOR PROFILES

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Dr. James Dwyer is a Certified Wildlife Biologist, a Part 107 certificated UAS pilot, and an environmental scientist at EDM International, Inc. with 15 years of experience using decision-relevant science and wildlife research to facilitate environmentally responsible electric utility, oil & gas, and industrial operations. He specializes in Avian Risk Assessments and Avian Protection Plans designed to mitigate negative interactions between wildlife electric utility systems at substations, on transmission lines, and on distribution systems throughout the U.S. and internationally. Dr. Dwyer also serves on the Board of Directors of the Raptor Research Foundation and has published more than 50 peer-reviewed scientific articles from his research.

Michael C. Tincher

Michael C. Tincher is the Rehabilitation Coordinator and a licensed raptor rehabilitator with the Rocky Mountain Raptor Program (RMRP). The RMRP admits more than 300 injured, ill, and orphaned raptors a year and services northeastern Colorado and eastern Wyoming. Tincher has 15 years of experience in the field of science based raptor rehabilitation and raptor banding. Tincher has participated in many research projects involving raptors that has included, but is not limited to, West Nile Virus monitoring, Avian

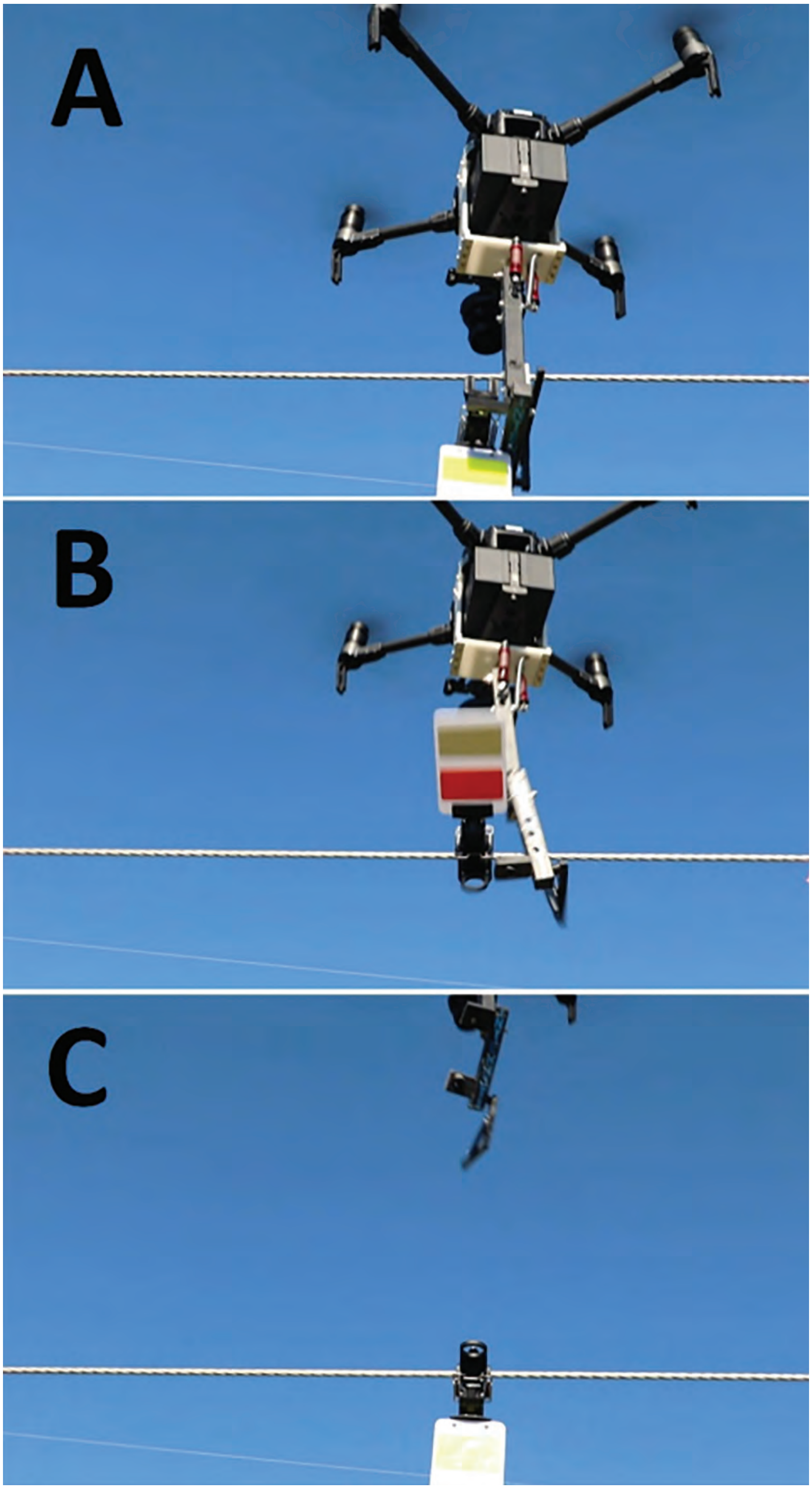

Figure 4. The authors piloting an UAS to deploy a line marker on the overhead shield wire of a powerline.

Influenza surveillance, and several different biometric studies involving multiple raptor species. He has also been involved in various studies at the RMRP to assess different power structure deterrents and configurations to mitigate raptor electrocutions. He has co-authored several articles about this work. He also works as liaison with wildlife agencies, energy entities, and the general public to rectify human/raptor conflicts.

The Effect of VM Approaches on Electric Transmission ROWS on Bees Pre- and Post-Treatment

Carolyn G. Mahan,
Brad D. Ross,
Hannah Stout, and
Dana Roberts

Powerline rights-of-way (ROW) must be managed to maintain early successional habitat, preventing vegetation from interfering with electrical lines. Thus, the area within ROWs has potential to provide conservation benefits for wild pollinators. Moreover, it is possible to provide conservation benefits with no additional cost to land managers if we identify the right management strategy. We surveyed flower-visiting insects in different vegetation management (VM) treatments in a long-term research ROW to determine which provides the best promoted pollinator abundance and species richness. We learned that the ROW had stabilized in an early successional state soon after its establishment and that this early successional state could be maintained with low levels of periodic maintenance. We collected a high diversity (96 bee species and 179 non-bee morphospecies) in six ROW sites. Our results suggest selective, low-volume herbicide applications may promote high pollinator abundance and species richness. This survey also shows that long-term maintenance of ROW habitat has the potential to support many wild pollinator species. Our results suggest further research into the conservation value of ROW for pollinators is warranted.

Keywords: Bees, Pollinators, Rights-of-Way (ROWs), Vegetation.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

This research is a continuation of a project that began in 1953, when researchers at the Pennsylvania State University designed an initial study to test the effects of herbicides and other vegetation management (VM) approaches on natural resources, including plant communities and various wildlife groups (Bramble and Byrnes 1983) in electrical ROW. The project was initiated on State Game Lands (SGL) 33 in Centre County, Pennsylvania with several partners, including Pennsylvania Electric Company (now First Energy Corp.), the Pennsylvania Game Commission, DuPont, AmChem (now Dow AgroSciences), and Asplundh Tree Expert Co. The year 2018 marked the 65th year of the original study, making SGL33 the site of the longest continuous study measuring the effects of herbicides and mechanical vegetation management (VM) practices on plant diversity, wildlife habitat, and wildlife use within a ROW.

For 65 years, multiple methods of VM were evaluated side by side to determine the effects on floral and faunal communities on a ROW at SGL 33 and GLR&D. Manual (and later, mechanical) brush cutting was compared to the use of herbicides in their effectiveness at controlling vegetation. Different types of herbicides and various means of application were also evaluated. Initially, at SGL 33, six mechanical and herbicidal treatment sites (with replicates) were established. These legacy treatments included: hand-cutting (HC), mowing (M), mowing plus herbicide (MH), foliage spray (F), stem foliar spray (SF), and basal low volume (BLV) (to be precise, basal high volume was used before BLV). Despite these general treatment approaches, actual vegetation treatments are adaptive and based on integrated VM (IVM). Therefore, treatment labels and terminology may not reflect *actual* recent treatment applied—creating some confusion. In general, sites are visited and "reset" once every four to six years based on IVM prescriptions with mechanical and chemical treatments applied in order to maintain an early successional stage of vegetation within the ROW. The objective of this research was to document bee richness in terms of taxa (morphospecies) occurrence on various treatment sites in the growing season (May–August) after a treatment.

METHODS

Bees were sampled at a small subset of treatments plots at SGL 33 as follows:

- F2 (Foliage spray; Legacy site name) = High volume foliar (HVF); HVF treatment in 2016
- SF2 (Stem foliar; Legacy site name) = Ultra low volume foliar (ULVF); HVF treatment in 2016
- MH3 (Mow plus herbicide; Legacy site name) = Mow cut stubble (MCS); ULVF treatment in 2016
- MH1 (Legacy site name) = Mow cut stubble (MCS); ULVF treatment in 2016
- BLV3 (BLV; Legacy site name) = Low volume basal (LVB); LVB treatment in 2016
- HC1 (Hand cut; Legacy site name) = HC; HC treatment in 2016

Bee surveys were conducted for two consecutive days per month for four months (May–August 2017). To account for potential bias caused by sampling in the morning versus in the afternoon, the order of visiting sites alternated between the two monthly collection dates. Bee survey sites were situated consecutively along the ROW, allowing for collectors to rotate between one set of three sites in the morning, and one set of the other three sites in the afternoon. On each field day, each collector used aerial nets and aspirators to collect Hymenoptera (or suspected Hymenoptera) from flowering vegetation within the 50 meter (m) by 25 m active collection area at each of the survey sites. For each field day, one net hour was spent at each of the six survey sites. "Net hours" are the total amount of time spent sweep net sampling at one site by all collectors (e.g., one collector netting at one site for one hour—two collectors netting at one site for 30 minutes). A total of eight net hours were spent at each of the survey sites—four hours of morning collections and four hours of afternoon collections.

All sample processing and sorting was performed by one entomologist (Dr. Stout) and two assistants (John Berger and Brad Ross), from September 19, 2016 to February 14, 2017. Bees were pinned, then sorted by Site (e.g., SGL 33), Plot (e.g., F2), Month, and Time of Day (TOD) (a.m. or p.m.). Each Site/Plot/Month/TOD group of bees was counted, and a corresponding number of Site Labels and Identifier Labels were created. For each group, all information from both labels was entered into a separate Excel worksheet. It was only after all of the bees were pinned and sorted that each was labeled with Site and Identifier Labels. This sequence of actions ensured that numerical sequences of Identifier Label numbers were assigned to specific groups of bees which helped to ensure accuracy.

RESULTS

In most of the world, "bees" are a group of insects comprised of six Hymenoptera Families:

- Andrenidae (mining bees)
- Apidae (cuckoo/carpenter/digger bees, bumble bees, and honey bees)
- Colletidae (plasterer bees and masked bees)
- Halictidae (sweat bees)
- Megachilidae (leaf-cutter bees and mason bees)
- Melittidae (oil-collecting bees—rare.)

VM treatments were performed at SGL 33 in August 2016; therefore, 2016 collections represent a "pre-treatment" state, and 2017 collections represent a "post-treatment" state. Major differences in bee families collected, total number of bees, and relative abundance of bees pre- and post-treatment are as follows:

2016—All six bee Families were collected at one SGL 33 plot (MH1). Five of the six bee Families were collected at four plots, and four Families were collected at one plot. Melittidae was only collected at MH1.

2017—All six bee Families were collected at one SGL 33 plot (F2). Five of the six bee Families were collected at the five remaining plots. Melittidae was only collected at F2.

2016—1,056 bees representing 95 taxa (morpho-species) from the six SGL 33 plots.

2017—1,288 bees representing 110 taxa (morpho-species) from the six SGL 33 plots.

2016—Bees from the Family Apidae comprised 44.1 percent of all bees collected at SGL 33 (N=466). *Apis mellifera*, the European honey bee, comprised 21.4 percent of the total collection (N=226).

2017—Bees from the Family Apidae comprised 52.9 percent of all bees collected at SGL 33 (n=681). *Bombus impatiens*, the common eastern bumble bee, comprised 21.4 percent of the total collection (n=276).

Taxa richness was greatest at BLV3 in 2016 and MH3 in 2017, but lowest at HC1 during both years.

DISCUSSION

The greatest abundance of bees was at BLV3—most of which were of one species, *Bombus impatiens*, the common eastern bumble bee. This bumble bee is a ubiquitous, generalist bee that is active all season long, and is known for dwelling within extraordinarily large nests.

Halictidae had the greatest richness of the six bee Families, due largely in part to its large number of "singletons" (one individual of one species). MH3 had the greatest richness, but it also had 13 *Lasioglossum* singletons, which could skew these results.

The "yellow bumble bee," *Bombus fervidus*, which is listed as "Vulnerable" on the IUCN Red List of Threatened Species (*iucnredlist.org*), was collected, and a SGL 33 treatment plot (MH3). A rare oil-collecting bee, *Macropis ciliata*, was also collected, but this time at F2. This species belongs to a family of bees that visits only loosestrife flowers. Specialist bees such as these are usually not as abundant as generalists and are especially vulnerable to threats such as habitat loss. Nine specialist bee species were collected at all six sites at SGL 33 in 2017.

More bees and more bee taxa were collected in 2017 than in 2016. As noted earlier, large social bee nests and numerous singleton species could be a factor. The apparent decline in richness at BLV3 from 2016 to 2017 could be due to the large *B. impatiens* population present there.

It is interesting to note the apparent shift in dominant taxa per plot from 2016 to 2017. In 2016, *Apis mellifera*, the European honey bee, was the dominant taxon for five of the six plots. In 2017, *A. mellifera* was not even collected at three of the six plots, and was not the dominant taxon at the three plots at which it was collected. For 2017, each plot had its own unique dominant taxon: *Bombus bimaculatus*, the two-spotted bumble bee (F2), *Andrena virginiana*, the Virginia mining bee (SF2), *Ceratina dupla*, the doubled small carpenter bee (MH3), *Lasioglossum cressonii*, Cresson's Dialictus sweat bee (MH1), *Bombus impatiens*, the common eastern bumble bee (BLV3), and *Augochloropsis metallica fulgida*, a green metallic sweat bee (HC1). *Andrena virginiana* was the dominant taxon for SF2 in 2016 and again in 2017.

CONCLUSIONS

Given the results of our 2016–2017 SGL 33 bee collections, "treatment effects" on bee abundance, richness, and diversity are not readily apparent. However, our results suggest selective, low-volume herbicide application may promote high pollinator abundance and species richness. Interpretation of the results is especially difficult because these are uncharted waters. Dozens of studies on bee diversity at transportation corridors and utility ROWs have been done, but none before have compared bee populations with the different VM methods used at these clearings, nor have any previous studies attempted to elucidate how these different methods may directly or indirectly affect bees. Our bee survey does indicate that long-term maintenance of ROW habitat has the potential to support many wild pollinator species.

With our 2016 and 2017 bee surveys at SGL 33 and with future studies at these and additional sites, we are laying a foundation of knowledge that will one-day help to answer the question about what vegetation treatment approach is best for bees.

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Carolyn Mahan

Dr. Carolyn Mahan is a professor of biology and environmental studies at Penn State Altoona. She has a PhD in Wildlife Science from the Pennsylvania State University and a Bachelor's degree from the University of Connecticut. Her research interests include the study of biodiversity in threatened ecosystems, the effects of human-modified landscapes on wildlife, and behavioral ecology of squirrels and other rare rodents (e.g., Allegheny woodrat, short-tailed chinchilla, northern flying squirrel). Her work has been published in a variety of scientific journals including *Environmental Management, Global Change Biology, Conservation Biology, Journal of Mammalogy*, and *Journal of Wildlife Diseases* among others. Dr. Mahan has secured more than $2.5 million dollars in external and internal research funding. Funding sources include the U.S. Department of the Interior, U.S. Fish and Wildlife (USFWS) Conservation Agencies, Pennsylvania Department of Conservation and Natural Resources (DCNR), the Pennsylvania Game Commission, the Hamer Foundation, Penn State's Huck Institute for Life Sciences, and Asplundh Tree Expert Company. Dr. Mahan has served on the board of directors of the Pennsylvania Wildlife Society, the Center for Private Forests, and The ClearWater Conservancy. She is past-president of the Pennsylvania Biological Survey. She currently serves on Governor Tom Wolf's Advisory Council for Natural Resources.

Transmission ROW Biosecurity Management in Queensland, Australia

Stephen Martin

Keywords: Biosecurity, Coordination, Weeds, Collaboration, Invasive Species.

Australia is famous for its unique wildlife and flora that has flourished as a result of millions of years of isolation. Post-European settlement has, however, since resulted in a widespread increase in invasive species, which pose threats to ecological and agricultural systems. Globalization and mobility associated with our modern way of life are placing increasing pressures on these systems.

Biosecurity threats (i.e., those organisms that potentially threated natural and agricultural ecosystems) are intrinsically difficult to control, requiring coordinated and sustained efforts to be successful. Network businesses—like those involving electrical transmission and oil pipeline industries—face this difficulty on a daily basis, with assets that traverse the landscape, crossing ecosystem, catchment, property, and political boundaries. Network businesses in isolation have no chance at success, and with increasing pressures to realize efficiencies, considerable resources could be wasted if they are not linked to broader control programs and initiatives.

The outcomes of work involving a series of four pest species in the agricultural landscape of the Surat Basin in southwest Queensland illustrated the importance of sharing information and resources to effectively manage regional biosecurity concerns. The area was largely free of biosecurity threats, with landowners concerned about the potential for new threats being introduced through pipeline and transmission line construction activities.

The establishment of a community-led collaboration network attempted to bridge some of the gaps that were present. The collaboration network was successful in bringing together landowner, industry, consultants, government, and environmental groups to discuss and help resolve key regional issues, during a period of rapid change, with coal seam gas expansion and investments in supporting infrastructure.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

INTRODUCTION

As linear assets that traverse the landscape, transmission lines cross catchment, electoral, property, and vegetation community boundaries. While not responsible for introducing biosecurity threats into the country, network businesses face the challenge of not contributing to the further spread of threats to ecological, agricultural, and economic systems.

Powerlink has a long-established network of vehicle cleaning facilities that supplement public and private facilities. Such facilities can include combinations of water, vacuums, and air cleaning options, depending on the location. Martin et. al. (2005) shared Powerlink's design parameters with stakeholders across the state and has made investments into public vehicle cleaning facilities for broader public benefit.

Low (2001) states:

> "Unfortunately, we can't do much about the pests already here; most of them are unstoppable. No matter how much we tried we could never destroy every spore, egg, or seed."

Legislative changes in 2014 have promoted a risk-based approach to be adopted by all those involved in managing biosecurity threats. Current control measures have often advanced in accordance with evolving landowner concerns. For example, regional natural resource management groups and local governments (City of Townsville 2017) are applying risk ratings on biosecurity threats at a landscape level to assist with prioritizing and coordinating limited resources. Such an approach is needed to consolidate control measures based on science and risk, while engaging with the broader community.

QESI Code includes biosecurity requirements within protected areas and Energy Networks Australia (ENA 2008) provides guidance at a national level. Both promote an integrated pest management approach with a focus on prevention.

DISCUSSION

The analysis of various case studies experienced by Powerlink Queensland has been used as examples of biosecurity management in Queensland, although they may not be representative of broader issues experienced across Australia.

Risk management, coordination, and collaboration are key elements of biosecurity management. Their absence results in ineffective and inefficient outcomes.

Risk Management

Environmental work plans (EWPs) are a spatial rendition of Powerlink's network, including environmental, landowner, and property information to assist with accessing assets. It includes the distribution of biosecurity threats, location of cleaning facilities, and access restrictions.

As a general principle, work is scheduled to progress from "clean" areas to "dirty" areas, where this does not conflict with other requirements with the objective of not moving threats into clean areas. Managing biosecurity threats associated with easements and access is a joint management responsibility, with a preference in working with landowners with formal management plans in place that are coordinating their efforts with neighbors and natural resource management organizations. Work is progressing to establish management zones based on risk, coordination, and the distribution of biosecurity threats to consolidate entry and cleaning requirements.

Education and awareness for weed identification and cleaning requirements are implemented with staff and contractors. Fact sheets are attached to EWPs and an online plant identification tool (P-List) is available for staff and contractors.

Notifications are raised in asset management systems (SAP) to flag the presence of biosecurity threats with priority ratings applied based on the risk of spread from Powerlink's activities. More frequent inspections are scheduled for cleaning facilities that are in strategic locations to ensure they are functioning as designed. Theft in some remote locations is an issue, particularly for attractive items like water pumps.

Powerlink cleaning facilities, as described in Martin et al. (2005), are installed to supplement the network of publically and privately owned and operated wash down facilities across the state. In some instances, Powerlink contributes to the installation and upgrade of publicly available facilities, particularly associated with construction activities in a new area.

Public cleaning facilities are typically owned and operated by local governments. They are open to the public and sometimes have cost recovery charges associated with their use. Typically designed to accommodate all types of vehicles, equipment, and conditions, these facilities are often popular with waiting periods to gain access.

Commercial cleaning facilities are typically owned and operated by private businesses. Their use is limited to standard 2WD and 4WD passenger vehicles in reasonable condition for the most part, not allowing trucks or vehicles coated heavily in mud.

Efficacy of cleanings have been evaluated by Atkins et al. (2011), finding that weed seed build-up on vehicles are dependent on seasons, vehicle design, type of cleaning, duration of the cleaning, and the type of soil traversed. Cleaning facilities with fixed jets, as illustrated in Figure 1, were only found to be effective as a loosening process with additional hand cleaning required to remove all weed seeds. Mud with high clay content took 20 minutes in order to remove all foreign material, while mud with high sand content achieved similar results in five minutes.

A review of cleaning facilities required across the state is underway, which is considering their use, proximity to changes in biosecurity threats, availability of alternative cleaning facilities, and community priorities. The review is designed to coincide with process changes to implement consistent record-keeping and risk management.

Figure 1. Commercial cleaning facility with fixed jets

Coordination

Powerlink's expansion in the Surat Basin in southwest Queensland to meet customer demand for high-voltage network connections followed years of liaisons between the community and the coal seam gas industry. This resulted in heightened interest in biosecurity management and conditions on entering properties. New biosecurity legislation was being drafted at the same time, with community consultations and workshops held by agricultural industry associations to assist members in adapting to the proposed changes.

Community consultation through the planning phase of the network expansion revealed a gap in processes, which resulted in the development of "biosecurity access protocols" (BAP). This was designed to engage with landowners during the planning phase when the biosecurity threats were unknown, and to ensure biosecurity threats were not inadvertently spread through initial survey and planning activities.

The BAP would no longer apply and would be replaced by EWPs once biosecurity threats were known and mapped, and risk-based control measures established. However, some confusion was introduced with newly developed "Land Access Protocols" (LAP), which were designed to capture landowner requests and conditions of entry. Biosecurity-related conditions were added to LAP agreements with landowners, which now present on-going constraints on maintenance activities.

Collaboration

Support for the regional Weed Society representative, Ursula Keating, was provided by Powerlink in an effort to improve coordination and risk management. A collaboration network was established and was successful in bringing together landowners, industry consultants, government, and environmental groups to discuss the key issues to the region during a period of rapid change.

A weed identification booklet, application, and a regional map of known outbreaks and potential movement of these threats were funded by Powerlink as a community investment. Additional community investments were made in public cleaning facilities in the region. Weed surveys undertaken before and after construction activities also informed Powerlink's specific control measures.

These investments and actions resulted in the timely construction of transmission network assets to meet customer requirements.

Species-Specific Case Studies

Parthenium hysterophorus is a now common exotic, invasive weed across large sections of central Queensland with scattered outbreaks in other parts of the state. The attributes of the seeds allow easy attachment to vehicles, and thus high risk of transport across wide areas. Being an annual plant also means that detecting the presence of the plant is difficult at certain times of the year.

Eradication in densely infested areas is not considered feasible by regulators with various programs failing to remove the plants from the landscape once introduced. However, avoiding already-infested areas to limit the further spread of the weed is considered whenever there is a network expansion. There is a broader, coordinated community approach to eradicate the weed where outbreaks are more scattered, often supported by Powerlink.

Panama disease (*Fusarium oxysporum*) has only recently been detected in tropical north Queensland. It has potential to drastically reduce banana production through a fungus entering plants through their root systems that block the plant's vascular system. Once present in the soil, the fungus cannot be eradicated and can survive in the soil for decades without host plants. The biosecurity threat is easily spread by movement of contaminated soil, water, and plant material.

Powerlink has transmission network assets in the general area, but none where the panama disease has been discovered. A Powerlink-installed cleaning facility in the area has become an essential part of the containment program, enabling regulators to clean vehicles and equipment before leaving the area. Powerlink has been acknowledged for its contribution in the containment efforts by Biosecurity Queensland (2018).

As another example, fire ants (*Solenopsis invicta*) were first discovered in Australia in 2001 in southeast Queensland. The State Government quickly established a detection and eradication program with specific regulatory provisions established to support the efforts of detecting and eradicating this threat, which Powerlink supported. As a government-owned utility, key staff were trained as inspectors with the ability to declare materials fire-ant-free.

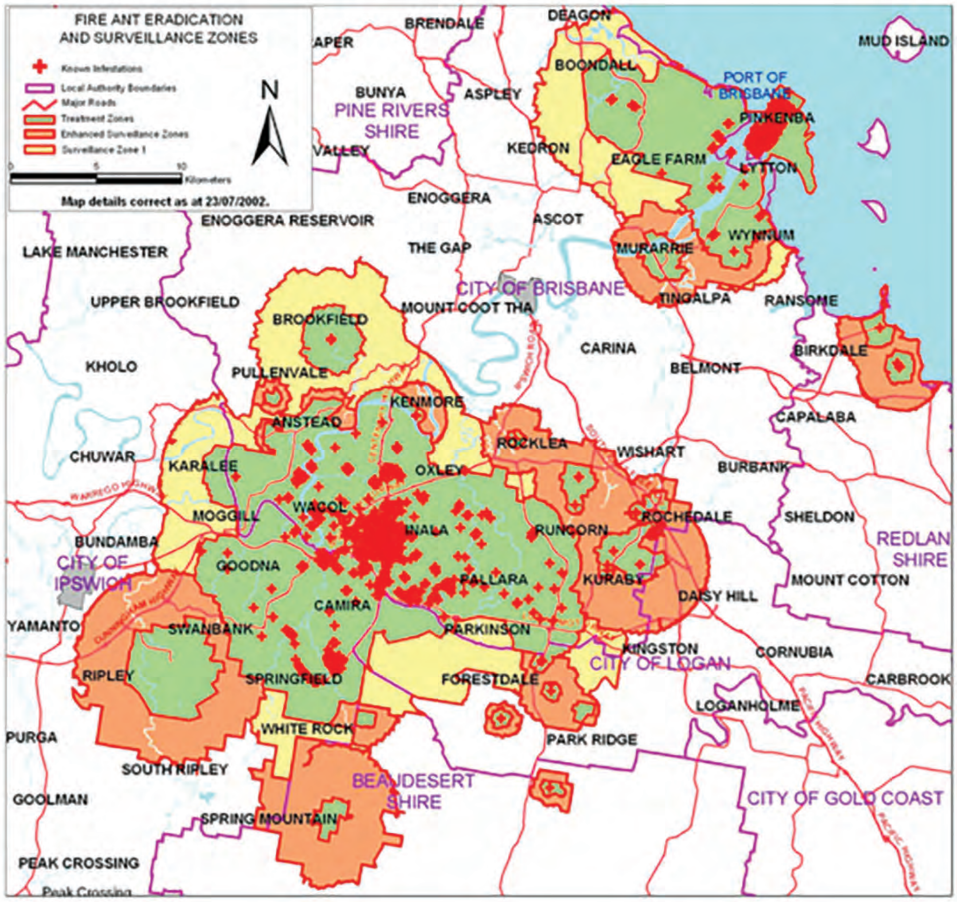

Figure 2. An early distribution map of Fire Ants with different management zones

Biosecurity Queensland soon discovered fire ants were no longer isolated and were becoming more widespread. Consequently, management zones were established around identified nest areas and treated, as illustrated in Figure 2.

Since 2001, Powerlink has detected several outbreaks near transmission network assets, which have been reported to Biosecurity Queensland. This has triggered rapid responses and treatments with ongoing monitoring to determine if treatments have been successful.

The management of fire ants as a biosecurity threat are now integrated into broader biosecurity regulation. The program has been successful in containing and restricting the spread of fire ants in Australia, but has not realized the initial plans of eradication.

Siam weeds (*Chromolaena odorata*) were first discovered in Australia in 1994 in tropical north Queensland. Some occurrences of siam weed have been found near Powerlink transmission network assets and Powerlink has supported the coordinated efforts of Biosecurity Queensland and Local Government to detect and eradicate the weed.

With a similar form to *Lantana camara* that is long established in Australia, it is thought that siam weed was present long before it was detected. This is supported from survey results coordinated by Biosecurity Queensland, which established its presence across large areas of northern Queensland following its initial detection. Based on these survey results, plans to eradicate siam weed were re-evaluated with a focus now on containment.

A similar, but more localized, instance of candy leaf (*Stevia ovata*) was discovered in north Queensland. Powerlink supported the investigations into its origins and subsequent control measures to contain its occurrence in the landscape.

CONCLUSIONS

Powerlink's risk management approach to biosecurity management is founded on the EWPs to document the presence of threats, control measures, and the location of cleaning facilities.

Applied research continues to be supported by Powerlink, with current research investigating the efficacy of herbicides for controlling introduced *Sporobolus* grass species and their persistence in the environment. This is being performed in partnership with state regulator Biosecurity Queensland to assist in determining if withholding conditions on the label of certain herbicides are supported by science.

Until the research has concluded, Powerlink has ceased the use of certain herbicides on easements.

A coordinated and risk-based approach is essential for successful biosecurity management. Powerlink's approach is to support the management of risks at a landscape level with appropriate investments for the public to collectively manage the risks. Where relevant parties don't coordinate their efforts, the results are not as effective or efficient.

Powerlink is taking an appropriate risk management approach to managing biosecurity threats. No single approach will eliminate the risks once the biosecurity threats have been introduced into the environment, but Powerlink is well positioned to effectively mitigate risks from its business activities in conjunction with the broader community.

ACKNOWLEDGEMENTS

Powerlink has provided me with many opportunities to gain knowledge and experience across a broad range of disciplines relating to land assets. My ability to contribute this paper is the result of their investment in me and land assets throughout an extended period of time.

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AUTHOR PROFILE

Stephen Martin

Martin is actively involved in knowledge-sharing, which is demonstrated through his involvement in various industry bodies, such as the Energy Network Association Vegetation Management (VM) Working Group. Presenting at the Right-of-Way (ROW) Symposium will fulfill a lifetime goal and ambition.

In addition to his lengthy experience within the electricity industry, Martin has worked for State Government in advising on land care and soil conservation practices, and has also been a director of a small consultancy business.

Martin is currently Land Strategist for Powerlink Queensland, which includes setting policy, monitoring performance, liaising with stakeholders, and identifying efficiencies during a period of significant change. He looks forward to providing some insights into biosecurity management in Queensland, Australia.

VM for the Trans Mountain Pipeline ROW and Strategic Measures to Avoid and Mitigate Disturbance to Oregon Forestsnail (*Allogona townsendiana*)

Selena Shay

Keywords: Aestivation, Oregon Forestsnail, Species At Risk Act (SARA), Stinging Nettle, Trans Mountain Pipeline (TMPL), Tree Inventory, VM (VM), Salvage, Relocation.

Environmental Concerns in Rights-of-Way Management
12th International Symposium

Trans Mountain Canada, Inc. operates the Trans Mountain Pipeline System in accordance with the federal National Energy Board (NEB) Act, Onshore Pipeline Regulations. Vegetation management (VM) for the Trans Mountain Pipeline (TMPL) right-of-way (ROW) is integral to monitoring and surveillance, integrity maintenance, and emergency response.

VM was required for a 1.4-kilometer (km) segment of the TMPL ROW on federal lands where Oregon Forestsnail (*Allogona townsendiana*) was present. The species is listed as "endangered" under the federal Species at Risk Act (SARA). The SARA protects listed individual organisms, their residences, and critical habitat on federally administered lands. VM required authorization from Environment Canada and Climate Change under Section 73 of the SARA for affecting a listed species.

Trans Mountain's VM plan was developed with strategic measures to avoid and mitigate direct and indirect impacts to Oregon Forestsnail. Works were scheduled during the species' dormancy period to minimize potential for encountering snails. Salvage and relocation was conducted to avoid harm to snails. Management prescriptions were modified and the works were conducted with specialized methods to avoid and minimize disturbance to biophysical attributes of critical habitat. Follow-up surveys determined survivorship of relocated snails and whether individuals dispersed back to the Trans Mountain Pipeline (TMPL) ROW to assess the effectiveness of salvage as a mitigation measure. Survival of marked snails and their continued persistence on the TMPL ROW suggest that VM does not appear to cause residual impacts that adversely affect the Oregon Forestsnail.

INTRODUCTION

The Trans Mountain Pipeline (TMPL) is a 1,147-kilometer (km) interprovincial pipeline that has been operated since 1953, which transports crude and refined oil from Edmonton, Alberta to the west coast of British Columbia (BC), Canada (Figure 1.0). As an interprovincial pipeline, Trans Mountain Canada, Inc. (Trans Mountain) is required to operate the TMPL system in accordance with the federal National Energy Board (NEB) Act, Onshore Pipeline Regulations. Trans Mountain is mandated to maintain above-ground identification, sight lines, and aerial surveillance capabilities along the TMPL right-of-way (ROW) for locating and accessing the pipeline for monitoring and inspections, integrity maintenance, and emergency response. These regulatory safeguards are in place to ensure the integrity and safe operation of the pipelines and to protect the public and the environment.

Vegetation management (VM) is an integral component of Trans Mountain's Operations and Maintenance program. Regular VM is required to maintain annual growth to prevent obstructed access and sight lines and canopy encroachment from treed perimeters, especially through undeveloped forested terrain. Trans Mountain's VM activities are conducted with due consideration of environmental sensitivities through its Environmental Protection Program. Works are conducted with acquisition of necessary regulatory permits and implementation of standards and best practices to avoid adverse impacts to instream, riparian, and terrestrial habitat values.

Transmission line corridors have been identified to provide important early successional habitats for a taxonomically rich array of invertebrates, native plants, and animal life, including populations of rare species (Wagner et al. 2014). Historical VM of the TMPL ROW, especially through forested areas, has maintained early successional habitat and abiotic features unique from surrounding areas. Oregon Forestsnail (*Allogona townsendiana*) is listed as "endangered" under Schedule 1 of the federal Species at Risk Act (SARA) and its occurrence is restricted to the Lower Mainland and Fraser Valley in the southwestern corner of British Columbia (BC) (Figure 2.0). The presence of Oregon Forestsnail is correlated with the presence of stinging nettle (*Utica dioica*) (MOE 2018). Stinging nettle appears to have high importance to Oregon Forestsnail populations for mating and egg-laying. Consumption of stinging nettle is likely needed for shell growth, as the plant contains high levels of calcium and other minerals needed to maintain shell durability (MOE 2012).

Trans Mountain has documented Oregon Forestsnail presence at various locations within the TMPL ROW, where it traverses through the species' geographic range. Where snails are present within the TMPL ROW, they are

Figure 1.0. Alignment of the 1,147-km TMPL System from Edmonton, Alberta to Burnaby, BC, Canada

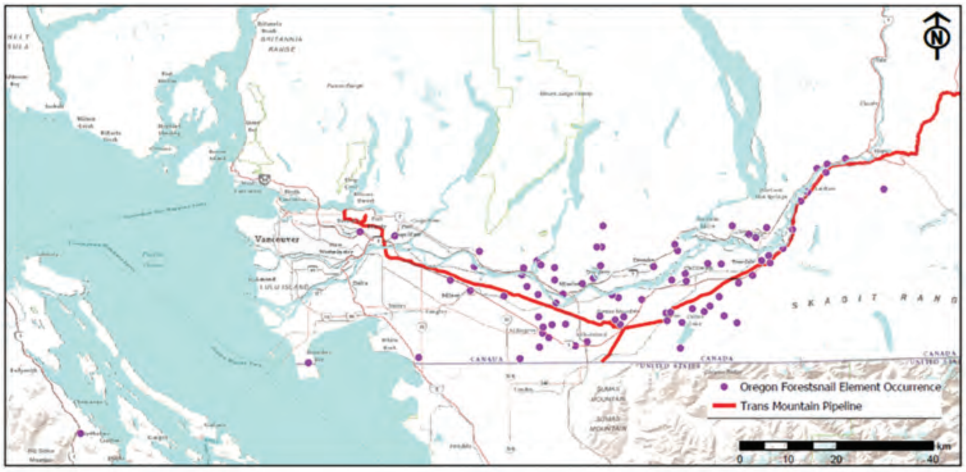

Figure 2.0. The Trans Mountain Pipeline and documented occurrences of Oregon Forestsnail in the southwest corner of BC (Base map reference: Ministry of Environment and Climate Change Strategy - Ecosystems, 2019).

typically located in patches of stinging nettle associated with bigleaf maple canopy. Historical VM of the TMPL ROW has maintained abiotic conditions conducive to stinging nettle growth and reproduction. Plant densities are often greater within the maintained TMPL ROW corridor compared to adjacent perimeters, especially through forested areas, likely due to increased light levels with reduced canopy closure. With Oregon Forestsnail's preference for stinging nettle, the species distribution often appears to be correlated with the alignment of the TMPL ROW.

The apparent association of Oregon Forestsnail to the TMPL ROW is similar to the observed affinity of the Karner Blue Butterfly (*Lycaeides melissa samuelis*), a federally listed endangered species in the U.S., to managed powerline corridors. Disturbance that natural wildfires once created is now replicated by logging practices or mowing along powerlines and roadways where ROW sites are kept clear of trees and shrubs (U.S. Fish and Wildlife 2014). In New York State, the Karner Blue Butterfly primarily occurs in powerline corridors where management practices, including regular cutting of woody species, maintain early successional habitat, where blue lupine (*Lupinus perennis*) persists (Forrester et al. 2005). Blue lupine is this sole food source for the larval stage of the Karner Blue. Studies have also reported introduction of Karner Blue to corridor sites, following VM, where the species had previously not been observed (Forrester et al. 2005).

In 2014, Trans Mountain identified overgrown vegetation and significant canopy encroachment over a 1.4-km segment of the TMPL ROW through the federal Peters Reserve No. 1 and No. 1A ("the project site"), approximately 20 km south of Hope, BC (Figure 3.0). VM was to be conducted to address obstructed ground access, sightlines, and canopy closure to ensure that operating conditions were compliant with regulatory requirements (Figure 4.0).

The Oregon Forestsnail was known to be present along this 1.4-km segment of the TMPL ROW. In BC, there is no provincial or local legislation that directly protects invertebrate species. Regulatory protection for the Oregon Forestsnail is only afforded through the federal SARA enacted in 2002 to protect endangered and threatened species and their habitats. The SARA directly protects listed organisms, their residences, and identified critical habitat on federally administered lands and species protected under the federal Migratory Birds Convention Act or aquatic species as defined in the Fisheries Act.

With known occurrence of the Oregon Forestsnail, salvage and relocation was identified by Trans Mountain as a mitigation measure necessary for the works to avoid contravention of Section 32 of the SARA that prohibits harming/killing a listed species. Federal lands jurisdiction states that this activity required authorization by Environment Canada and Climate Change (ECCC) under Section 73 of the SARA for incidentally affecting a listed species. This marked the first time that Trans Mountain was required to obtain authorization from ECCC to conduct operational and maintenance activities mandated by the NEB.

Trans Mountain was required to incorporate extraordinary measures with their VM plan to minimize impact to the Oregon Forestsnail and meet preconditions of Section 73(3) of the SARA. Acquisition of the Section 73 SARA permit was a rigorous, 18-month process that required development of strategic planning and mitigation measures based on Oregon Forestsnail's ecology and life history. Trans Mountain modified their original scope of work to avoid and mitigate impacts to Oregon Forestsnail. This included limiting the extent of prescribed VM activities to avoid and reduce disturbance of biophysical attributes; scheduling works during specific timing windows to avoid active snails; and incorporating stringent and unconventional practices for utility corridor maintenance to further minimize habitat disturbance.

Figure 3.0. Configuration of the Trans Mountain Pipeline (red line) through rural, forested lands at the federal Peters Reserve No. 1 and No.1A (yellow line).

Figure 4.0. Overgrown vegetation and canopy encroachment within the Trans Mountain Pipeline ROW prior to works at the project site demonstrating the justification for VM (July 26, 2016)

In March 2016, ECCC issued a three-year term Section 73 SARA permit to authorize the VM work for the TMPL ROW, including capture and relocation of Oregon Forestsnail, with the following conditions:

- Works restricted to December 1 and February 28 (i.e., winter hibernation) or between August 1 and August 30 (summer aestivation).
- Pruning and removal activities restricted to trees identified by the project's tree inventory.
- Understory brushing restricted to a six-meter (m) swath directly over the pipeline.
- Oregon Forestsnail survey to be conducted within 48 hours prior to any VM works. Snails to be relocated to the nearest suitable habitat within 26 m of capture.

- Rig matting to be installed to prevent soil rutting/compaction with heavy machinery operation.
- Rigging to be used for canopy pruning and tree removal in areas with high-rated habitat.

The execution and completion of these VM works has been an even further protracted undertaking. Requirements for VM were originally identified and proposed for completion in late 2014. Due to stringent permit conditions and restricted timing windows, the works have required a phased, multi-year program with multiple mobilization and demobilization efforts. Four years after identifying the requirement for these works, Trans Mountain has only completed VM for 60 percent of the 1.4-km segment of the TMPL ROW. Routine VM works such as these would have ordinarily been completed in approximately two to three consecutive months. Trans Mountain received an extension of the Section 73 SARA permit in August 2018 to allow for completion of VM for the remainder of the works to be conducted in 2019 and 2020. These works have become the largest VM effort and expenditure for the Trans Mountain Pipeline in its 65-year history.

This paper outlines the process by which Trans Mountain developed their VM plan to meet requirements for authorization under Section 73 of the SARA. Methodology and results of the Oregon Forestsnail salvage and relocation program are provided, as well as results from follow-up monitoring of relocated snails to determine the effectiveness of salvage as a mitigation measure. Discussion has also been provided on VM and its significance to maintaining biophysical attributes for habitat with high suitability for Oregon Forestsnail.

Federal SARA Permitting

Oregon Forestsnail was anticipated to be encountered during VM of the 1.4-km segment of TMPL ROW through federal reserve. Activities undertaken on federal lands affecting a species listed on Schedule 1 of the SARA as extirpated, endangered, or threatened, and which contravene the Act's general or critical habitat prohibitions require authorization by ECCC under Section 73 of the SARA.

Per Section 32 of the SARA, it is an offense to kill, harm, harass, capture, or take an individual of a species that is listed as extirpated, endangered, or threatened. Trans Mountain identified that salvage and relocation of snails from the project site was a necessary mitigation measure to avoid contravention of the aforementioned prohibition. Collection of a listed species on federal lands requires authorization under Section 73 of the SARA.

Per Section 33 of the SARA, it is an offense to damage or destroy a residence of a listed extirpated, endangered, or threatened species. At the time of Trans Mountain's application for a Section 73 permit, a residence description for Oregon Forestsnail had not been posted—and has yet to be posted—to the SARA Public Registry (Environment Canada, 2016).

Similarly, Section 58 of the SARA prohibits destruction of any part of critical habitat as identified in a listed species' Recovery Strategy and within federally administered lands. The proposed Recovery Strategy for the Oregon Forestsnail in Canada was published to the SARA registry in December 2014. At that time, the Trans Mountain's Section 73 permit application was being reviewed (ECCC 2014). The Recovery Strategy adopted under Section 44 of the SARA in 2016 identified critical habitat polygons at various locations in the Lower Mainland and Fraser Valley of BC. Critical habitat designations were not applied to the area overlapping the TMPL ROW project site. Critical habitat polygon mapping is limited in that it is based on historically documented species occurrences combined with broad scale Terrestrial Ecoystem Mapping. Critical habitat designations do not necessarily reflect actual habitat conditions in that biophysical attributes and the species may not be present within these polygons. Likewise, the mapping is not comprehensive in that it does not necessarily represent all areas with suitable habitat and species presence.

To receive authorization to salvage and relocate Oregon Forestsnails, Trans Mountain was required to demonstrate that the works would meet preconditions set out in section 73(3) of SARA listed below.

a) All reasonable alternatives to the activity that would reduce the impact on the species have been considered and the best solution has been adopted.

b) All feasible measures will be taken to minimize the impact of the activity on the species or its critical habitat or the residences of its individuals.

c) The activity will not jeopardize the survival or recovery of the species.

To demonstrate compliance with these preconditions, Trans Mountain assessed the potential direct and indirect impacts of the VM works to Oregon Forestsnail and habitat at the project site. Despite the absence of critical habitat designation, Trans Mountain evaluated the potential for disturbance to the recognized biophysical attributes of Oregon Forestsnail critical habitat. To receive authorization, Trans Mountain was required modify VM prescriptions and incorporate strategic measures to prevent direct impacts (i.e., harm, mortality) and avoid and/or mitigate indirect impacts to habitat that might limit survival or recovery of Oregon Forestsnail.

ECCC Canadian Wildlife Service (CWS) issued Trans Mountain a Section 73 SARA permit (SARA-PYR-2016-0323) in March 2016. The permit authorized the VM works and salvaging (i.e., capture and relocation) of Oregon Forestsnail found in the TMPL ROW prior to VM activities.

OREGON FORESTSNAIL ECOLOGY & LIFECYCLE

The Oregon Forestsnail is a terrestrial gastropod endemic to western North America. In Canada, Oregon Forestsnail is restricted to southwestern BC. The BC populations represent the northern limits of the species' geographical range (COSEWIC 2002, 2013). Distribution overlaps with the most heavily populated areas of BC, where forest habitat has been altered and diminished as a result of urban development, agriculture, and other human land uses (ECCC 2016). All known Canadian Oregon Forestsnail populations are found in habitats lower than 360 m above sea level (ECCC 2016). Trans Mountain has observed Oregon Forestsnail to occur at various locations along the TMPL ROW where it traverses the species' geographical range.

The shells of mature snails are pale brown or straw yellow, round and flattened in form, and range from 28 to 35 millimeters (mm) in diameter. The main distinguishing feature of Oregon Forestsnail adults is a distinct whitish apertural "lip" or rim at the shell opening, which is thickened and strongly flared outward (ECCC 2016).

The life cycle of the Oregon Forestsnail is connected to seasonal changes in temperature, day length, humidity, and climate conditions within the habitat it occupies (ECCC 2016). Mating begins as early as February and continues until early June. The Oregon Forestsnail enters into two periods of dormancy—summer aestivation and winter hibernation triggered by seasonal changes in temperature and humidity. With increased ambient temperature and decreased humidity levels during the summer (i.e., July and August), snails seek refuge within leaf litter and beneath coarse woody debris where temperatures may be cooler and moisture is retained. Individuals seal their shell's aperture with an epiphragm from dried mucus to retain moisture. The species becomes active again with the return of cooler temperatures and moisture with increased precipitation in mid- to late-September. Hibernation is typically triggered by the first frost in late October to late November and lasts until February. During hibernation, snails bury themselves within leaf litter, moss, soil, or other forms of cover; they form an ephiphragm and orient themselves with the aperture of the shell upwards (Steensma et al. 2009).

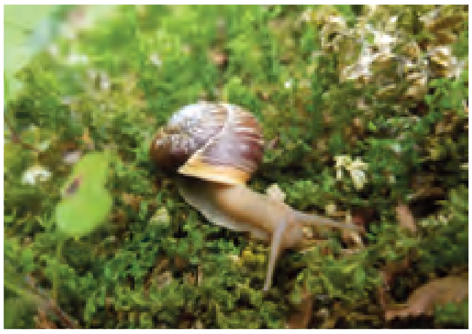

Figure 5.0. Oregon Forestsnail encountered over moss covered woody debris within the Trans Mountain Pipeline ROW at the project site (Photograph May 17, 2018, S. Shay)

Oregon Forestsnail occurrence is often associated with mixed wood and deciduous forest habitat, typically dominated by bigleaf maple (*Acer macrophyllum*), black cottonwood (*Populus trichocarpa*), and western redcedar (*Thuja plicata*). Occurrences are associated with riparian habitats and forest edges, where understory vegetation is comprised of dense native shrub and herbaceous species. Presence of Oregon Forestsnail is correlated with the presence of stinging nettle (MOE 2012).

Biophysical attributes of critical habitat, as defined by the federal Recovery Strategy for the Oregon Forestsnail in Canada, are listed below (ECCC 2016):

- Intact deciduous and/or mixed wood, and/or dense shrub or herbaceous canopy, to maintain moist microclimate
- Patches of stinging nettle to support feeding, mating, oviposition, and healthy shell growth
- Dense understory vegetation to provide cover and maintain moisture
- Coarse woody debris and leaf litter to provide cover and substrate for aestivation and nesting

These biophysical attributes occur at various locations along the Trans Mountain Pipeline's alignment through the species' range. Occurrence of Oregon Forestsnail along the TMPL ROW is typically associated with stinging nettle and bigleaf maple canopy. Stinging nettle densities are often greater within the maintained TMPL ROW corridor compared to adjacent areas, especially through forested terrain. Given the affinity of Oregon Forestsnail for stinging nettle, the species distribution often appears correlated to the TMPL ROW alignment.

Historical VM of the TMPL ROW has maintained abiotic conditions conducive to the reproduction and population dynamics of stinging nettle. Stinging nettle invades disturbed sites and has intermediate shade tolerance. The plant reproduces vegetatively and by seed, where the latter is significantly dependent on high light levels. Factors preventing nettle from becoming more widespread and abundant include shade in forested areas (Bassett et al. 1977). Regular VM through the TMPL ROW corridor maintains low canopy closure, and thereby, increased forest floor light levels which in turn promote growth of stinging nettle. In effect, VM of the TMPL ROW has maintained this biophysical attribute that increases habitat suitability for Oregon Forestsnail. Were VM for the TMPL ROW to cease, the corridor would likely revert back to coniferous forest with decreased light levels and likely reduced occurrence of nettle, which in turn would diminish habitat suitability for Oregon Forestsnail. With this, maintenance of the TMPL ROW since 1953 has likely not jeopardized the survival of the species; rather, it has maintained suitable habitat to which this species life history is reliant upon.

Oregon Forestsnail Habitat Impact Assessment

To obtain authorization under Section 73 of the SARA, Trans Mountain was required to incorporate all feasible measures to minimize impact to Oregon Forestsnail and its critical habitat. In absence of formally designated critical habitat, Trans Mountain assessed the potential impacts to biophysical attributes based on the disturbances anticipated to occur with the proposed scope of work. Through this assessment, Trans Mountain identified specific opportunities to modify management prescriptions to avoid and/or minimize disturbance biophysical attributes.

Stinging Nettle

The mechanism by which VM maintains successional habitat within utility corridors was significant to Trans Mountain's evaluation of how the works would impact stinging nettle as a biophysical attribute. As described above, historical VM of the TMPL ROW has maintained abiotic conditions conducive to stinging nettle growth. Given Oregon Forestsnail's preference for stinging nettle and its importance to the species' life history, the works were not anticipated to result in permanent adverse impacts.

The VM works were expected to result in temporary disturbance to stinging nettle, with a short duration limited to a period when individuals were to be dormant. Given the perennial nature of the plant, new growth was anticipated to re-establish within the same growing season, and when individuals were to become active. With this, the disturbance was considered to be insignificant to the species' life history in that it would not affect the ability of individuals to utilize the biophysical attribute. Overall, VM to address canopy encroachment of the TMPL ROW was anticipated to maintain, and possibly enhance, stinging nettle growth at the project site given the species' previously described shade intolerance.

Leaf Litter and Coarse Woody Debris

Oregon Forestsnail has been observed to have long, narrow home ranges and follow coarse woody debris (MOE, 2012). Large-diameter, damp rotten logs may act as dispersal corridors and shelter during seasonal drought (Burke et al., 1999). The Recovery Strategy identifies that activities that result in removal of coarse woody debris can destroy proposed critical habitat for Oregon Forestsnail (ECCC 2014).

Given the mixed-wood, forested landscape, leaf litter inputs were not observed to be limiting to Oregon Forestsnail at the TMPL ROW. Senescent deciduous litter was present throughout the TMPL ROW. With ROW maintenance and access requirements, coarse woody debris is typically in low abundance within the TMPL ROW. Coarse woody debris was present in the forested perimeters alongside the TMPL ROW and not limiting.

With the Section 73 permit application, Trans Mountain proposed to conduct the strategic application of coarse woody debris alongside the TMPL ROW in a network to enhance connectivity of the open corridor and adjacent forest. These enhancement measures would have also increased availability of suitable substrate for nesting and aestivation and increase microsite moisture. Despite the proposal to incorporate terrestrial enhancement activities, Trans Mountain was not permitted by ECCC to conduct coarse woody debris application with their works.

Forest Canopy Cover

The Recovery Strategy identifies that canopy removal can affect proposed critical habitat for the Oregon Forestsnail. Potential mechanisms by which this can occur includes drying of the microclimate, altering the moisture regime required for maintenance of an Oregon Forestsnail population. It can also result in the long-term loss of aestivation and nesting substrate by loss of coarse woody debris inputs (ECCC 2014).

Continuous, intact forest canopy was not limiting to Oregon Forestsnail at the project site. Average width of forested areas with elevations less than 360 m (the maximum elevation that Oregon Forestsnail is known to occur) alongside the TMPL ROW ranged between 40 m and 690 m. The general landscape and topography of the project site limited the potential for reduction in canopy cover to result in extreme conditions that may be caused by direct sun exposure. The presence of continuous forested vegetation on both sides of the TMPL ROW and its general north-to-south configuration would reduce the duration and intensity of direct sunlight exposure of the maintained corridor. Additionally, the mountainous terrain east, alongside the TMPL ROW, would further reduce the duration that the site is under full sun.

Reducing canopy closure was anticipated to result in increased understory light levels, in a setting where it was already limiting to shade intolerant plant species, including stinging nettle. In effect, these works were anticipated to maintain, if not promote, the occurrence of another biophysical attribute of critical habitat. As mentioned above, recent studies on the habitat function provided by utility corridors have identified them to be vital to the conservation of hundreds of invertebrate species (University of Connecticut 2014). Wagner postulated that if the semi-open landscapes in transmission corridors, areas of grass and weeds, shrubs, and young forest growth was not managed, the land would eventually turn into dense forest with heavy cover and limited sunlight, unsuitable for many of the species that utilize them in their maintained state (University of Connecticut 2014).

Understory Canopy

Shrub and herbaceous species composition and density varied along the TMPL ROW through the project site. Continuous vegetation along both sides of the TMPL ROW reduced the likelihood that the works would alter the site's moisture regime that would cause desiccation of snails. Disturbance caused by brushing and placement of access mats and general foot traffic was anticipated to reduce the availability of stinging nettle and protective ground cover on the TMPL ROW; however, given the aggressive growth habit of shrub species at these sites, the disturbance would be temporary. Salmonberry and thimbleberry are native shrub species recognized to exhibit aggressive growth (MFLNRO 2015). The works were not anticipated to result in remnant habitat pockets in which Oregon Forestsnail would become isolated. Brushing would also enable establishment of herbaceous species, including perhaps stinging nettle, where it was being outcompeted by overgrown woody shrubs.

Strategic Planning and Mitigation Measures to Avoid Direct Impacts

VM of the TMPL ROW required incorporation of strategic planning and mitigation measures to prevent direct impacts to Oregon Forestsnail (e.g., harm, mortality) to avoid contravention of Section 32 of the SARA. Provincial best management practices (BMP) for ROW maintenance developed for the species identified that works should be avoided during oviposition and nesting periods (March to June) when snails are most active on the ground surface and depositing eggs. Preferably, works should be conducted during dry periods in summer (July to August) or cold periods in winter (November to February) when snails are inactive (MOE 2018).

Through its historical VM program, Trans Mountain has observed temporal changes in the presence of Oregon Forestsnail within the TMPL ROW. These changes are seasonal and generally follow the stages of the species' life history and likely attributable to the spatial transition in habitat features and abiotic conditions resulting from maintenance of the TMPL ROW, especially through forested settings. Occurrence of Oregon Forestsnail within the TMPL ROW is typically greatest during the active phases of its life history (i.e., oviposition/nesting). Onset of activity typically coincides with emergence of stinging nettle with early spring weather conditions. When the species enters its first period of dormancy during extreme summer weather, the presence of snails within the open corridor of the TMPL ROW diminishes. During this time, snails retreat to the perimeters of the TMPL ROW where habitat features such as coarse woody debris and tall vegetation provide shelter and abiotic conditions (i.e., shade and moisture) that offer refuge from extreme weather conditions. With return of cooler temperatures and precipitation in late summer and early fall, active snails return within the maintained TMPL ROW. Presence within the corridor diminishes with the onset of winter weather conditions.

Seasonal changes in the spatial distribution of Oregon Forestsnail within the TMPL ROW allowed Trans Mountain to optimize timing for the works to avoid direct harm to the species. Trans Mountain scheduled the works to be conducted during hibernation (November to February) and aestivation (July to August) periods when Oregon Forestsnail is dormant and least likely to be present within the open corridor of the TMPL ROW. This strategic timing window was intended to minimize the likelihood of encountering snails in the work area, thus, reducing the necessity for salvage and relocation as a mitigation measure.

To further avoid contravention of Section 32 of the SARA, the project site was to be surveyed for Oregon Forestsnail immediately prior to commencement of works. Live snails were to be salvaged, marked, and relocated to the nearest suitable habitat alongside the TMPL ROW. For salvage and relocation to be authorized as a mitigation measure, Trans Mountain was required to demonstrate that the activity would meet preconditions set out in section 73(3) of the SARA; in particular, that it would not jeopardize the survival or recovery of the species. Currently, and at the time of Trans Mountain's SARA permit application, information was not available to assess the success of salvage and relocation as a mitigative measure for Oregon Forestsnail (MOE 2018).

Trans Mountain's salvage activities were to be undertaken to avoid adverse impacts to the local Oregon Forstsnail population. Snails were to be relocated outside of the work area to suitable habitat immediately adjacent from where they were found and within dispersal distances and home ranges documented for the species (Edworthy et al. 2012; MOE 2013). Measures described below to limit habitat disturbance would further allow for salvaged snails to be relocated within known dispersal distances. In turn, this would also allow retention of snails within their home range and avoid introduction of salvaged snails to areas with saturated habitat where populations are at capacity. Given the 18.3-m width of the TMPL ROW width, anticipated footprint of disturbance, and known locations with suitable habitat, the relocation distances for salvaged snails was expected to be approximately 25 m. Post-works adaptive monitoring was to be conducted to assess the effectiveness of salvage as a mitigation measure.

Strategic Planning and Mitigation Measures to Avoid Indirect Impacts

Salvage and relocation of Oregon Forestsnail was required for the TMPL ROW VM works to avoid contravention of Section 32 of the SARA. To receive authorization of this activity under Section 73 of the SARA, Trans Mountain was required to incorporate all feasible measures to minimize the impact of the activity on Oregon Forestsnail such that survival or recovery of the species would not be jeopardized. With evaluation of the potential impacts to biophysical attributes, Trans Mountain identified opportunities to modify management prescriptions to avoid and minimize habitat disturbance to avoid indirect impacts to Oregon Forestsnail.

Trans Mountain's original scope of work was developed through a legal site survey and tree inventory to limit disturbance to only that necessary for operational requirements. The survey was completed to identify the exact alignment and legal boundaries of the TMPL ROW to allow accurate identification of trees resulting in canopy encroachment. Management prescriptions for either pruning or selective removal were assigned for each tree identified to be causing encroachment and obstructing surveillance of the TMPL ROW. These trees were tagged and assigned an identifier number and a catalogue was compiled that included tree species, size (diameter breast height), global positioning system (GPS) coordinated, and location with respect to the ROW boundaries. A total of 439 trees were inventoried and included in the management plan.

To meet the preconditions of subsection 73(3) of the SARA, Trans Mountain modified their original scope of work and reduced the extent of vegetation removal to limit impact to Oregon Forestsnail habitat. A habitat assessment of the project site included assignment of a suitability rating of low, moderate, and high for each inventoried tree with respect to Oregon Forestsnail based on presence of biophysical attributes (Bianchini Biological Services 2015). Treatment prescriptions to address canopy encroachment for inventoried trees deemed to provide high-rated habitat and located outside the TMPL ROW boundaries were modified from removal to selective pruning. BMPs for ROW maintenance in riparian areas were also incorporated at stream crossings. Inventoried trees inside the TMPL ROW boundaries would still be removed as originally prescribed, as allowing trees to grow inside the TMPL ROW was not a compatible practice for Trans Mountain to meet the regulatory mandate for pipeline protection. With these modifications, Trans Mountain was able to retain 71 trees, providing high-rated Oregon Forestsnail habitat and 59 trees from riparian habitat. Overall, this resulted in a 33 percent reduction in the total number of trees to be removed for the 1.4-km TMPL ROW segment. The tree inventory and approved BMPs were appended to the SARA permit. Furthermore, the width of understory brushing was to be reduced from the full 18.3 m width of the TMPL ROW and limited to a six-meter swath overtop the pipeline.

The following strategic methods and management practices were also integrated into the work plan to further limit the area of incidental disturbance associated with the works:

- Installation of temporary matted access roads along the TMPL ROW to prevent soil rutting and compaction with operation of trucks and machinery.
- Implementation of spurless climbing techniques for canopy pruning to minimize tree damage.
- Employment of novel equipment as an alternative to traditional logging equipment to minimize habitat disturbance. An all-terrain excavator was used to provide machine assist for falling activities with controlled descent. With the use of a grappling attachment and unique maneuvering capability, the machine was able to lower an entire main stem to rig-matted areas without ground strike and with minimal disturbance to surrounding vegetation. Rigging for tree works associated with high-rated habitat to provide controlled descent. With this process, the canopy and main stem were systematically removed in increments to targeted ground locations to minimize understory disturbance

Results Oregon Forestsnail Salvage and Relocation

Visual encounter surveys for Oregon Forestsnail were completed immediately prior to VM works to avoid contravention of the SARA (Section 32). Located snails were salvaged, marked, and relocated immediately alongside the work areas. Temperature and humidity levels were monitored in advance of commencing the survey and salvage program to confirm that conditions were suitable for triggering aestivation and that snail occurrence within the TMPL ROW had diminished. Within the last three years of the program, these surveys were completed the last week of July with notification provided to ECCC for the advance start-up.

The TMPL ROW was partitioned into 10-meter survey intervals to facilitate a focused search effort, data collection, and to minimize holding time and relocation distances. The survey was conducted by personnel traversing linear transects of the TMPL ROW, including the tree perimeters where pruning and falling was to be conducted. Follow-up surveys were conducted daily, following mobilization of equipment and immediately prior to commencement of works at each tree.

Vegetation, leaf litter, and coarse woody debris were manually displaced to search for snails. Encountered snails were handled by the shell, without disturbance to soft body parts, and placed in clean plastic pails lined with native soil and covered with leaf litter. Snails were marked following the protocol described by Lilley & Bianchini (2012) and immediately relocated to areas with suitable habitat alongside and contiguous with the TMPL ROW within 26 m of the salvage location to enable dispersal within their home range following completion of works. Snails were relocated at densities to which they were originally observed at their capture location. Flagging was hung to demarcate the relocation areas and GPS data was recorded to facilitate follow-up surveys.

For works conducted in 2017, there were instances where suitable habitat for Oregon Forestsnail could not be located outside the work area within 26 m of the salvage location. In these areas, habitat suitability was observed to diminish with distance from the maintained ROW corridor. Specifically, stinging nettle was not present within the forested perimeters alongside the work area. This was likely attributable to low light levels due to dense canopy cover in the forested setting. Soil moisture also decreased particularly in these areas likely on account of accumulated dry coniferous needles/boughs. Under these circumstances, Trans Mountain relocated snails to the nearest site alongside the TMPL ROW with suitable habitat. These observations further support the postulation that historical maintenance of the TMPL ROW leads to the preservation of habitat attributes significant to Oregon Forestsnail.

Overall survey efforts averaged one hour per 170 m^2. While there is no industry standard for survey effort for Oregon Forestsnail, this exceeded survey efforts of one hour per 350 m^2 that Trans Mountain's Qualified Environmental Professional (QEPs) have identified to be typically required in similar settings. Observational accounts made during the surveys are summarized below.

- Snails were found the entire length of the TMPL ROW work segments and occurrences were generally clustered (i.e. >1 snail/1 m^2).
- Occurrence was more frequent in areas where stinging nettle was present with a bigleaf maple canopy. Occurrence was also associated with the presence of Japanese butterbur (*Petasites japonicas*), an introduced vegetation species. Japanese butterbur is a succulent plant; as such, its presence may have just been an indicator of the presence of suitable abiotic conditions (i.e., moisture, temperature). Similar associations have been seen between Oregon Forestsnail and other succulent invasive vegetation such as Himalayan balsam (ECCC 2016).
- Snail occurrence appeared to be associated with areas with higher ground light levels in areas with reduced canopy closure. This observation may be on account of these areas supporting greater densities of stinging nettle.
- Snail occurrences increased with proximity to stream crossings, likely due to localized favorable conditions (i.e., increased humidity, decreased temperature) during hot and dry summer conditions. Conversely, occurrences diminished in areas with dry, rocky soil conditions.

VM Works

With extreme diligence by Trans Mountain's project team, works to date have been completed, meeting permit conditions. This has included an orchestrated and coordinated deployment of falling crew with QEP oversight through a stringent monitoring protocol. Monitoring has included a sign-off procedure to confirm approved daily work areas and works at each inventoried tree to ensure that authorized prescriptions are carried out for the correct inventoried tree. The objective of this process was to avoid unauthorized activities (i.e., falling an unauthorized tree or tree authorized only for selective pruning) and to maintain a verification record of project mitigation.

Due to stringent mitigation measures and restricted timing windows, Trans Mountain has only been able to complete tree management activities in approximately 270-m segments annually since issuance of the permit. Works have not been conducted during the winter hibernation windows due to periods of heavy and prolonged snowfall posing hazards to personnel safety, erosion, and sediment control.

The total number of trees removed each year has been less than that authorized for each specified segment (Table 1.0). Opportunities to further reduce habitat impacts have been identified by Trans Mountain each year that works have been conducted. In some circumstances, where operationally feasible, prescriptions for tree removal has been modified to pruning or omitted from the plan.

Remaining works are still required for approximately 500 m of the TMPL ROW and will be completed in 2019 and 2020. CWS recently extended Trans Mountain's SARA permit for an additional three years to facilitate completion of the remaining works.

Project Year	Length of TMPL ROW Work Interval	Total No. Inventoried Trees	Actual No. Managed Trees	No. of Trees Pruned (No. Authorized)	No. of Trees Removed (No. Authorized)
2016	270 m	94	89	33 (39)	56 (55)
2017	260 m	111	95	28 (25)	67 (86)
2018	280 m	88	80	19 (23)	61 (65)

Table 1.0. Annual Summary of VM Works Completed for the Trans Mountain Pipeline ROW Under the SARA SECTION 73 Permit (SARA-PYR-2016-0323)

Project Year	No. OFS with Original Survey	No. OFS with Follow-up survey (No. OFS within maintained corridor)	No. Marked Live (Empty) OFS	No. Nest Sites with Active Oviposition (Marked OFS)	Recapture % of Marked OFS	Percentage of OFS Encountered within Maintained ROW Corridor
2016 (270 m)	201	488 (296)	21 (2)	2 (1)	10.40%	61%
2017 (260 m)	318	304 (185)	65 (5)	3 (1)	20.40%	61%
Total	519	792 (481)	86 (7)	5	16.6% (combined)	

Table 2.0. Summary of Follow-Up Survey for Oregon Forestsnail on the Trans Mountain Pipeline ROW 2016 and 2017 VM Work Segments

Post-Works Follow-Up Monitoring

Post-works follow-up monitoring was conducted to assess the effectiveness of measures implemented to avoid direct harm and indirect impacts to Oregon Forestsnail.

A follow-up visual encounter survey for the Oregon Forestsnail was conducted in May 2017 of the TMPL ROW, where work had been completed in 2016. Point searches were conducted at the relocations sites and at 5 m by 5 m plots within the maintained corridor of the TMPL ROW in proximity to the relocation sites. A total of 47 live snails, including one marked specimen, and two empty unmarked shells, were located with the survey. Although the recapture of marked snails was limited (i.e., <1 percent), the total number of encountered snails (marked and unmarked) was nearly 25 percent of the total number encountered during the original salvage (n=201). These returns were considered by Trans Mountain to be reasonable and expected, given that the point searches had been intentionally less intensive to minimize disturbance to vegetation. Survey effort for the follow-up survey (n=8 hours) was only 4.5 percent of the time for the original survey (n=181.5 hours) for salvage and relocation conducted prior to works. No empty and/or broken marked shells were encountered during the follow-up surveys.

Trans Mountain conducted additional follow-up surveys for the 2016 and 2017 work segments in May 2018 with increased search effort. Objectives were to determine survivorship of relocated (i.e., marked) snails and identify whether they dispersed back to the TMPL ROW from relocation sites. The survey was scheduled to coincide with peak Oregon Forestsnail activity to maximize the likelihood of encountering snails (MOE 2018). Survey was conducted in the same manner as the original salvage program, with an average survey effort of one hour per 200 m2. The entire width of the TMPL ROW, where previous VM had been completed was surveyed. Relocation sites, including a 35 m search radius, were also surveyed. This search radius was based on maximum known home range/displacement distance of 32.2 m for Oregon Forestsnail (Edworthy et al., 2012). Geographical Positioning System (GPS) data was recorded for each encountered marked specimen.

The survey by Trans Mountain identified that Oregon Forestsnail (marked and unmarked) dispersed back to the TMPL ROW (Table 2.0). Snails were encountered the entire length of the TMPL ROW where works had been conducted. One marked snail was located 42 m from the nearest relocation site, which exceeds maximum known displacement distance for the species. Recapture of relocated snails was 20.4 percent for the 2017 segment and 10.4 percent for the 2016 segment. A total of seven empty marked shells were encountered between the two segments. Damaged marked shells were not located during the survey.

Figure 5.0. Marked Oregon Forestsnail encountered during the May 2018 follow-up monitoring. Snail was actively ovipositing in soil within the Trans Mountain Pipeline ROW, where VM had been completed the previous year.

Five nest sites with active oviposition by Oregon Forestsnail (two marked and three unmarked snails) were encountered during the follow-up survey (Figure 5.0). Four of the ovipositing snails were within the maintained corridor of the TMPL ROW and one ovipositing snail (unmarked) was located at the 35-meter limit of the survey area. One marked snail was observed ovipositing into the cut stump of one of the trees felled in 2016. Two Pacific Sidebands (*Monadenia fidelis*) were observed at one the nest sites, one of which had an egg on its dorsal side. The following day, the eggs were not present and presumed to have been predated by the Pacific Sideband.

Occurrence associations with vegetation type, streams, and soil conditions were similar to those observed with the original survey work. Association with presence of Japanese butterbur was observed. Several snails were observed at the base of the plants and appeared to be feeding or perhaps obtaining water from stalks. Occurrence was also observed to be associated with the presence of Devil's Club (*Oplopanax horridus*) in areas outside of the TMPL ROW.

Follow-up monitoring also included assessment of the re-establishment of understory vegetation, where there had been temporary disturbance due to VM activity (i.e., placement of access mats and foot traffic). Understory vegetation, including stinging nettle, was observed to have re-established to preconstruction conditions and in some areas, was approximately 1.5 m in height.

DISCUSSION

VM of the TMPL ROW through federally administered lands with the presence of a listed species required authorization under Section 73 of the SARA. Trans Mountain developed a management plan with measures to minimize impact to Oregon Forestsnail. Given the necessity for regular VM to address aggressive annual growth within a coastal temperate rainforest setting, Trans Mountain anticipated that understory vegetation would re-establish within the following growing season. Likewise, given the persistence of Oregon Forestsnail on the TMPL ROW with historical maintenance in the last 65 years, expectations were for snails to reoccupy the TMPL ROW following completion of works.

Vegetation was re-established in areas of temporary disturbance within the TMPL ROW within the same growing season and continued to mature thereafter. In some areas, shrub vegetation exceeded 1.5 m in height and exceeded thresholds for maintaining sightlines. This observation demonstrates the justification for routine VM as part of Trans Mountain's Operation and Maintenance Program. More importantly, stinging nettle were re-established to pre-construction conditions, with densities greater within the maintained TMPL ROW compared to the forested perimeters. As stinging nettle is a main component of critical habitat for Oregon Forestsnail, VM activities that maintain abiotic features that promote stinging nettle growth, as described by Bassett et al. (1977), need further consideration with respect to their significance to the presence of Oregon Forestsnail. Cessation of management activities of the TMPL ROW, especially through forested landscapes, would result in progression toward a climax vegetation community with decreased canopy clearance and forest floor light levels. Where these conditions are less conducive for stinging nettle, it is likely that habitat suitability for Oregon Forestsnail would also be diminished.

Follow-up monitoring identified that the VM works, including the salvage and relocation activities, had not prevented the dispersal of Oregon Forestsnail back to the TMPL ROW. Occurrence of snails was greater within the maintained corridor of the TMPL ROW (61 percent) compared to the adjacent treed areas alongside the TMPL ROW for both segments. Additionally, marked snails were only encountered in the areas between the relocation sites and the TMPL ROW, indicating a tendency for snails to mobilize towards the TMPL ROW.

Although the recapture rates for the 2017 segment (20.4 percent) were greater than that for the 2016 segment (10.4 percent), the abundance of snails (marked and unmarked) encountered within the 2016 TMPL ROW corridor (n=296) exceeded the original survey numbers (n=201). With re-establishment of the mature understory vegetation, snails would have continued to populate the maintained corridor of the TMPL ROW. The abundance of snails recaptured within the 2017 work segment (n=185) was less than the total number originally salvaged (n=318); however, as vegetation was still re-establishing within the TMPL ROW, individuals may have been favoring the perimeter habitat where understory vegetation was more established.

Encounter of marked snails ovipositing was significant in that it demonstrated that salvage did not impact the ability for relocated snails to reproduce. Furthermore, observation of marked and unmarked snails ovipositing within the TMPL ROW, including a cut tree stump, demonstrated that the maintained corridor provides habitat qualities essential to the species' life history.

Low encounter of empty marked shells and no damaged shells suggests there was not a high level of mortality of relocated snails. There are various factors potentially limiting the recovery of marked snails with post-works monitoring.

Difficulty in locating snails in complex habitat. Coarse, woody debris in the perimeters of the TMPL ROW was extremely dense at some locations. The survey crew searched beneath debris to the extent possible; however, there were some areas where searching through debris would have required heavy machinery and not feasible.

- **Emigration from study site.** Marked snails may have emigrated out of the project site. The survey area included all relocation sites with a 35-meter search radius based on literature values for maximum dispersal distances. One marked specimen was located 42 m from the nearest relocation site. While it is possible that marked snails could be present outside of the relocation site search areas, the entire TMPL ROW work areas were surveyed. Based on monitoring observations, it appeared that relocated snails exhibited a tendency of mobilization towards the TMPL ROW. With this, it is unlikely that marked snails dispersed beyond the 35-m search areas associated with the relocation sites.
- **Natural mortality.** Seven empty marked shells were encountered. When compared to the number of unmarked empty shells (n=69) encountered, it did not appear that marked snails experienced greater mortality than unmarked snails.

- **Natural mortality due to predation.** It is possible that marked snails succumbed to natural predation. With predation, there would be an expectation to find empty and/or damaged shells; however, there were a relatively low number of empty marked shells encountered with the survey.
- **Increased predation due to markings.** Predators of Oregon Forestsnail include Robust lancetooth and ground beetles. Both species follow slime trails to locate prey. Other potential predators for the project site would include birds, salamanders, and small rodents. Canadian goose has been reported to predate upon Oregon Forestsnail (ECCC 2016). Canadian goose does not occur at the project site. Salamanders and rodents feed nocturnally; as such, it is highly unlikely that colored marking would be a factor in prey detection. Invasive gastropod species may pose a predatory threat to OFS; however, none were encountered during the survey.
- **Wearing of markings.** Overall, the markings were observed to be in overall good condition with little wear.

Overall, the quantitative findings from the follow-up monitoring suggest that the VM and associated mitigation measures (i.e., salvage and relocation) do not appear to result in residual impacts that adversely affected the local Oregon Forestsnail population. The extent to which each mitigation measure effectively prevented impact to snails is unknown. Incorporation of all the measures implemented for this project is likely not feasible and would protract routine works that are required on an annual basis. Per common VM practices, Trans Mountain exercises diligence at a level deemed appropriate by a QEP. Timing of works is typically more flexible and mitigated with the use of pre-works salvage and relocation; additionally, the requirement for rigging, fortified access, and restrictions for hand tools is less stringent. Nevertheless, the findings from this project support Trans Mountain's postulation that VM works are not anticipated to jeopardize the survival or recovery of the species, per section 73(3)(c) of the SARA.

Due to the regulatory constraints for works on federal lands with presence of a listed species, Trans Mountain was required to commit to an extraordinary level of diligence, resources, and effort in planning and executing routine VM works federally mandated by the NEB. Four years after initiating works, Trans Mountain has only completed 60 percent of the works necessary to restore overhead surveillance capabilities, ground access, and sightlines for this 1.4-km segment of the TMPL ROW. According to standard practices, these works should have taken approximately two months to complete. Adherence to restrictions and mitigation measures to the extent employed for this project may not be feasible or sustainable for maintaining operational and regulatory compliance for a pipeline ROW. Given the persistence of Oregon Forestsnail on the TMPL ROW with ongoing maintenance for the last 65 years, it is likely that the species is resilient to this activity and likely benefits from the maintenance of habitat features. With this, the regulatory requirement for VM of pipeline and utility ROWs should be appropriately balanced with the necessity to limit impacts to protected species by implementing practicable environmental stewardship and BMPs for industry.

CONCLUSIONS

Regular VM activities for the TMPL ROW are integral to maintaining regulatory compliance with federally legislated requirements for ensuring the integrity and safe operation of the pipelines and to protect the public and the environment. This regulatory obligation is ultimately in conflict with the mandate of the federal SARA in circumstances where protected species, such as the Oregon Forestsnail occupy the TMPL ROW. As a result, routine maintenance works are subject to delays due to regulatory permitting requirements and extraordinary measures that in many ways are excessive when compared to common industry practice and standards.

Monitoring for this project site and in other corridors (Wagner et al. 2014) in North America indicate that operational settings through forested landscapes provide important early successional habitats necessary for the distribution, reproduction, and population growth for protected species. The persistence and apparent affinity of Oregon Forestsnail for the maintained TMPL ROW is significant to further understanding the species' habitat requirements for purposes of developing recovery and survival strategies. The role of VM in maintaining habitat attributes deserves further consideration by the regulatory agencies when developing Recovery Strategies and BMPs and for the issuance of permits.

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