UNIVERSITY OF CALGARY

A LANDSCAPE-SCALE MODEL TO PREDICT THE RISK OF BIRD COLLISIONS WITH ELECTRIC POWER TRANSMISSION LINES IN ALBERTA

By

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The undersigned certify that they have read, and recommend to the Faculty of Environmental Design for acceptance, a Master's Degree Project entitled A Landscape-Scale Model to Predict the Risk of Bird Collisions with Electric Power Transmission Lines in Alberta by Nicole Heck in partial fulfillment of the requirements for the degree of Master in Environmental Design.

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ABSTRACT

A Landscape-Scale Model to Predict the Risk of Bird Collisions with Electric Power Transmission Lines in Alberta

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A great number of birds are killed each year through collisions with power lines. AltaLink, like other electric utility companies, operates thousands of kilometers of transmission line, making it nearly impossible to identify and prioritize areas according to the degree of risk they pose to birds. The potential severity and magnitude of collisions is not well understood, because unless reported by the public, utility companies are generally unaware of problem sites. This is because unlike electrocutions, collisions do not cause power outages and do very little damage to the line itself. Problems occur in specific situations where certain factors exist to create high collision potential. Past research has been focused on localized sites and has not been assessed at a larger scale. I developed a method to assess collision risk at a landscape scale using risk modeling and spatial ecological analysis. To spatially identify and prioritize high-risk areas, Saaty's *Analytical Hierarchy Technique* using *Pairwise Comparison Analysis* in Idrisi32 and then raster calculator in ArcGIS 9.0 were used. Model validation occurred through ground truthing at select sites. Results show that this methodology can predict where high-risk collision areas are. It will enable a population-level management approach to target and prioritize the higher risk sites for subsequent mitigation.

Key Words: Bird Collisions, Power Lines, Electrical Facilities, Waterfowl, Risk Assessment, Ecological Risk Modeling, Geographic Information System (GIS), Decision Support System (DSS)

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

LIST OF APPENDICES

“We cannot solve the problems that we have created with the same thinking that created them”

~ Albert Einstein

CHAPTER 1: INTRODUCTION

1.1 POWER LINES ON THE LANDSCAPE: THE BIRD COLLISION ISSUE

Power lines are large, geographically dispersed industrial systems on the modern landscape. As with other anthropogenic industrial features, power lines have significant environmental effects, including an ever-growing impact to wildlife (USFWS 2002). Birds in particular are significantly affected by overhead power lines because they can collide with the wires while in flight (Rubolini et al. 2005). Recent estimates of bird mortality from collisions with power lines are in the range of 130 to 174 million per year in the USA (Erickson et al. 2001). The electric utility industry and other affected interests are challenged with addressing this problem (Bridges and Anderson 2002).

The biological and environmental factors that can increase the risk for bird collisions and the resulting biological, social-political and economic consequences have been well documented. This study assesses the phenomenon of bird collisions with power lines and employs relevant factors to develop a risk assessment approach and GIS modeling method to predict where high-risk collision sites are located in south and central Alberta. It then makes landscape-scale management recommendations for utility operators on where and how to mitigated the higher risk portions of power lines to reduce overall bird collision mortality.

1.2 TRANSMISSION VS DISTRIBUTION POWER SYSTEMS

1.2.1 Electricity 101

There are two main types of power lines, transmission lines and distribution lines (figure 1.1). Transmission lines are the larger, higher voltage power lines (typically 69kV to 500kV) commonly seen in rural areas. They are located overhead and according to the Canadian Standards Association (2001) are required to be a certain height above the ground (typically 5.8 to 13.3 m depending on voltage class). Transmission lines carry current from generating stations (e.g. coal, gas, hydro, wind) long distances to distribution points called substations where the current is stepped down to a lower voltage (AESO 2007a). From those substations, the lower voltage distribution power lines (typically 25kV) provide electricity to homes, farms, and businesses (AESO 2007a). Distribution lines may be located overhead or underground. Transmission lines were the focus of this research.

In Canada there are over 160,000 km of overheard transmission lines (Industry Canada 2003, CEA 1999). AltaLink Management Ltd (AltaLink) is Alberta’s primary electrical transmission service provider, operating and maintaining nearly 12,000 km of line in central and southern Alberta and servicing 85% of Alberta’s 3.5 million person population (AltaLink 2003). With increasing development world wide, more and more power lines are required to support residential and industry demands. In Alberta, $3.5 billion in transmission upgrades are expected to be required in the next ten years (AESO 2007b). In the USA transmission lines have increased from 588,447 km in 1977 to over 800,000 km in 2000, and that number is projected to keep growing (EEI 2001). These figures do not include distribution lines.

1.2.2. Bird Mortality from Transmission and Distribution Power Lines

Bird mortality from power lines can result from either electrocution or collision (Rubolini et al. 2005, Bevanger 1994). Every year, a large number of hawks, eagles, owls, waterfowl and other birds die from these two sources (Stephens 2002). Recent estimates in the USA have shown that bird deaths from electrocution are in the range of thousands per year while collisions are in the range of millions per year (Erikson et al. 2001, APLIC 2006). Electrocution and collision affect different types of birds, dependent upon behaviour, size and flight maneuverability (Bevanger 1998).

When birds collide with transmission wires they are not electrocuted. To be electrocuted, a bird must simultaneously contact two energized wires or grounds (AltaLink 2006). Electrocutions occur primarily on distribution lines and in substations. This is because the energized parts are close together and increase the risk that birds will bridge the gap between currents and unwittingly become a current-carrying portion of the circuit (Platt 2005). Raptors are the most common victims of electrocutions because of their natural attraction to power poles for roosting, nesting, courtship, and hunting (APLIC 2006). Electrocutions cost power companies millions of dollars every year. In California it was estimated that annual costs resulting from wildlife caused power outages were in the range of $1 Billion (Hunting 2002). In addition to economic losses, wildlife related power outages compromise system reliability, leading to customer dissatisfaction and public awareness which can lead to negative publicity (Platt 2005).

Contrary to popular belief, transmission lines rarely cause electrocutions (Bradley 2003, Platt 2005). This is because the energized parts have enough separation that it is virtually impossible for even a very large bird to contact more than one energized part at once. Waterfowl and other large heavy bodied birds such as cranes, most often collide with the overhead shield wire (shield wire), the line that protects the system from lightning damage. Unlike electrocutions, collisions do not cause power outages and do virtually no damage to the line itself. Collisions do, however, have significant social-political and biological consequences, and some minor economic consequences.

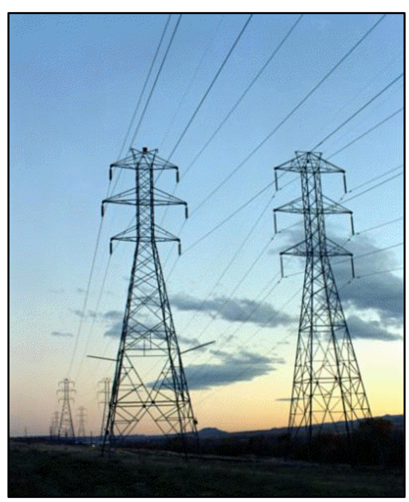


Figure 1.1: Photos showing distribution and transmission power lines. Left: 25kV Distribution structure (photo courtesy of Cindy Platt); right, 240kV transmission tower (photo source: www.renewableenergyaccess.com).

1.3 BIRD COLLISIONS WITH TRANSMISSION LINES

Bird collisions were first documented in *American Naturalist Journal* in 1876 by Coues after he had observed 100 horned larks colliding with telegraph wires. The issue did not become elevated to national attention in the USA until the 1980s when numerous whooping cranes, an endangered species, were seen colliding with power lines in the San Luis Valley, Colorado (Carlton and Harness 2001). Since then, collisions have become an increasing concern to power companies, conservationists and other affected interests (Bevanger and Brøseth 2001). Bird collisions are now considered to be a major impact associated with transmission lines (Bridges and Anderson 2002). It is estimated that bird mortality from power line collisions may be as high as 174 million annually in the USA (Erickson et al. 2001).

There are significant consequences associated with collisions. Biologically, collisions can have an impact at the population level for species, especially for threatened or endangered species (APLIC 1994). Social-political consequences can result when people are present to witness collisions (Crowder and Rhodes 2002). The level of risk for any particular site can be determined by assessing the interaction of environmental risk factors and social-political consequence factors. Additionally, some economic consequences can result from fines, the cost to retrofit lines, and the cost of relocating lines if the problem is severe enough.

The shield wire is the wire most often struck by birds in flight (Scott et al. 1972, Faanes 1987, Brown 1993, Savereno et al. 1996). It is located above the energized conductor wires and serves the purpose of protecting the system from lightning damage (Kurtz and Shoemaker 1986). Transmission lines must be designed and constructed to withstand the effects of lightning with a minimum amount of damage and interruption of operation (Kurtz and Shoemaker 1986). The shield wire is smaller in diameter, and therefore less visible than the primary conductor wires (figure 1.2 and 1.3). Birds have been observed flaring to avoid the lower primary conductors and then colliding with the less visible overhead shield wires (Crowder 2000). When birds in flight unexpectedly encounter the shield wire, they often cannot react quickly enough to avoid collision. These collisions do not typically cause a power outage, nor cause damage to equipment. They can however, result in regulatory repercussions (e.g. fines, penalties) and negatively impact public relations.

Figure 1.2: 240kV transmission tower with the overhead shield wire circled in red. Notice how difficult the shield wire is to see, compared to the much larger conductor wires below.

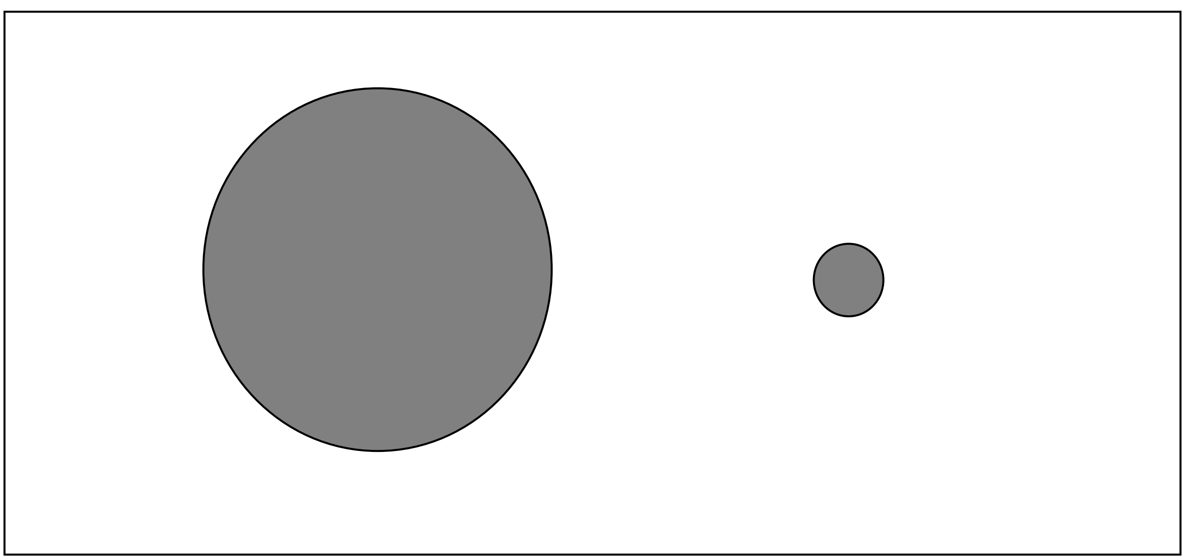


Figure 1.3: Actual sizes in cross section of a 240kV conductor wire (left) compared to that of an overhead shield wire (right).

1.4 LEGISLATION

In addition to conservation, public relations and system reliability, power companies should be concerned about their impact to birds for regulatory reasons. Bird collisions, although incidental, could result in non-compliance with provincial and federal legislation. The Alberta Wildlife Act (Alberta Sustainable Resource Development 2003), the federal Species at Risk Act (Department of Justice Canada 2002) and the Migratory Birds Convention Act (Environment Canada 2002) protect many species of birds in Alberta. Failure to comply with legislation and regulations can result in individual fines, corporate fines, loss of employment, or even jail time.

1.5 JUSTIFICATION FOR THE ECOLOGICAL MODELING APPROACH

1.5.1 Corporate Perspectives and Unknown Issues

AltaLink is responsible for operating and maintaining almost 12,000 km of overhead transmission line throughout central and southern Alberta. With so many thousands of km of line, it is nearly impossible to identify and prioritize high-risk areas for mitigation. This is because problems occur in very specific situations where combinations of factors exist to create high collision potential (APLIC 1994).

Like most electric utility operators, AltaLink only becomes aware of a collision area when the public, media or other stakeholder group, reports it. Collisions are a difficult issue to quantify because they do not result in a power outage and cause virtually no damage to the line itself. Despite occasional public input, awareness of the problem is generally very low because many power lines are in remote areas and the dead birds are often concealed by marsh and upland vegetation, and predators and scavengers frequently remove injured or dead birds from these areas, further reducing the apparent size of this loss (Faanes 1987). Due to the reasons described above, the extent and impact of bird collisions in Alberta is unknown; however, it is suspected to be significant.

1.5.2 Need for a Landscape Level Methodology to Predict Collision Risk

Many site and species specific studies aimed at determining the extent and impact of bird collisions have been conducted (see Faanes 1987, Winning and Murray 1997, Rubolini et al. 2001, De La Zerda and Rosselli 2002, Bevanger and Brøseth 2004, and Rubolini et al. 2005). However, the numbers and impacts reported are difficult to extrapolate to a broader scale for the following four reasons: 1. there is geographical variation with respect to species composition, population densities and life history traits (e.g. breeding, migration, overwintering); 2. landscape variables such as topography, vegetation, presence of water bodies, and extent of human development varies among regions; 3. electric utility companies route power lines differently and have a broad range of standards, influenced by local governing legislation and regulations, for routing in environmentally sensitive areas (e.g. wetlands, ecological reserves, federal lands); and 4. local climatic factors (e.g. precipitation, seasonal temperature extremes, wind speed) vary significantly (Platt 2005). What can be extrapolated from these studies are the factors and combinations of factors that can cause an area to have high collision risk.

The potential severity of the problem and the difficulty in assessing collision mortality at a larger scale than individual sites indicates that there is a need for a new method to assess risk. There are potentially an enormous number of high-risk areas that the public and utility operators are unaware of. Neither retrofitting a few sites nor retrofitting every power line would be an effective solution. The cost of electricity to customers is influenced by a utility's expenditures (Rasmussen 2007: personal communication). Thus, utility operators must be able to justify environmental mitigation expenditures as prudent cost.

The factors that can influence collisions have been well documented by past researchers but, to date, have not been examined collectively and applied to any specific area at the landscape scale. This study does so by applying collision risk factors in a spatial data system to AltaLink's transmission grid and categorizes sites based on collision risk. This will allow AltaLink to focus mitigation efforts at the higher risk sites. By identifying these high-risk areas for subsequent mitigation, AltaLink would benefit from the prevention of financial losses that can result non-compliance with legislation, effectively manage and provide justification for expenditures that result from mitigating lines, have improved public relations, be due diligent, and be corporately environmentally responsible. If successful, this modeling method could be applied to electric utilities worldwide and could significantly decrease bird collisions.

1.6 MDP OVERVIEW

1.6.1 Purpose

The purpose of this research is to: 1) research, identify and evaluate risk factors that lead to increased bird collision risk with overhead electrical power transmission lines, and 2) employ risk modeling in conjunction with spatial ecological analysis in GIS as tools to identify high-risk areas to prioritize for mitigation activities.

1.6.2 Objectives

The objectives of this research are to:

1. Identify and describe relevant bird types that are at a high-risk for colliding with transmission lines in Alberta;

2. Identify and evaluate key risk factors that contribute to bird - transmission line collision risk;

3. Develop a risk model by assigning a risk assessment score to each biological and environmental characteristic in relation to the probability of a collision occurrence;

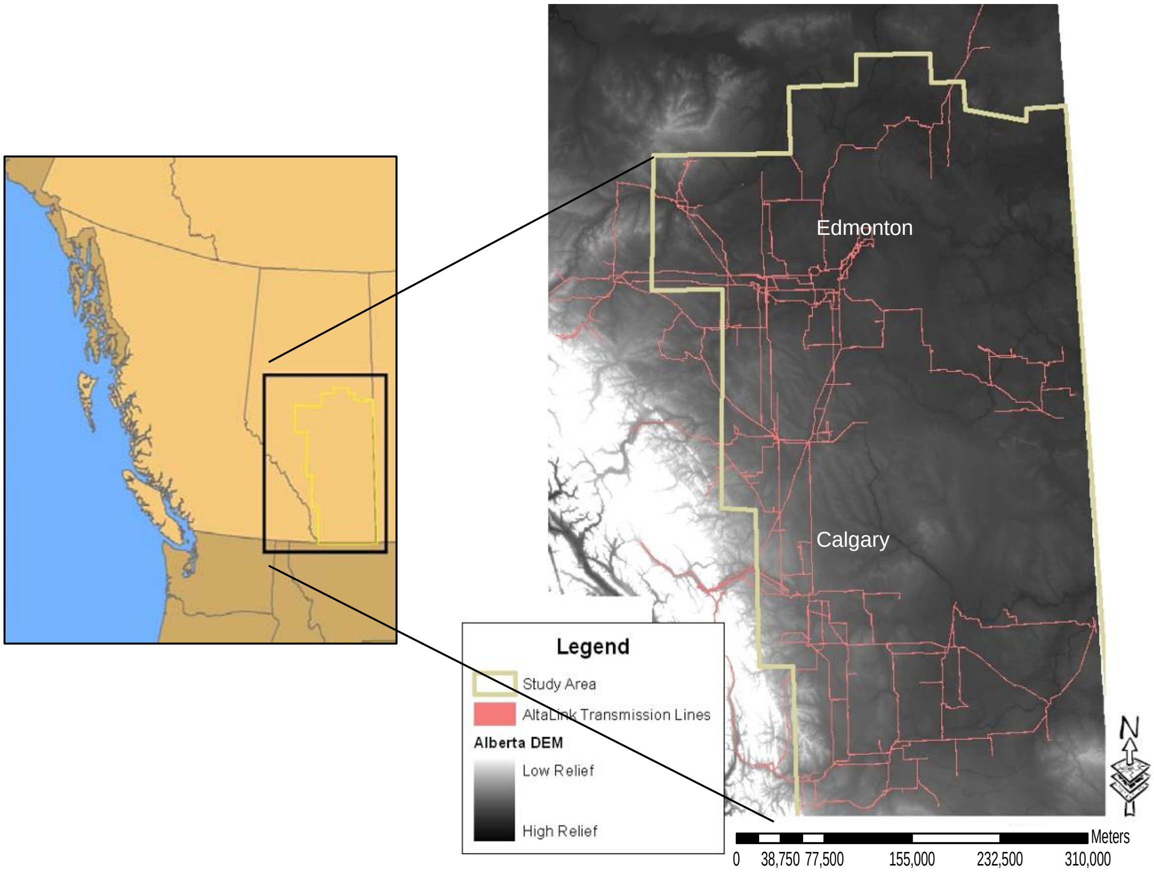
4. Develop a geographic information system (GIS) model that categorizes transmission line corridors in relation to their degree of risk for bird – transmission line collisions;

5. Conduct a field assessment to verify the GIS model ; and

6. Use the information gained to make spatially-explicit recommendations to Alberta utility companies on where to mitigate the effects of existing electrical transmission lines on bird species.

1.6.3 Study Area

This study was conducted in south and central Alberta, Canada within AltaLink's service area (map 1.1). The boundaries were determined by choosing the largest possible area where GIS data coverage's representing the study criteria were available. This area forms part of the Pacific and Central flyways, two major corridors for migratory birds (Lincoln 1935). It is ecologically diverse, comprising five out of six of Alberta's natural regions: the grasslands, parklands, foothills, boreal and Rocky Mountain natural regions of Alberta (ANHIC 2005) (Appendix 1). Approximately 85% of Alberta's 3.5 million people reside within this area including residents from the two major urban centers, Calgary and Edmonton.



Map 1.1: Study area map showing locations of AltaLink's transmission line system and locations of the two major urban centers, Calgary and Edmonton.

CHAPTER 2: BIOLOGICAL AND ENVIRONMENTAL RISK FACTORS

"Avian power line collision is a widespread problem with potentially significant local impacts when high-risk conditions are present. Understanding the nature of this mortality factor requires the examination of a series of physical and biological and of the relationships between these factors that magnify collision hazards"

~ Hunting 2002

2.1 CHAPTER OBJECTIVES

The objectives for this component of the research were as follows:

1. Identify and describe relevant types of birds that are at a high-risk for collisions with transmission lines in central and southern Alberta; and
2. Identify and describe environmental characteristics that influence collision risk.

2.2 METHODS

A literature review was conducted to synthesize information on bird - transmission line interactions, and to identify and describe the types of birds that have a high-risk of colliding with transmission lines. Information was obtained from peer reviewed journals, books, textbooks, websites, and informal conversations with industry experts. Key words used as search terms included: power lines, waterfowl, collisions, and electricity.

The Avian Power Line Interaction Committee's (APLIC) publication, *Mitigating Bird Collisions with Power Lines: the State of the Art in 1994,* was used as one of the initial sources of information for studies prior to 1994. This publication is often referred to as the "collision bible" among industry experts and researchers. It is an excellent summary and discussion of the research conducted prior to 1994 on the topic of bird collisions with power lines.

2.3 INTRODUCTION

Bird collisions with power lines are recognized as a widespread problem that may have significant local impacts when certain species and environmental conditions are present (Hunting 2002). Although birds are highly adapted to aerial mode of existence, they have difficulty in coping with anthropogenic obstacles such as power lines (Hunting 2002). Nearly every type of bird has been observed to fly into overhead transmission lines (Appendix 2). However, waterfowl, and other heavy bodied birds such as cranes and herons seem to be particularly at risk (APLIC 1994, Crowder 2000). Raptors and ravens are less likely to become victims of power line collisions because they fly slower and are more maneuverable (APLIC 1994).

There are many situations where birds can exist near transmission lines without a significant risk of collisions. Problems occur in very specific situations where the combination of environmental, morphological and behavioural characteristics creates high collision potential (APLIC 1994). For example, body size and maneuverability, flight behaviour, age, and sex are all species characteristics that can lead to increased collision risk (APLC 1994). Land use, topography, vegetation, wind patterns, and line placement are all environmental factors that may increase collisions risk at a particular site (APLIC 1994). The purpose of this chapter is to examine the physical and behavioural characteristics of those types of birds most likely to collide with overhead transmission lines and the environmental characteristics of those landscapes that they occupy.

2.4 BIOLOGICAL FACTORS

2.4.1 Species

Not all birds are equally susceptible to collisions (Bradley 2003). Many studies have been undertaken to determine which types are at highest risk for collision. Brown et al. (1987) found that out of 115 collisions, sandhill cranes were the most frequent mortalities (67.5%), followed by ducks (17.4%), geese (7.0%) and whooping cranes (2.6%). When these results were standardized, it was found that whooping cranes were the most frequent casualties in proportion to their abundance. Cornwell (1968) found that 1,500 of 2,000,000 non-hunting waterfowl fatalities in the USA and Canada were from collisions with power lines. The NUS Corporation (1979) found that species with relatively long legs or necks struck lines more frequently than those with compact profiles; for example, Great Blue Herons (Rusz et al. 1986) and Sandhill Cranes (Hunting 2002) have been observed to strike power lines frequently. A recent study in Italy (Rubolini et al. 2005) also found that Herons, Cranes and allies were most susceptible to power line strikes. Faanes (1987) found that 90% of observed mortality in his study was waterfowl.

2.4.2 Body Size and Maneuverability

A bird's body shape plays a large role in how susceptible it is to colliding with obstacles. Birds were first categorized according to their behaviour, physiology and morphology in 1988 by Rayner (figure 2.1). Since then several researchers (Bevanger 1998, Janss 2000, Crowder and Rhodes 2002, Rubolini et al. 2005) have closely examined this categorization in relation to collisions with overhead power lines. Results of these studies show that the size of the bird and its wing shape and morphology play an important role in determining susceptibility for power line collisions. Birds with restricted biomechanical qualities, for example large, heavy-bodied birds such as ducks, geese, cranes and herons have been observed to collide with power lines much more frequently than others (Bevanger 1998, Bevanger and Brøseth 2004). Their large wingspan and lack of agility to maneuver around obstacles seems to make them most susceptible.

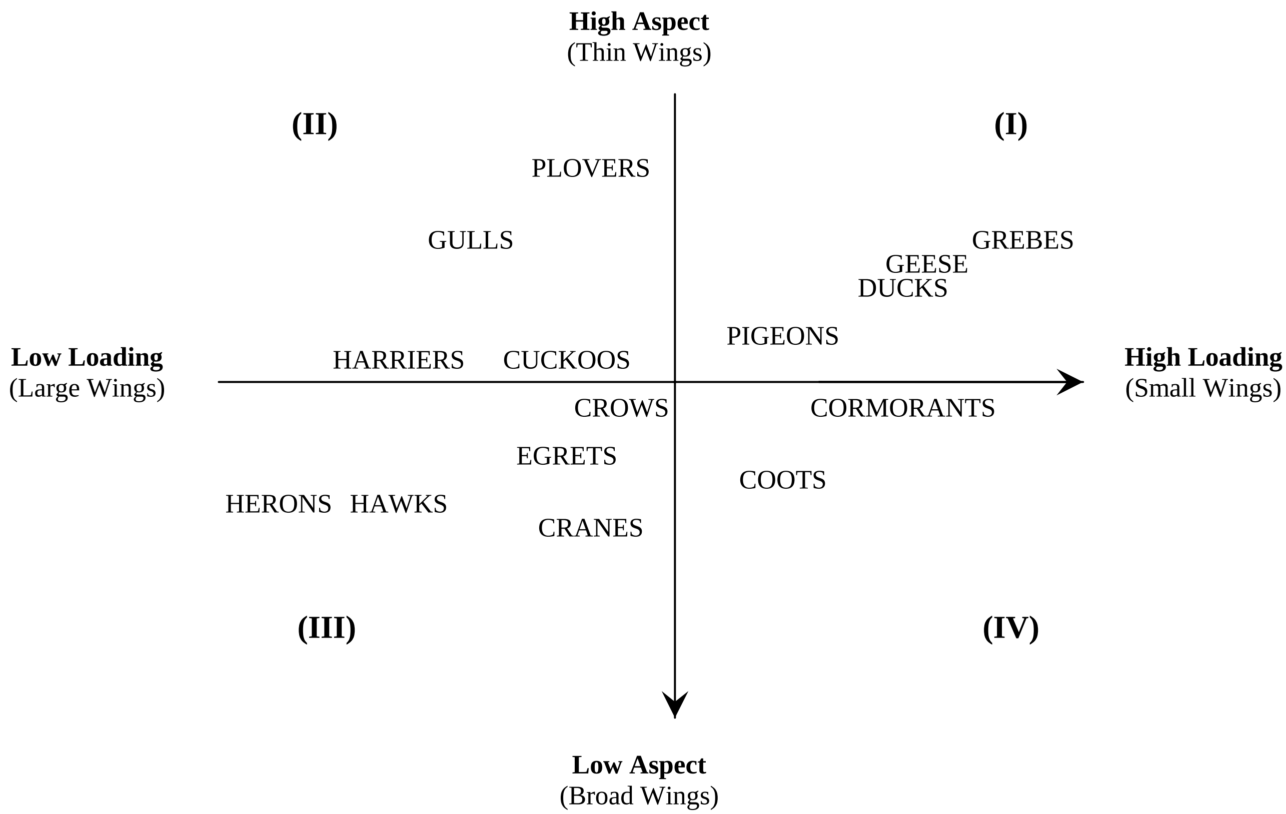


Figure 2.1: Groups of birds found to interact with power lines arranged according to wing morphology expressed in principal-components form where statistically independent measures of size and wing proportions are derived (Modified by Crowder and Rhodes 2002 after Rayner 1988). As shown by the arrows, as a bird's wing loading increases and/or aspect ratio decreases, susceptibility for power line collisions increases.

The shape of the wing is important in determining the type of flight for which a bird is capable (Alexander 2002). Wing shape can be described in terms of aspect ratio (mean wingspan divided by wing area) and wing loading (ratio of weight to wing area) (Alexander 2002). In general, it can be said that as a birds wing loading increase and/or aspect ratio decreases, susceptibility for colliding with power lines increases because the combination of heavy body and small wings restricts swift reactions to unexpected obstacles (Bevanger 1998). This research is consistent with findings from Faanes (1987), APLIC (1994), Jaanes (2000), Crowder (2000), and Hunting (2002) who found that ducks, and other heavy bodied waterfowl such as cranes and herons are at a high-risk for colliding with overhead electrical transmission lines. For example, Faanes (1987) found that 90% observed mortality fell into this category. Similarly, Meyer (1978), James and Haak (1979), and Beaulaurier (1981) found that ducks are 50 to 100 times more likely to collide than gulls. Birds such as raptors and ravens are less likely to become victims of power line collisions because they fly slower, and are more maneuverable (i.e. lower wing loading).

Figure 2.2: Male mallard in mid-flight, showing high wing loading, moderate aspect ratio of wings. Source: Wilson 2006.

2.4.3 Flight Behaviour

How birds use habitats near power lines affects the probability of collisions. Crossing frequency, time of day, flocking behaviour, approach, and age and sex are all aspects of flight behaviour that have been shown to influence collision risk (APLIC 1994).

2.4.3.1 Crossing and Frequency

Anytime a bird has to cross a power line it runs a risk of collision. It has been found that most collisions occur within daily homerange (APLIC 1994). Therefore, a power line that intersects a birds daily homerange will be at high-risk for power line collisions. Homerange often includes two or more types of habitat, for example, feeding, breeding and resting areas. Ducks, for example, make frequent low altitude and high speed flights within their daily use area (APLIC 1994). When a power line comes between two or more types of habitat used by birds (figure 2.3) the chance for collisions will increase (Thompson 1978 in APLIC 1994).

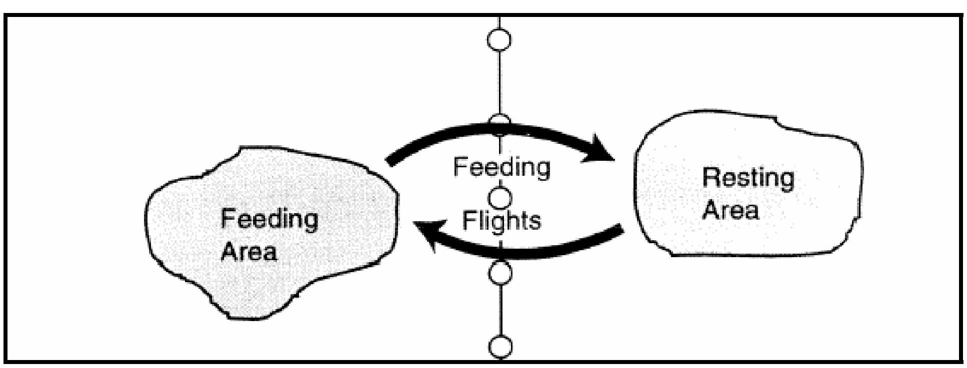


Figure 2.3: When a power line is located between two or more types of bird use habitat such as this the chance for collisions will increase (after Thompson 1978 in APLIC 1994).

2.4.3.2 Time of day

Birds that make flights during the night, at sunrise, and at dusk, may be at a higher risk for collisions than species that make their flights during the day. For example, waterfowl tend to make their feeding flights during times before sunrise and at dusk (APLIC 1994). At these times, there is reduced visibility of the power lines. As the overhead shield wire has such a narrow diameter, it is nearly impossible to see during these conditions. Birds will often fly up to clear the conductors but not see the shield wire until it is too late. As discussed in section 2.4.2, the physiology and morphology of ducks and other heavy bodied water birds does not allow them to react quickly to the presence of wires. This makes them particularly susceptible to colliding with the power lines during times of limited visibility.

Birds that migrate at night (for example, some ducks and geese) may be forced to make landings in poor conditions may be more susceptible to strikes (Bevanger 1998). During the night, the conductors and shield wires are nearly invisible to migrating birds, especially in poor weather such as precipitation and fog. Although birds prefer to not fly during these conditions, problems develop when birds encounter poor weather unexpectedly (APLIC 1994). These sorts of hazardous conditions increase the chance for collisions because birds react to poor weather by decreasing their altitude of flight (Gauthreaux 1978 in APLIC 1994) and therefore running the risk of encountering a power line unexpectedly.

2.4.3.3 Flocking

Species that congregate in large flocks are more vulnerable to collisions than are solitary species (APLIC 1994). Flocking can cause confusion when encountering a power line and lead to strikes because of the reduced visibility of the trailing birds (Crowder 2000). Birds most susceptible that exhibit this type of flocking behaviour include cranes, storks and swans (APLIC 1994, Janss 2000).

In general, the greater the bird population in an area, the greater is the risk for power line collisions (Bradley 2003). Therefore, areas that harbor large numbers of congregating birds would be at a higher risk. Birds such as ducks, geese, cranes, pelicans, and swans often congregate in large groups (Lincoln 1935). This sort of congregation behaviour in areas where the power line intersects important habitat (figure 2.3) where the birds present (e.g. ducks) are engaged in high-speed low altitude flights would make a particularly high-risk area (Bradley 2003).

2.4.3.4 Approach

There is considerable evidence that when birds approach power lines near the height of the wire, they are most likely to see them and react in time to avoid a collision (Crowder and Rhodes 2002). When birds approach the line at a height of greater than 10 m below the overhead shield wires they are not likely to see them in time to react and clear the line safely (APLIC 1994). This is because they are able to see the conductors, and fly upwards to avoid them but are often unable to perceive the overhead wires. Risk would increase, for example in adverse weather such as fog or strong winds where the conditions make it even more difficult for the overheads to be perceived (Bradley 2003).

2.4.3.5 Age and Sex

It has been hypothesized that younger birds may be more susceptible to collisions than adults because they are less maneuverable (APLIC 1994). Males tend to be more susceptible due to differential movement behaviour between sexes of most duck species (Crowder 2000). Faanes (1987) noted that the inattentiveness of male waterfowl during the spring breeding period makes then susceptible to collisions. As Bradley (2003: 8) stated it, “birds distracted by sex are capable of flying into anything”.

2.5 ENVIRONMENTAL FACTORS

Environmental factors are those that attract relevant bird types to a particular area. The environment that birds occupy, surrounding human land use, and power line placement, orientation and configuration in relation to that environment have an influence on the probability of collisions.

2.5.1 Land Use

Land use influences the potential for collisions because it affects the attractiveness of habitats near power lines. Power lines that are situated in areas that are attractive to birds, such as wetlands, conservation areas, agricultural fields, and industrial lands will pose a risk for collisions (APLIC 1994). Wetlands often support significant numbers of waterfowl and other water birds and power lines located in close proximity will have a significant influence on collision risk. Conservation areas are often attractive to birds because there is less disturbance and more natural wetlands and vegetation (APLIC 1994). Cranes, waterfowl, and blackbirds feed in grain fields that are close to wetlands thus agricultural fields are attractive; collision problems often develop when birds must cross power lines to make daily, low-altitude flights to and from croplands. Industrial lands may also increase the chance of collisions if, for example, there is a landfill in the area attracting scavenging birds such as gulls (APLIC 1994).

Hazardous areas can be created if a land use change occurs. For example, Malcolm (1982) measured collision mortality along a section of transmission line in Montana constructed over a dry lake bed which subsequently filled with water, attracting a large waterfowl population. He recorded 2,530 fatal bird strikes in a 6-month period along the 2-3 mile stretch bisecting the wetland.

2.5.2 Vegetation and Topography

Topographical depressions and other similar landscape features attract birds and may be hazardous if interrupted by a power line. Birds use flight lanes such as topographical depressions, valleys, linear vegetation breaks, and other features interrupting the visual horizon as directional cues during regional flight and migration (Lincoln 1935, Bevanger 1994). In Alberta, the mountain ranges, valleys and rivers are oriented in the same direction as migratory flight paths (Lincoln 1935). A power line spanning one of these flight lanes (figure 2.4) may force birds in flight to deviate from their natural flight path horizontally or vertically, or the resistance by birds in doing so, may be a factor in collision fatalities (Bevanger 1994).

Vegetation may also play a role in increasing or decreasing the collision risk in an area. Power lines that are at or below the height of nearby trees rarely present a problem because large birds will gain altitude to clear the highly visible tree line (figure 2.6), consequently avoiding the power line (APLIC 1994). This same principle can be applied to topography (figure 2.5). Lines that are located near a cliff base or any other tall object have a lower probability of receiving strikes (Thompson 1978 in APLIC 1994, Crowder 2000).

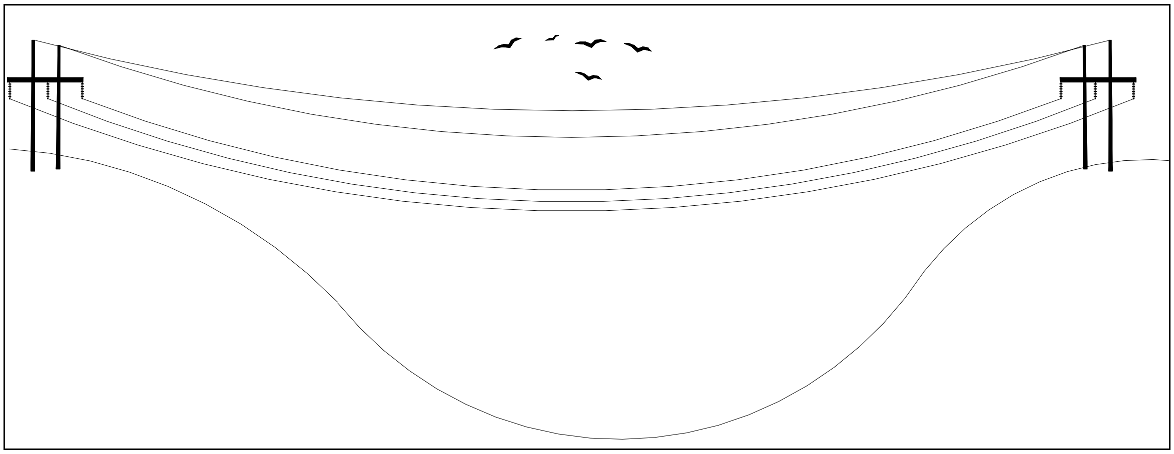


Figure 2.4: Topographical depression spanned by power line in cross section. If used as a flight lane by birds, it could be a high-risk collision area.

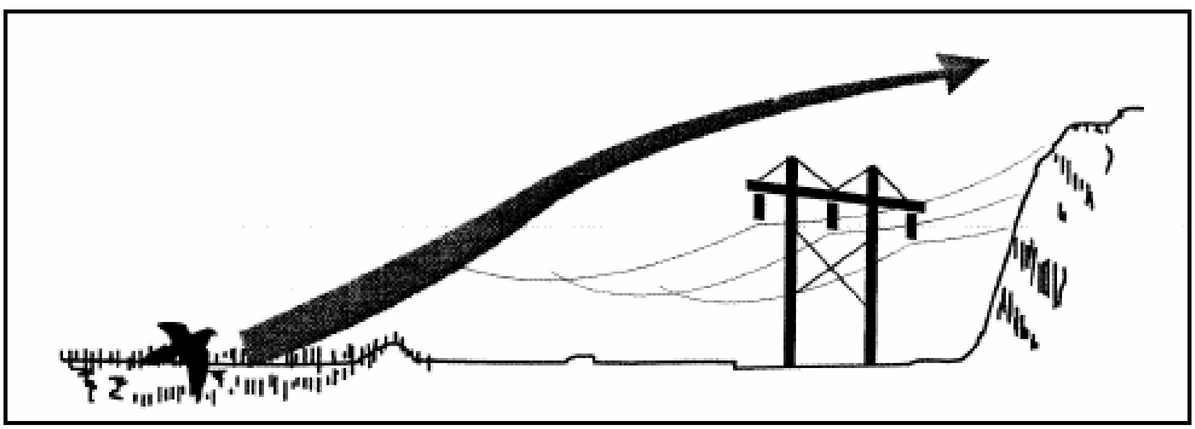


Figure 2.5: Power lines located at the base of a cliff will be less likely to receive strikes because the bird fly's higher to clear the cliff and at the same time makes it over the power line with minimal risk (after Thompson 1978 in APLIC 1994).

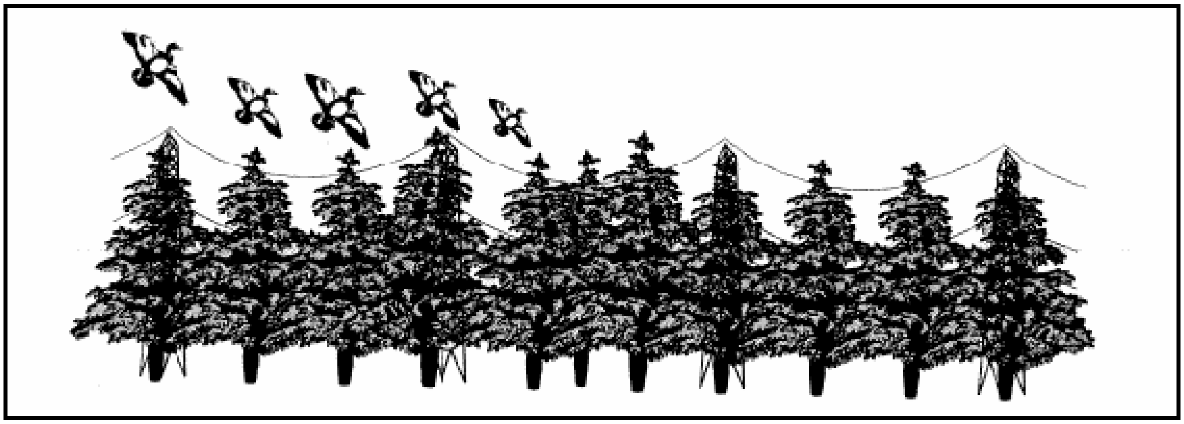


Figure 2.6: Power lines located at the base of tall vegetation will be less likely to receive strikes because the bird fly's higher to clear the vegetation and at the same time makes it over the power line with minimal risk (after Thompson 1978 in APLIC 1994).

2.5.3 Line Placement, Orientation and Configuration

The manner in which a power line is designed and placed within an area that is attractive to birds has an influence on the risk for collision. Proximity to priority bird habitat (e.g. staging wetlands), orientation of power line in relation to flight path, surrounding and upland vegetation, and local topography all effect collision risk.

Proximity of power lines to important bird habitat is likely the most important collision risk factor. Brown (1987) found that power lines within 1.6 km of a wetland posed a collision risk. Faanes (1987) found that 90% of collisions occurred where the power line was located within 400 m of water. Although there have been no formal studies to test this, evidence suggests that collision risk increases with power lines situated very close to water.

When a power line is located directly overtop of or adjacent to a wetland area or other important bird habitat area, it's orientation to local flight path becomes important (APLIC 1994). Lines that are located perpendicular to local avian flight patterns are more likely to receive strikes than are lines located parallel (Crowder 2000). Birds commonly take off into the wind and thus, lines oriented perpendicular to prevailing wind directions are at a higher risk for collisions.

Birds are able to sense prevailing wind direction as the wind gusts ruffle their feathers and stimulate sensory receptors located in the skin around the base of the feather (Lincoln 1935). Wind is often a factor in collisions when birds cross power lines during their low altitude daily flights (APLIC 1994). High winds have the ability to buffet birds into fully visible power lines with which they are quite familiar, but which they cannot avoid without flight control (APLIC 1994). In central Alberta, there are prevailing northwesterly winds and therefore most birds will take off along a northwesterly path (Thompson 2005: personal communication). Conversely, when landing, birds most often approach a wetland from a southwesterly direction to land into the wind (Thompson 2005: personal communication). Therefore, it can be presumed that in central Alberta, power lines that are oriented in a north – south direction would promote more collisions than would power lines oriented east – west.

2.7 DISCUSSION

As summarized in this chapter, waterfowl and other medium to large water birds are at higher risk for colliding with power lines. This is largely due to the physiological and behavioural characteristics exhibited by these types of birds. Power lines that are located in areas that attract these birds are of higher risk than a power lines located in a less attractive area. There are certain characteristics of power line design and placement within high-risk areas that can dramatically increase collision risk. The impact area, i.e. the area where power lines have a behavioural or ecological effect (Cassel 1978 in Bevanger 2004) must be considered according to species-specific movement patterns (Bevanger and Brøseth 2004).

Areas with multiple high-risk factors present can be particularly hazardous to birds. The combination of various biological, environmental and power line factors seems to make certain locations higher risk than others; for example, the number of daily crossing of the line, the species size and maneuverability, flocking behaviour (increased risk with denser groupings), and the height at which the species flies (Bradley 2003). In general, collision risk increases when transmission lines are located near wetlands, in areas supporting concentrated bird use (e.g. foraging, roosting, or breeding sites), in landscapes with features that concentrate birds into the path of overhead wires, and during inclement weather (APLIC 1994, Hunting 2002).

In this chapter relevant types of birds at risk for colliding with power lines were identified and the environmental factors of those habitats that they occupy were described. This was important because, as will be seen in Chapter 3 and 4, it has enabled priority areas within the study area to be established through a risk assessment process.

CHAPTER 3: RISK ASSESSMENT

"Thousands of utility poles are located in areas of suitable habitat for migratory birds. Because remedial actions on all poles in such areas are not economically or biologically necessary, a method is needed to identify configurations or locations of greatest risk. While utilities vary based on geographic scale, available data, funding resources, risk assessment studies and models can be used by any utility to more effectively protect migratory birds. Risk assessments may use existing data sources or new information collected specifically for the purpose. Although individual layers alone may be inadequate for risk assessment, when all risk assessment data are overlaid, high-risk locations, configurations may become apparent. Following a risk assessment, remedial actions can be prioritized throughout a utilities transmission and distribution system."

~ APLIC 2006

3.1 CHAPTER OBJECTIVES

The objectives for this component of the research were as follows:

1. Define *risk* and *risk assessment* in relation to bird collisions with power lines; and
2. Determine unacceptable risk in relation to the context of bird collisions with power lines

3.2 INTRODUCTION

All overhead power transmission lines pose a risk to birds in flight. The significance of the risk is a function of biological, environmental and socio-political factors; “avian power line collisions are a widespread problem with potentially significant local impacts when high-risk conditions are present” (Hunting 2002: 4). However, simply knowing that particular factors create higher risk is not enough when assessing thousands of kilometers of power line across a landscape. A risk assessment methodology is necessary to evaluate and then prioritize power lines for mitigation (APLIC 2006). The approach to assessing risk in this study follows Kirkland and Thompson (2002). It defines the problem, estimates probability and consequence, and characterizes risk. This risk assessment will be used as a proactive measure to facilitate the reduction of avian mortality from collisions on existing AltaLink transmission lines and will allow AltaLink a means to prioritize power lines for remedial mitigation action.

The concept of risk was first introduced in the 1800s as a tool for making financial decisions (Kirkland and Thompson 2002). Since then, it has evolved to include a wide variety of situations; for example, trading natural gas, launching a new business, military adventures, asking for a pay raise, skydiving, romance, chemical exposure, and uncertainty (Holton 2004). How risk is actually defined depends on the specific application and situational context. In general, risk can be thought of as the relation of expected losses to the probability of the event occurring (Holton 2004).

Once risk has been defined, a risk assessment can be carried out. Risk assessment is an estimation of the likelihood of an undesired effect occurring due to a risk (Kirkland and Thompson 2002). The primary reason to perform a risk assessment is to evaluate the uncertainty associated with a project or activity (Koller 1999). It is a very powerful 'front end' tool for decision making and is often used to compare, rank, and manage possible options (Koller 1999). The type of assessment taken depends on the type of risk and there are a number of risk assessments that can be utilized (Power and McCarty 2002).

There are three main approaches to risk assessment, the actuarial approach, the (eco)toxicological approach, and the engineering approach. All three of these methods are very different and it is important that the correct approach is applied to specific situations (Kirkland and Thompson 2002). The actuarial approach involves assessing unchangeable factors and is often used by insurance providers. For example a life insurance company would assess family medical history. The (eco)toxicological approach is used when the concepts of stressors, pathways and receptors are involved, for example, acceptable levels of human exposure to a toxic compound. The engineering approach to risk assessment defines risk as probability x consequence. In this approach, as either the probability or consequence increases, so does the risk. In this study, the engineering approach to risk assessment will be taken.

The purpose of this chapter is to use the engineering approach to risk assessment to develop a method that will utilize GIS (Chapter 4) to determine which areas along AltaLink's existing transmission system have unacceptable risk for bird collisions. This is important to determine since it is not financially feasible to mitigate all power lines. Those areas that are determined to have an unacceptably high level of risk should be mitigated to lower the probability of bird collision occurrence.

3.3 UNCERTAINTY AND ASSUMPTIONS IN RISK ASSESSMENT

Determining risk using the engineering approach involves probability, professional judgments and predictions based on past research and therefore inherently involves uncertainty (Kirkland and Thompson 2002). In this study, risk assessment has been based on a review of past research and professional judgment. Therefore one of the main assumptions is that past research has been correct. This creates a level of uncertainty in the risk assessment. Accuracy depends on uncertainty in the inputs used to estimate probability, variability in situational circumstances, the researcher's ability to understand and characterize situations in relation to the context of the given problem, and lack of historical records (Kirkland and Thompson 2002). In general, the data and information used to characterize issues always involve uncertainty and it is ultimately up to decision makers to rely on subjective judgment (Bonano and Apostolakis 1991). This uncertainty is reduced by using multiple peer reviewed sources for information and thorough, careful examination of relevant information upon which informed decisions can be based.

3.4 PROBLEM DEFINITION: REVIEW

It has been estimated that bird power line collisions may be as high as 174 million per year in the USA (Erickson et al. 2001). Like all other transmission companies, unless reported by the public, collisions are not detectible by AltaLink because they do not cause a power outage and do no damage to equipment. An exception to this would be on a distribution system where a large bird contacts more than one phase during the collision and causes a power outage. This is known as a “fly-in” and almost exclusively occurs on distribution systems (Harness et al. 2003).

It is difficult to evaluate thousands of km of power line in relation to bird collision risk. For this reason, it is appropriate that a risk assessment be undertaken that assesses AltaLink’s entire system. This will allow priority areas to be identified for mitigation.

3.5 DETERMINING UNACCEPTABLE RISK

Unacceptable risk is determined by assessing the interaction of economic, political and scientific realities of the problem (Kirkland and Thompson 2002).

Realities refer to unchangeable factors that can influence risk. In this assessment, ecological resources are balanced with social-political and economic sustainability. Where the overlap of these interactions occurs is where the highest management value would be obtained from mitigating transmission lines.

For the purpose of this study, unacceptable risk can be thought of where there is highest business risk (i.e. where there is an overlap of economic, social-political and environmental realities). Although these factors are discussed separately in the following three sections, it is important to note that there are strong linkages between them. For example, if stakeholders (e.g. landowners, regulators) were to perceive that transmission lines have a negative environmental effect on birds, the ability for electric utility operators to obtain approvals for new lines, as well as conduct regular operation and maintenance on existing lines, could become challenging.

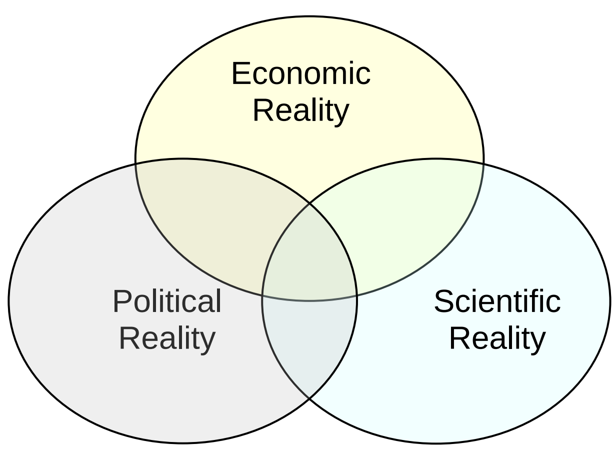


Figure 3.1: Unacceptable risk is determined by assessing economic, social and political realities. Source: Kirkland and Thompson 2002.

3.5.1 Biological Reality of Bird Collisions with Power Lines

For an event to have biological significance, it must have a measurable impact on the population and/or its habitat which could reasonably be expected to affect a population's finite rate of increase or its stability, and as a result, influence a population's viability (Strickland 2003). Several researchers have attempted to determine the biological loss from collisions. Past studies have shown that, in general, bird deaths due to collisions with power lines are considered an unimportant source of mortality at the population level (Bevanger 1994). However, under certain circumstances collision losses can be biologically significant, for example, if the species is threatened or endangered.

If the species is limited in geographical distribution, or has extremely low numbers then population losses from power line collisions could be considered biologically significant (APLIC 1994). For example, the death of just one whooping crane (*Grus americana*), an endangered species, would be considered biologically significant (Crowder and Rhodes 2002). Because of their body morphology, whooping cranes are also one of the most susceptible species to power line collisions (Brown 1987). In Alberta it has been found that the number one cause of death of fledged whooping cranes is from power line collisions (Alberta Government 2002). According to Brown and Drewian (1995) 39% of all fledging whooping crane mortality is from power line collisions.

In contrast to whooping crane collisions, the death of one thousand mallards would not be considered biologically significant because it would not affect their ability to sustain the population (Crowder and Rhodes 2002). However, this sort of event could be considered socially-politically significant.

3.5.2 Social-Political Reality

In the past, risk assessment has moved away from being strictly scientific based and less technical (USEPA 1998). This means that for environmental risk, quantitative estimates will have a lesser focus; instead, balancing multiple social interests will become important (Power and McCarty 2002). This can be difficult when several stakeholder groups are involved, each supporting their own diverse objectives and values (Zio 2003). There seems to be recent, increased awareness and involvement in environmental risk by the public (Zio 2003). Bird collisions are a good example of an issue that has experienced this same trend. The two main factors electric utility companies use in prioritizing bird mortality caused from collisions with power lines are biological significance and social-political significance (Crowder and Rhodes 2002).

The social and political implications of bird-power line collisions should not be underestimated. Whether or not the species in question is considered to be in low numbers, people may become extremely concerned if they see, or see evidence of, collision(s). As previously discussed, the death of a thousand mallards would not be considered biologically significant (Crowder and Rhodes

2002). However, if these collisions took place in direct observation of environmental groups or the general public, or any other type of situation where the media or politicians would be notified, then it would be considered a politically significant event (Willard 1978 in Crowder and Rhodes 2002).

Even though the collisions may or may not be biologically significant, how the public perceives the problem may be very different. Public perception is much richer and more complex than the quantitative way that experts would perceive it because they bring an array of psychological, social, institutional, and cultural factors (Kailan and Thompson 2002). Increasingly, societal and public concerns are forcing organizations to take a broader view in decision making (Harvey et al. 2004). The following example describes how bird – power lines collisions can escalate into a social-political issue.

Lois Hole Park is located just northwest of the city of St. Albert in Alberta and is home to over 235 species of birds including species at risk and migratory waterfowl (BLESS 2005). At the east end of the lake there is a public path, a viewing platform and a power line. This viewing platform is a popular place for both bird watchers and the general public to gather. Unfortunately because it is situated beneath the power line, it is also the ideal place to witness bird collisions which often results in mortality. After colliding with the transmission line, the dead birds and/or their parts often drop onto the public pathway (personal observation). This power line has received so much publicity that AltaLink has publicly stated that they are considering relocating the line.

St. Albert Gazette

Serving St. Albert and surrounding area since 196

Letters to the Editor - February 28, 2007

Power lines a bigger threat than ATVs

I thank you all for your many concerned letters regarding my ATV and sled use on Big Lake. A bylaw enforcer was good enough to call and tell me not to ride through town on the river and district conservation officer Rob Spelliscy was kind enough to call and tell me to stop riding on the lake.

Now that I have more of your attention, could you dedicated supporters of nature please help stop the slaughter of birds on those horrible transmission lines that greet all who come to view our beautiful Louis Hole Provincial Park?

Some of you wonder who I am. Well, I am the guy BLESS gave a certificate of honour to on Oct. 24, 1997 for my efforts in bringing Trans Alta's attention to the slaughter of birds on their power lines down by the viewing platform. I've written a couple of letters since then that the Gazette was kind enough to print but there was never a single reply from any of you, so the birds keep dying and you all keep feeling honoured and self-righteous over this new provincial park. I thought the park was only another attempt to stop the west road. Because of these power lines, I am ashamed of this park and I have a feeling Lois Hole would be, too.

By their own accounts over 700 birds die on those lines every year. Doesn't that bother any of you? Do you know how big a pile 700 dead birds will make? It is about eight feet high and 10 feet across and that is every year. Now multiply that by 35 years or more. And you complain about bull rushes and death by a thousand cuts, try 10,000 birds.

Do any of you have the courage to voice your concerns to the power company? I hope this new letter will encourage someone but I'm not holding my breath. I'll make you a deal, I will stop riding my ATV in Lois Hole Provincial Park when I see those power lines moved alongside the west road.

To answer a couple more of your concerns, the only trail I followed along the south side of the lake was the one made by the bulldozer that knocked down the trees for the golf course that was never built. The steep track up the side of the hill that a lot of us liked to test our courage on is the one made by the oil companies over 50 years ago. I can honestly say me and my off-highway vehicles have never killed a single bird or harmed a single critter out there.

High-wire bird hazards fitted with lights

St. Albert's Big Lake wetlands area used to test special reflectors

JEFF HOLUBITSKY
Journal Staff Writer
EDMONTON

If a utility company's project works out, about 75 bright little warning signs swaying on power lines above St. Albert's Big Lake wetland area should make life safer for migrating birds this fall.

"Anytime there is a structure in the air it can pose a hazard to birds, and in the Big Lake area there is a lot of activity with different types of waterfowl," says John Rasmussen, environment manager of AltaLink, Alberta's largest rural electrical transmission company with more than 11,000 kilometres of power lines.

He says the Big Lake area was chosen for the $10,000 pilot project because it is easy to monitor and because it has a large number of migrating birds in the spring and fall. "There have been impacts on the wire, so obviously we are aware of that, and that is why we are initiating a pilot project there to see what we can do to mitigate it."

The orange, yellow and white markers were installed every five to 10 metres over Riel Pond and the Sturgeon River last week by crews using a helicopter.

Rasmussen says the types of birds most at risk are the larger ones, such as herons or swans, as well as the smaller diving ducks.

The index-card-sized markers, which cost about $50 each, were chosen because positive results in U.S. trials indicated reflectors can reduce collisions with wires by up to 90 per cent, he says. "We did a lot of research to find the best marking device and there are a lot out there."

Atco also is testing the reflectors near Drumheller.

Rasmussen says the devices reflect visible and ultraviolet light because birds are capable of seeing both. "That's quite important because in low light or overcast conditions you still get a lot of UV coming through the cloud cover."

The markers also glow faintly in the dark, helping to make wires visible during short migration days in early spring or late fall, Rasmussen adds.

AltaLink will have staff monitor the Big Lake reflectors to see how effective the markers are. If they live up to their early promise, the reflectors could be used at other locations in the province, such as at wetlands near Brooks.

While the reflectors might provide migrating birds with some warning, Alberta Fish and Wildlife biologist Mark Heckbert says the only way to prevent bird deaths would be to move the electrical lines away from wetlands or to bury them.

"These things are not a solution to proper line routing," Heckbert says. "What I advocate is to make sure these lines, if they are above ground, are not placed in important pathways to and from a lake."

Few studies in Alberta or across North America accurately document the number of birds killed in collisions with power lines, he says, because carcasses are usually eaten quickly by scavengers such as coyotes or crows, before anyone finds them. However, Heckbert believes power lines are the biggest killer of trumpeter swans, a species particularly susceptible to collisions because their large size makes it difficult to change directions quickly.

"Power lines in Alberta are the biggest single known mortality for adult trumpeter swans," he says, adding that he was not aware of any similar studies on other Alberta species.

Every year between six and 10 swan carcasses are found beneath lines in the Grande Prairie area, but Heckbert says this number is likely a tiny fraction of the total deaths. "I think the reflectors are of limited value because they are not going to work well during foggy conditions or in snow storms, which are common conditions during peak migration times for birds in Alberta."

University of Alberta graduate researcher Cindy Platt, with the Wildlife Rehabilitation Society of Edmonton, welcomes the project and was on hand last week to see the reflectors installed.

"We do get some birds at the rehab that have collided with the power lines and anything they can do to reduce that is all right," she says.

"It has worked in the States and I'm very optimistic it will work here."

AltaLink environmental specialist Nikki Krachko holds up a reflector designed to prevent migrating birds from flying into power lines.

The St. Albert Gazette, Saturday, October 14, 2006 - 7

Big Lake power lines electrocute approximately 400 birds per year

Power line move being studied

BY KEVIN MA
Staff Writer

The City of St. Albert is hatching a plan to move the power lines that cross Big Lake.

Local binders have criticized the lines in the past because they tend to electrocute birds — up to 400 a year, according to a report from the Big Lake Environment Support Society (BLESS).

"This has been going on forever," said local environmentalist Elke Blodgett. The lines run between Big Lake and Riel Pond, she explained. Birds landing in the pond don't have enough flight-path to fly over the lines easily, so they hit them.

"Quite often, you will sit at a picnic table and hear this 'thunk' like a bow and that's a bird hitting a line," she said. "For a couple of years [in the late 1990s] a great blue heron was hanging in the power lines by its neck until it disintegrated."

Recently, AltaLink spokespersons confirmed that they were in talks with the city to move the lines so they follow the west regional road in an effort to reduce the chance of birds hitting them.

"This is not something we'd consider in our normal course of business," said company spokesperson Scott Schreiner. "To my knowledge, this will be the first time we've gone to this step."

AltaLink plans to move about five stretches of line at an estimated cost of $350,000, Schreiner said. The company is talking with the city to figure out who would pay and still has to get approval from the Alberta Energy and Utilities Board (EUB) before doing the move.

> "To my knowledge, this will be the first time we've gone to this step."
> SCOTT SCHREINER
> *AltaLink*

Birds hit power lines all over Alberta, said AltaLink environmental advisor Nikki Heck. Most collisions involve the shield wire, a thin, tough to see line at the top of a power pole that acts as a lightning rod to protect other lines. At the request of the city, AltaLink installed reflectors on the Big Lake wires last summer to make them more visible to birds.

Unfortunately, Heck said, the reflectors didn't work. Collisions actually increased after they went in. This was due to the construction of the west road, she explained. The road took out part of Riel Pond, making it more difficult for birds to gain altitude and dodge the lines. The situation could get worse in the future, she added. The road plans include a constructed wetland with an educational platform facing the lines, meaning there could soon be more birds and more collisions.

These factors motivated the company to move the lines, Schreiner said. "Realistically, there's still a chance that birds will collide with lines in the area," he said, but moving the lines should reduce that chance.

The company hopes to send its application to move the lines to the EUB soon, Schreiner said, but has to work out payment details with the city first. The EUB might let the company finance the move through a rate increase, he explained, but might also drop the bill on the province or the City of St. Albert. It could also deny the application.

Continued on page 8

Figure 3.2: Newspaper clippings from articles related to bird – power line collisions at Big Lake.

3.5.3 Economic Reality

From a utility operator's perspective, there is very little direct economic risk associated with bird-power line collisions. Birds striking the line do virtually no damage to equipment and do not cause a power outage. However, economic repercussion could result from fines resulting from being non-compliant with legislation, and the potential cost of retrofitting or relocating power lines after they are built. Economic gain from proactively mitigating lines through a risk-based approach would result from the utility operator having clear knowledge on where their higher risk sites are located for the purpose of managing mitigation efforts. This allows them to justify mitigation expenditures as being prudent costs.

The Alberta Wildlife Act, the federal Species at Risk Act and the Migratory Birds Convention Act protects a broad range of migratory species from harm. The contravention of any of these regulations could result in substantial fines to the utility. In 1999, the Moon Lake Electrical Association, an electric utility in Utah and Colorado, USA, was fined a total of $100,000 and forced to retrofit all their dangerous structures after 17 raptors were found electrocuted over 13 years (Melcher and Suazo 1999). In another case in 2002, Pacific Gas and Electric in California, USA, entered into a $10,000,000 Memorandum of Understanding with the U.S. Fish and Wildlife Services that required them to survey minimum 200 miles and retrofit minimum 2,000 poles annually (Best 2007, personal communication).

To date in Canada there has not been a case a utility being fined for a violation of these regulations. However, it is reasonable to assume that Canadian utility companies will encounter similar repercussions as in the USA. Canada shares international standards with the USA, for example the Migratory Birds Convention Act which protects all native, migratory birds. Canada should uphold and enforce this Act, along with the USA.

Utility operators must be able to justify their expenditures as prudent. The cost of retrofitting or relocating a power line may be great. For example, the cost of installing visibility markers, a common approach to mitigation, along a 300 m stretch of line could range from $6,000 to $15,000 (Hill 2007: personal communication). Additionally, a power outage is also often required, meaning potentially having to temporarily interrupt service to a customer. Therefore, it would not be cost effective nor practical to mitigate every stretch of line.

In extremely high-risk areas, the power line may need to be relocated or buried (section 3.5.2). The cost of doing this would range from hundreds of thousands to millions of dollars depending on the length of the power line and surrounding habitat (APLIC 1994).

3.5.4 Alberta Context

AltaLink’s electric transmission grid is located in central and southern Alberta within two of the four major migration corridors in North America, the Pacific and

Central flyways (figure 3.3). Furthermore, Alberta hosts an enormous percentage of the world's wetland areas in its Prairie Pothole Region (PPR), 770,000 km^2 created by retreating glaciers (figure 3.4). The PPR is nicknamed the "duck factory" of North America because it has the most productive breeding habitat in North America for hundreds of migratory bird species (USFWS 2003). In fact, this region in the Canadian prairies is where over half of all of North America's waterfowl breed each year (Ducks Unlimited 2006). Bradley (2003) has suggested that collision risk increases as the density waterfowl increases. Thus, AltaLink's transmission system is particularly susceptible to collisions.

Waterfowl migration occurs during the spring and fall of each year and thus, it is during these two seasons where the majority of collisions occur. Waterfowl and other water birds use different types of wetlands for a variety of purposes including breeding, nesting, molting, feeding and staging. Wetland classification is a complex matter (Thompson 2005: personal communication) and for this research, the USFWS "Classification of natural ponds and lakes in the glaciated prairie region" (Stewart and Katrud 1971) has been used. This classification system is used by Ducks Unlimited because it works well for classifying wetlands in central and southern Alberta (Thompson 2005: personal communication).

Seasonal wetlands (also called type III) are generally shallow with abundant emergent vegetation. These types of wetlands are often used by hens in the spring during nesting and feeding times. They provide ideal nesting and feeding habitat because of food and security cover. Semi permanent wetlands (type IV) are more of the classic type of wetland, with plenty of emergent bulrush and cattails. Shortly after their eggs hatch, hens often move their brood to these areas because they provide a good balance of open water and cover for protection from predators. These types of wetlands are also used during molting stage when the birds lose their flight feathers and grow new ones. Again, the balance of open water with lots of emergent vegetation provides protection from predators during this very sensitive time when the birds are not capable of flight. Permanent wetlands (type V) are large areas of open water with vegetation along shorelines. These wetlands are used most often for staging prior to fall migration. According to Hopkins (2005: personal communication), types III, IV and V wetlands that harbor 30 or more breeding pairs are considered to be high priority wetlands for waterfowl production.

This context, unique to Alberta, will affect both the biological, social-political and economic aspects of bird collisions. Because so many breeding waterfowl occur in the province, the biological aspects may be higher than in other areas located outside of the PPR. This prairie pothole region is also where 85% of Alberta's growing human population resides and therefore the chance for social-political consequences is greater.

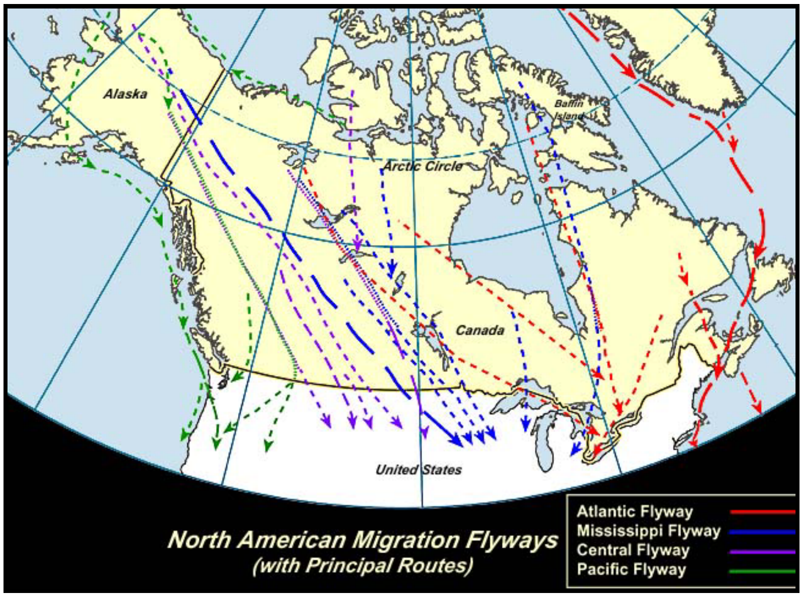


Figure 3.3: Locations of the four major North American migratory flyways. Source: BirdNature.com

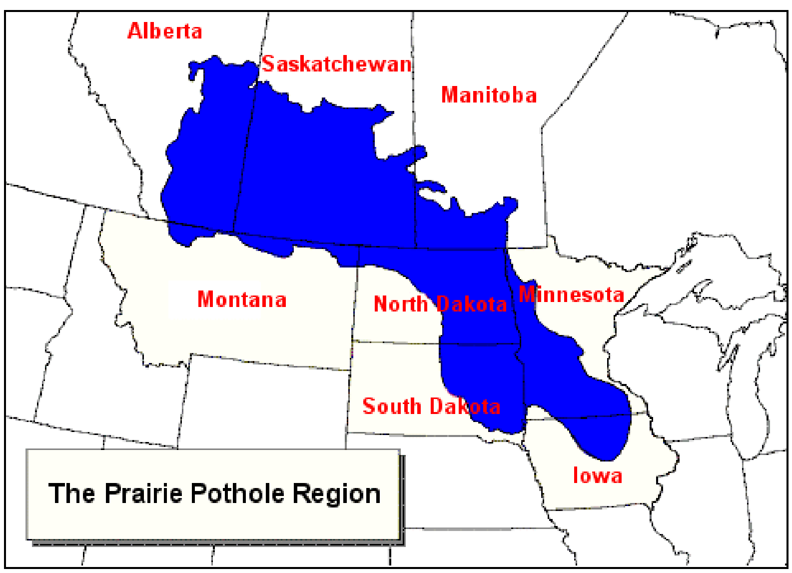


Figure 3.4: The Prairie Pothole Region (PPR) of North America. Source: USFWS 2003

3.6 DEFINING RISK IN TERMS OF BIRD COLLISIONS WITH POWER LINES

In the engineering assessment, risk is defined as probability multiplied by consequence.

Risk = Probability X Consequence

The information gained through the literature review in Chapter 2 has been used to determine probability and consequence. The environment that species occupy, surrounding human land use, and power line placement, orientation and configuration in relation to that environment has an influence on the probability of collisions (APLIC 1994). The consequence of these collisions depends on the types of species present, and whether the collisions will become social-political events. Given this, it can be said that:

Probability = (Habitat suitability x Likelihood for collision)

Consequence = (Social and political consequences)

Therefore,

Risk is a function of:

(Habitat suitability x Likelihood for collision) (Social and political consequences)

3.6.1 Habitat Suitability

The following areas provide suitable habitat for waterfowl and spatial data is available. These data were used in the GIS modeling portion of this study (Chapter 4).

- **Ducks Unlimited Molting and Staging Wetlands:** Ducks Unlimited is a national, private, non-profit organization dedicated to conserving wetlands and their associated habitats (Ducks Unlimited Canada 2007). They have identified key moulting and staging areas for waterfowl in Alberta.

- **Important Bird Areas (IBA):** An IBA is a site providing essential habitat for one or more species of breeding or non-breeding birds. These sites may contain threatened species, endemic species, species representative of a biome, or highly exceptional concentrations of birds (BirdLife International 2004).

- **Trumpeter Swan Stopover Wetlands:** The Rocky Mountain trumpeter swan population migrates approximately 1400 km to their breeding grounds in Grand Prairie, Alberta every spring (Mackay 1978). During this migration, they stopover at select ponds, located west of Calgary within AltaLink's service area (Fontana 2006, personal communication). These spring migration stopovers are very important because they affect breeding success by providing the necessary energy reserves (LaMontagne et al. 2003).

- **Top Birding Sites:** have been identified in Fisher and Accorn's (1998) field guide to "Birds of Alberta". These sites were identified in the guide because of their reputation for "rewarding birding experiences" and accessibility to the public.

- **Wildlife Viewing Areas**: These areas have been obtained from an *Alberta Forestry, Lands and Wildlife* publication titled "Alberta wildlife viewing guide", a comprehensive guide to Alberta's finest wildlife viewing sites. Areas that identified key waterfowl and other water bird were used as part of the analysis.

- **Natural Areas:** are sensitive or scenic public lands, or natural features on public lands that are protected from disturbance (Alberta Environment 1997).

- **Ecological Reserves:** are any area of public land designated by the Lieutenant Governor in Council as: 1. being suitable for scientific research associated with the studies of natural ecosystems; 2. a representative example of a native ecosystem in Alberta; 3. serving as an example of an ecosystem that has been modified by humans and that offers an opportunity to study the recovery of the ecosystem from that modification; 4. containing rare or endangered native plants or animals that should be preserved; and 5. containing unique or rare examples of natural biological or physical features (Alberta Environment 1997).

- **Provincial Parks:** are areas designated by the province and have minimal development and therefore may be attractive to birds.

- **Federal Lands:** are areas designated by the federal government and have minimal development and therefore may be attractive to birds. Federal lands include National Parks, Military Bases and Indian Reserves.

- **Standing Water:** Standing water is an attractant to waterfowl and other water birds and includes wetlands, lakes and reservoirs. Waterfowl and water birds can be found in nearly any area with permanent or semi-permanent standing water (personal observation).

- **Flowing Water:** Like standing water, flowing water such as streams and rivers may also attract waterfowl and other water birds, though presumably not has many as do areas with standing water.

- **Steep Topography:** Areas where slope is greater than ten degrees may have an increased chance for collisions if intersected perpendicularly by a power line. In this study, a steep slope was defined as one greater than ten degrees, based on the slope of the Elbow River valley in Calgary, Alberta, determined through GIS analysis. "Birds, especially wetland species tend to follow linear wetlands when moving from one area to another. Hence, lines that cross perpendicular to such waterway corridors tend to have higher impacts" (Bradley 2003: 12).

3.6.2 Likelihood for Collisions

Presence of overhead shield wires (OHSW) has been cited by many researchers as having a significant affect on collision risk including, Faanes (1987), and

Bevanger and Brøseth (2001). APLIC (1994) estimated that as high as 90% of bird mortality from collisions may be with the shield wires. Therefore power lines with no shield wires were considered to be much lower risk than lines with one or two shield wires.

There are other power line factors that may affect the probability of collisions such as vertical or horizontal conductor configuration, and amount of sag for the overhead wire(s) (Harness and Carleton 2001). However, these factors cannot be mapped in GIS because AltaLink's database does not currently have the ability to do this. In the future, if the data was available, this would be useful information to integrate into the risk assessment.

3.6.3 Social Political Consequences

The following includes areas where the public could become involved in and voice a concern over bird collisions. Spatial data for these areas is available. These data were used in the GIS modeling portion of this study (Chapter 4).

- **Dwellings:** 15 dwellings per hectare and greater was used to determine where enough people resided to become potentially concerned over bird collisions. This number was obtained from the City of Calgary's Municipal Development Plan (1998: 39) where they advise that "within a community plan/area structure plan area, a density range of between 6-8 units per gross residential acre should be worked towards over time". 1 Hectare equals 2.47 acres so 6-8 units per acre equals 15-20 units per hectare

- **Top Birding Sites:** In addition to providing suitable bird habitat, these areas, as described by Fisher and Accorn (1998) in their field guide to "Birds of Alberta", are highly used by the birding community in Alberta. These sites were identified in the guide because of their reputation for "rewarding birding experiences" and accessibility to the public.
- **Wildlife Viewing Areas**: As with Top Birding Sites (see above), Wildlife Viewing Areas were described in an *Alberta Forestry, Lands and Wildlife* publication titled "Alberta wildlife viewing guide", a comprehensive guide to Alberta's finest wildlife viewing sites. These areas are easily accessible to the public and are frequently visited by birders and the public.
- **Provincial Parks:** Provincial parks attract people. Because of their high public use, the public could become extremely concerned where collision areas occur within provincial parks.
- **Proximity to Standing Water:** was also considered in this assessment because the public uses lakes and reservoirs as recreational areas.

The following table describes the factors that lead to increased risk for bird collisions and how they have been categorized for the purpose of this risk assessment and how important they are in relation to collision potential.

Importance is based on findings from past research (Chapter 2) and professional judgment. These factors were weighted numerically in Chapter 4.

Table 3.1: Collision Factors Characterized According to Risk

Category	**Description of Category**	**Criteria in category**	**Importance in Relation to Collision Potential**
Productive Bird Area	These are areas where the largest concentration of waterfowl and water birds are expected to be found in Alberta	1. Duck's Unlimited molting and staging wetlands 2. Important Bird Areas 3. Trumpeter Swan stopover wetlands 4. Top Birding Sites 5. Wildlife Viewing Areas	Very Important
High Habitat Use Areas	Areas that would attract waterfowl and water birds but wouldn't necessary support large populations	1. Natural Areas 2. Environmental Reserves 3. Provincial Parks 4. Federal Lands	Important
Standing Water	These are areas where waterfowl and water birds would be expected to be found but are not actually designated as productive bird areas	Includes standing water features (wetlands, lakes, reservoirs).	Somewhat important
Moving Water	These are areas where waterfowl and water birds may be found but less likely than standing water areas and productive bird areas	Includes all flowing water	Less important
Topography	Areas with a slope greater than 10% relief were used as the cutoff for assigning a value. All other areas were assigned a value of 0. that could be used as flight corridors for birds	Includes river valleys and other areas of steep linear depressions	Less Important

Overhead Shield Wire (OHSW)	Because 90% of collisions occur on the OHSW (APLIC 1994), it is important to be able to identify their presence or absence	1. 0 OHSW 2. 1 OHSW 3. 2 OHSW	Important
Social Political Consequence Areas	These are areas where people are likely to witness collisions	1. Areas with greater than 15 dwellings per hectare 2. Proximity to Productive Bird Area 3. Proximity to High Habitat Use area 4. Proximity to water (river, stream, wetland, lake, or reservoir)	Important

3.7 DISCUSSION

This chapter has described the risk assessment process used to evaluate and rank the bird – power line collision potential on existing AltaLink transmission lines. To date, there has been no methods available that has allowed electric utility operators to do this. No power outages occur and no damage to equipment is done when birds strike transmission lines and therefore, identifying high-risk sites is a great challenge for utility operators. Recently, there has been a push for utility companies to do this, especially in the USA where Moon Lake and Pacific Gas & Electric have been issued large fines.

Like other risk assessments, there is a certain level of uncertainty involved (Kirkland and Thompson 2002). In this assessment uncertainty may result from:

- uncertainty in the inputs used to estimate probability;
- variability in situations or those being affected;
- inability of the researcher to understand and characterize situations;
- variability in ecosystems;
- limited ability to measure and model uncertainty accurately; and
- lack of available records and data (Kirkland and Thompson 2002).

These uncertainties have been controlled by using multiple peer reviewed sources for information, and thorough, careful examination of relevant information upon which informed decisions can be based. The assessment provides a means for identifying areas of risk that the utility may have been previously unaware of. Although it is unlikely that every high-risk site will be identified, it will help to greatly reduce collision risk mortality once mitigation measures have been taken. Furthermore, the public demands that environmental controls and checks are in place in large organizations where their infrastructure affects the landscape. “There has been increasing pressure for communication and transparency, reflecting social desires for reassurance on the use of appropriate risk controls in organizations” (Pritchard 2000: 1). As more research emerges on power line collisions and spatial data becomes more accessible, the assessment can be improved.

CHAPTER 4: GIS MODELING

4.1 CHAPTER OBJECTIVE

The objective for this component of the research was to utilize a Decision Support System in GIS to create a risk model for bird collisions with electric power transmission lines in south and central Alberta

4.2 INTRODUCTION

GIS has been defined as "a system of hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth" (Dueker and Kjerne 1989 in Lillesand and Kiefer 1994: 38). It captures, manages, integrates, and displays data that is spatially referenced to the Earth by enabling the display and analysis of various layers of information with common geography in reference to each other. It is useful for data analysis, research development, monitoring programs, and tracking efforts (Landon and Harness 2002). In recent years, GIS has become a highly flexible modeling tool that can greatly enhance resource management (Alexander 1997). For the purposes of the electric utility industry, it can be used as a proactive tool for overlaying electric utility infrastructure management needs with biodiversity conservation opportunities (Southerland et al. 2002).

GIS can be used as part of a decision support system (DSS) to assist in solving a wide variety of land use type problems (Eastman 1999). In this study, DSS has been applied as a tool for identifying high-risk bird–power line collision sites on AltaLink's electric power transmission line system. The use of a DSS differs from the traditional reactionary approach that electric utilities take in solving collisions. This traditional approach is to respond to outside pressures by conducting a site specific study and then carry out some sort of action to retrofit the line (such as the installation of line marking devices) (APLIC 1994). The reason this approach has been traditionally employed is because the factors that create a hazard for birds near power lines are complex and site-specific and therefore it has been reasoned that the most effective solution for correcting a problem line is a site-specific plan that satisfies unique local conditions (APLIC 1994). The use of DSS and GIS technology would allow for collision risk to be assessed across a larger scale, enabling utilities to be proactive in identifying high-risk sites for mitigation. The information gained from the literature review has been used to build a knowledge based, GIS model that categorizes transmission line corridors according to the degree of risk they pose for bird collisions.

4.3 METHODS

This section details the methodological processes used in the final risk model development. The decision problem, computer software, collision risk factors, pairwise comparison analysis process, collection and creation of baseline data, and final model creation is described. A literature review was used to gain background information on GIS and GIS modeling methodologies. Sources of information was obtained from peer reviewed journals, books, textbooks, websites, and informal conversations with industry experts. Key words used as search terms included: GIS, geographic information system, modeling, decision support, landscape, habitat, and spatial analysis.

4.3.1 The Knowledge Based Approach

A knowledge based system for analysis was chosen for the purpose of this study. In the knowledge based approach, mathematical relationships are established based on hypotheses generated from expert opinion and life history literature (Eastman et al. 1995). Examples of this type of system include pairwise comparison analysis, multi-criteria evaluation (MCE) and multiple objective land allocation (MOLA) (Logan 2003). These types of knowledge driven systems differ from traditional data driven systems such as logistic regression, multivariate analysis, and Mahalanobis distance or discriminant function analysis (DFA) where locational data sources are already available (Logan 2003).

The knowledge based approach to modeling is appropriate for this study for three reasons:

1. Lack of current available bird collision data in the study area;

2. Difficulty in collecting large amounts of data over a large scale. Surveying every kilometer of power line would be extremely expensive and time consuming; and
3. There has been a large amount of past research that has already been done on the biological and environmental characteristics that increase the risk for collisions.

Because of the reasons presented above, it was determined that the most effective approach would be to create a GIS model that is based on current expert opinion and past research. “Knowledge of the biologically important variables helps to make informed decisions and more accurate predictions of bird occurrence in new, unsurveyed sites” (Young and Hutto 2002: 107).

4.3.2 The Decision Problem

Where are the locations of highest business risk related to bird collisions? This is a spatial problem with spatially variable outcomes and consequences (Malczewski 1997). The evaluation was based on multiple criteria that could be spatially associated with the problem. The factors had to be available as a GIS data layers within the study area boundary (table 3.1).

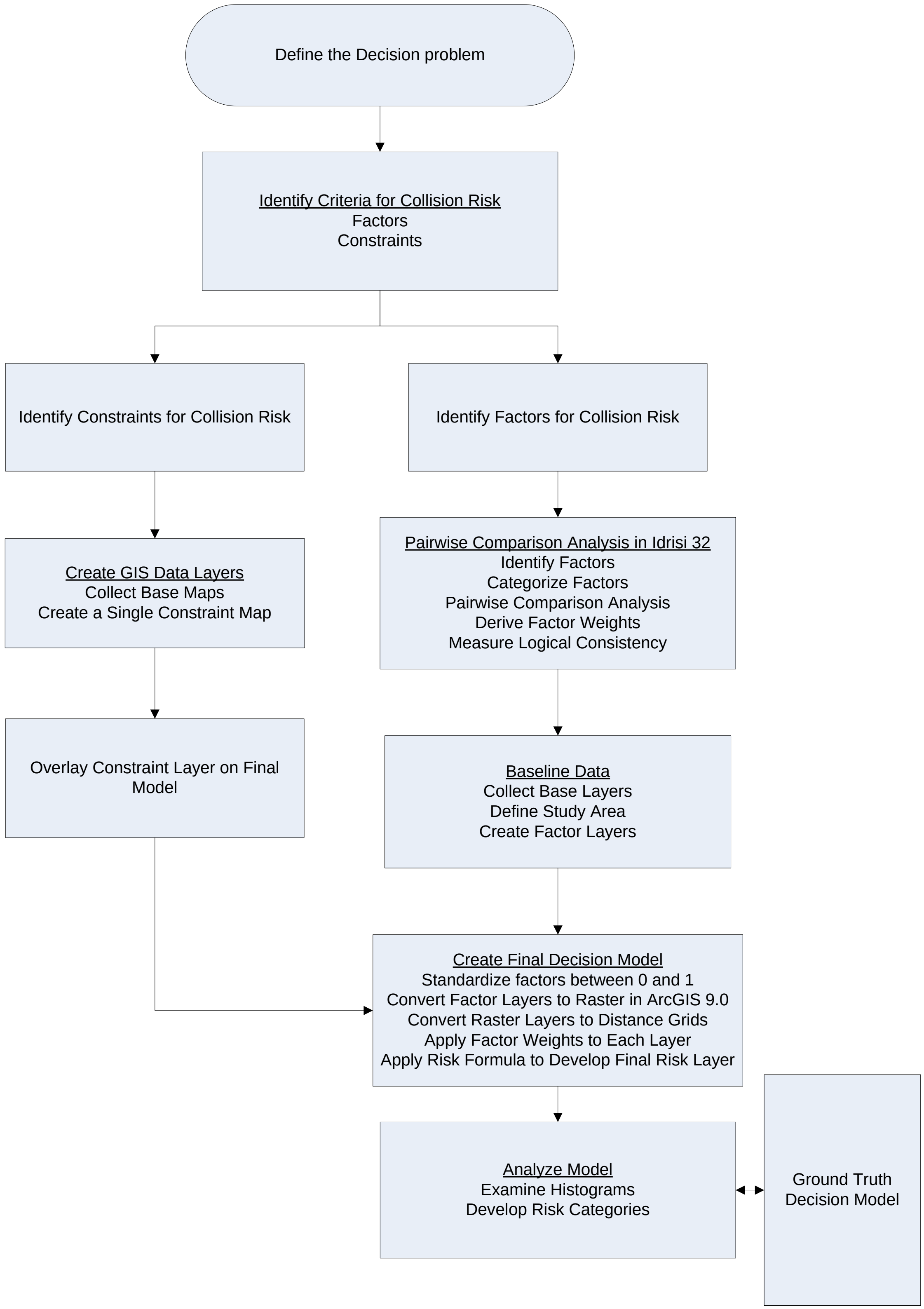


Figure 4.1: Flowchart of the Decision Support Process

4.3.3 Decision Criteria

To solve a decision problem, criteria are identified. Criteria are landscape features that can be represented as layers of geographic data to be used in the DSS (Eastman 1999). Factors and constraints are two types of criteria that are measurable based on which decisions about land quality and its suitability for a specific use can be made (Mwasi 2001). A factor is a continuous geographic attribute that enhances or diminishes the suitability of an area towards meeting a specific objective and a constraint limits the available alternatives by imposing restrictions (Mwasi 2001).

4.3.3.1 Identifying Factors

Factors are those criteria that define some sort of suitability for a geographic region (Eastman 1999). Factors with high scores enhance the suitability and factors with low score detract from the suitability of an area (Eastman 1999). Factors arise from situational conditions such as the relationships between a site and its surroundings; identification is a technical exercise that is based on theory, empirical research, and common sense (Mwasi 2001). In this study, factors that make an area suitable to birds are also those that will lead to collision risk when a power line is present. These factors were identified through the literature review and are discussed in Chapter 2.

4.3.3.2 Identifying Constraints

Constraints are those criteria that limit the analysis of particular geographic regions (Eastmen 1999). They are always expressed in the form of Boolean logic map (0 or 1) (Eastman 1999). The constraint layer was applied as a Boolean mask in the final risk modeling stage.

4.3.4 Pairwise Comparison Analysis

Pairwise comparison analysis (Saaty 1980), a decision support system, was used to develop this model. Pairwise Comparison Analysis (PCA) allows the means for analyzing complex trade-offs between choice alternatives with different environmental and socio-economic impacts (Carver 1991).

PCA was carried out using a method known as Weighted Linear Combination (WLC). WLC is a method used to standardize the decision factors along a continuous scale by allowing them to be compared, combined, and traded-off with one another (Eastman 1999). This process can be thought of as a hierarchy called the Analytical Hierarchy Technique (figure 4.2) where the relative value of a site is viewed as the focus (F), which is obtained by combining several factors, each with its own relative importance, weight or priority with respect its contribution to the overall focus (Anselin and Meire 1989). In the example shown in figure 4.2, the factors are represented by A, B, and C, each of which influences F. Each factor has several indicators associated with it, which are shown as A_n, B_n and C_n, all carrying various weights of importance to F.

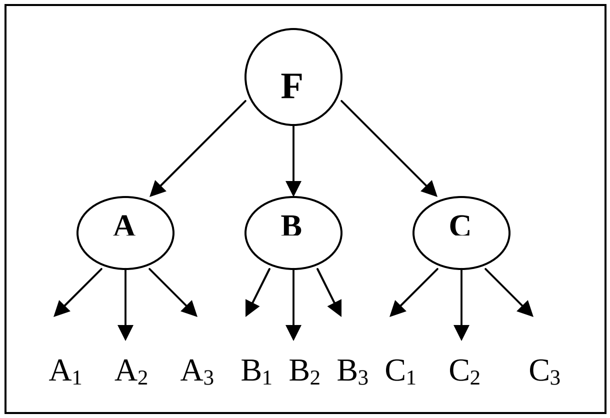


Figure 4.2: The Analytical Hierarchy Process, adapted from Anselin and Meire (1989).

Factors that could be represented spatially using available GIS data were identified and grouped into categories (table 3.1). Certain factors will have higher suitability scores than others allowing them to be traded off with each other. Factors are ranked using PCA to weight each factor relative to the next and indicate a factor's importance relative to all the other factors (Eastman 1999).

Past literature, and professional opinion were used to rank the pairs. The factors were compared and then ranked with Saaty's (1980) pairwise comparison matrix, using the 9-point rating scale (figure 4.3). In this rating scale, the most important of each possible pair effects is selected, followed by subsequent comparison established in qualitative terms to what extent one effect is more important than the other one to express the differences of importance. Anselin and Meire (1989) have outlined the following procedure. From the 9-point weighting scale, weights are derived from the principal eigenvector of the square reciprocal matrix of pairwise comparison between all contributing factors. This is done by allowing the factor *n*, to be assigned relative weights of importance of *w*1, *w*2, …*w*n, and then the comparison of the relative importance of factors *j* to give a value of *F(i,j)* = *wj/wi* = *1/(i,j)*. The factors are compared to build up a comparison matrix. The eigenvector associated with the largest eigenvector then gives a best estimate of the weights attached to each factor.

Saaty's (1980) 9-Point Rating Scale

9: relative to the column variable, the row variable is extremely important
8
7
6: relative to the column variable, the row variable is moderately important
5
4: relative to the column variable, the row variable is moderately more important
3
2
1: relative to the column variable, the row variable is equally more important
1/2
1/3
1/4: relative to the column variable, the row variable is moderately less important
1/5
1/6: relative to the column variable, the row variable is strongly less important
1/7
1/8
1/9: relative to the column variable, the row variable is extremely less important

Figure 4.3: Saaty's (1980) 9-Point Rating Scale

Breaking the information down into simple pairwise comparison in which only two criteria need to be considered at a time greatly facilitates the weighting process, and produces a more robust set of criteria weights (Eastman 1999). It also provides an organized structure for group discussions, and helping the decision making group hone in on areas of agreement and disagreement in setting criterion weights (Eastman 1999).

These factors were weighted using the WEIGHT module from the Analysis/Decision Support menu in Idrisi 32. The WEIGHT module calculates the weight of each factor in relation to all the other in the table. It does this by calculating the weights with each column and then averaging over all columns. All of the weights produced sum to one, as is required by the weighted linear combination procedure (Eastman 1999). In order to ensure that no inconsistencies were made during the pairwise comparison process, Consistency Ratio (CR) in Idrisi 32 was used. This ensures that the probabilities of the matrix ratings were randomly generated. According to Saaty (1980), matrices with CR ratings greater than 0.10 must be re-evaluated.

4.3.5 Collection and Production of Baseline Data

Baseline layers were obtained or created for factors identified in the decision problem as influences to collision risk. For each input variable in the weighted linear combination equations, an associated GIS data layer was either obtained or created. Spatial proximity indices with a 50 m pixel resolution were created for each layer using the distance tool from Spatial Analyst tool pack in ArcGIS 9.0. Distance grids were calculated such that each pixel's value represents the Euclidean (straight line) distance to the nearest feature of interest (steep slope, wetland, productive bird area, etc). This was completed by a GIS Technician (Greg Chernoff) at the Miistakis Institute for the Rockies.

4.3.6 Creation of the Final Decision Model

The final risk surface was created by applying the WLC formulae to the input GIS data using Spatial Analyst's Raster Calculator module in ArcGIS 9.0. Distance grids were assigned weights, as calculated in the PCA, and were inputted into the formula, risk = probability X consequence where probability = (habitat suitability) (likelihood for collision) and consequence = (socio-political potential) to develop the final risk model. For the constraint layer, the final output layers were clipped to 1600 m on each side of existing AltaLink infrastructure, as the model does not produce meaningful results beyond this buffer. To rank areas according to risk, the respective histograms under Layer Properties Classification tab in ArcGIS 9.0 were analyzed. Categories created were based on manually selecting the breaks where natural categories of data formed.

4.4 RESULTS

4.4.1 Defining the Decision Problem

The DSS took place within the defined study area boundary, chosen based on availability of GIS data coverages (figure 1.4). The decision problem ranks and compares each area on the landscape in terms of their risk for bird collisions against all other areas within the study area.

4.4.2 Identification of Criteria: Factors and Constraints

The following flowchart summarizes the analytical hierarchy process used in the Decision Support System for bird – power line collisions. Environmental, power line, and social-political features identified through the literature review (Chapter 2) as influencing collision risk that could be represented spatially were used as factors. Presence (1) or absence (0) of a power line was used as the constraint layer. All areas on the landscape that were within 1.6 km of a power transmission line were assigned the value of 1 and all other areas were assigned a value of 0. This is because a transmission line must be present for bird mortality from collision to occur. Brown (1987) found that power lines within 1.6 km of suitable bird habitat could have an effect.

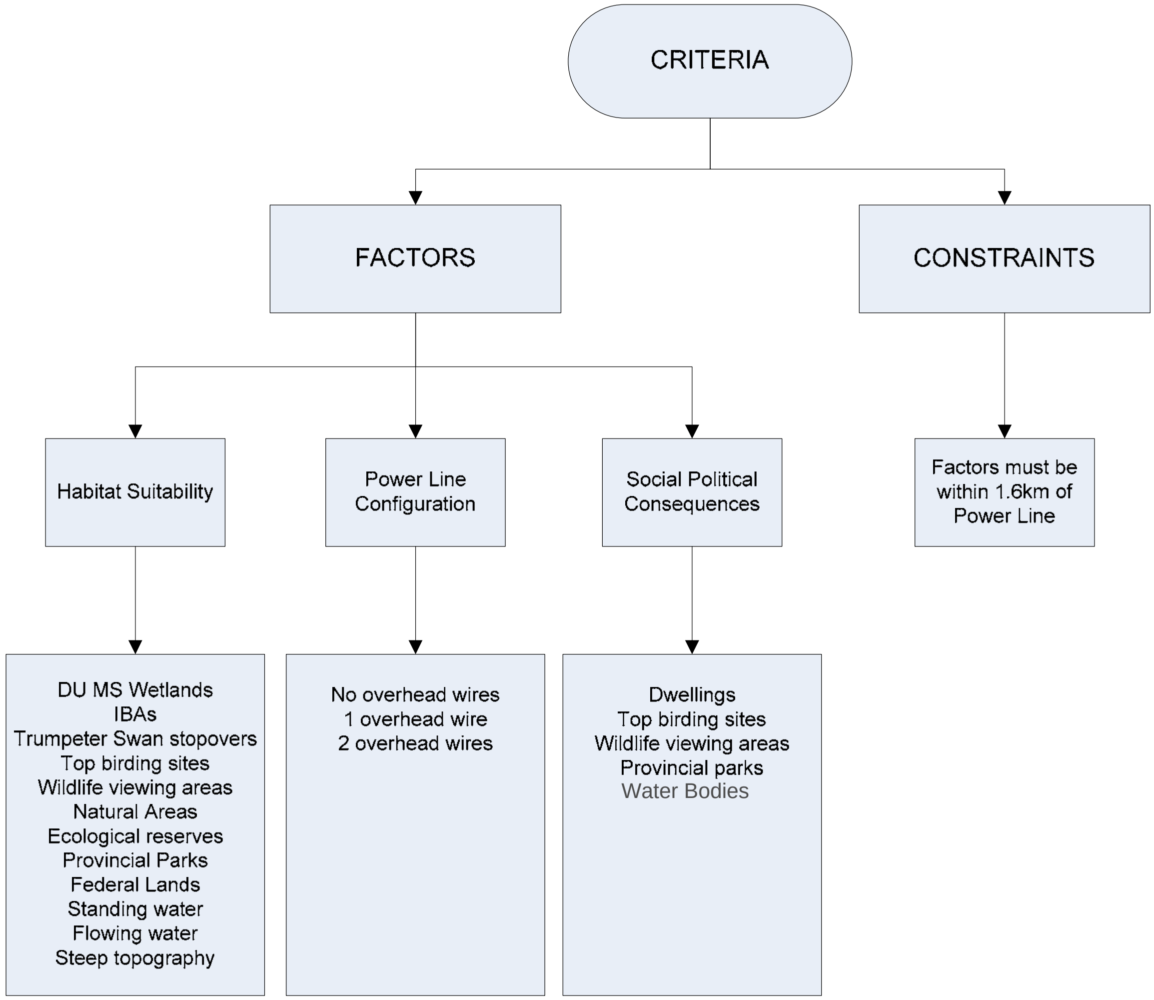


Figure 4.4: Analytical hierarchy technique used for this bird – power line collision DSS.

4.4.3 Weighted Linear Combination Using Pairwise Comparison

The following matrixes were constructed for each factor using Saaty's 9-point rating scale. Below each matrix are the results of the WEIGHT module in Idrisi 32 and the consistency ratio. All ratios were calculated to be below 0.10, indicating that the logic used to determine factor weights was consistent.

Table 4.1: Pairwise Comparison Matrix (Saaty 1980) for Suitable Habitat Probability Factors

	Proximity to Productive Birds Area	Proximity to High Habitat Use Area	Proximity to Standing Water	Proximity to stream or river	Proximity to Topography
Proximity to Productive Bird Area	1				
Proximity to High Habitat Use Area	***1/3***	1			
Proximity to Standing Water	***1/6***	***1/5***	1		
Proximity to stream or river	***1/7***	***1/6***	***1/4***	1	
Proximity to Topography	***1/7***	***1/6***	***1/4***	***1***	1

WEIGHT Module Results

Proximity to Bird Area: 0.5032
Proximity to High Habitat Use Area: 0.2930
Proximity to Standing Water: 0.1146
Proximity to Moving Water: 0.0446
Proximity to Steep Topography: 0.0446

Consistency ratio = 0.08
Consistency is acceptable.

Table 4.2: Pairwise Comparison Matrix (Saaty 1980) for Collision Probability Factors

	0 OHSW	1 OHSW	2 OHSW
0 OHSW	1		
1 OHSW	***7***	1	
2 OHSW	***8***	***1/7***	1

WEIGHT Module Results

0 OHSW: 0.0614

1 OHSW: 0.5659
2 OHSW: 0.3727

Consistency ratio = 0.07
Consistency is acceptable.

Table 4.3: Pairwise Comparison Matrix (Saaty 1980) for Social and Political Consequence Factors

	Proximity to Urban Centre	Proximity to Productive Bird Area	Proximity to High Habitat Use Area	Proximity to Standing Water
Proximity to Urban Centre	1			
Proximity to Productive Bird Areas	***1/3***	1		
Proximity to High Habitat Use Area	***1/2***	***2***	1	
Proximity to Standing Water	***1/4***	***1/3***	***1/2***	1

WEIGHT Module Results

Proximity to Urban Area: 0.4642
Proximity to Productive Bird Area: 0.1839
Proximity to High Habitat Use Area: 0.2544
Proximity to Standing Water: 0.0975

Consistency ratio = 0.05
Consistency is acceptable

4.4.4 Baseline Mapping

GIS data layers detailing suitable bird habitat, high-risk power line configuration, and social political consequence areas (table 3.1 and table 4.1) were obtained from a number of sources (table 4.1). Proximity indices with 50 m pixel resolution were created for each raster layer and projected in 10TM.

Table 4.4: Description and Source for DSS Input Variables

Variable	Abbreviation	Source	Positional Accuracy	Description
Distance to Productive Bird Area	d2_prod_ba	Multiple Sources	+/- 5 m	Euclidean distance to productive bird areas (Ducks Unlimited Canada, BirdLife International, Alberta Conservation Association, Fisher and Accorn (1998) and Alberta Forestry, Lands and Wildlife)
Distance to High Habitat Use Areas	d2_high_hab	Multiple Sources	+/- 5 m	Euclidean distance to high habitat use areas (Parks and Protected Areas, Environmental Reserves, Federal lands)
Distance to Standing Water	d2_h2o_std	Alberta Base Features	+/- 20 m	Euclidean distance to standing water
Distance to Moving Water	d2_h2o_mov	Alberta Base Features	+/- 20 m	Euclidean distance to moving water
Distance to Steep Slopes	d2_steeps	Derived from Alberta Base Features DEM	+ / - 10 to 30 m (vertically and/or horizontally)	Euclidean distance to steep slopes as designated by Miistakis Institute
Distance to Power Line with 0 OHSW	d2_ohsw_0	AltaLink	+/- 50 m	Euclidean distance to power lines with no OHSW
Distance to Power Line with 1 OHSW	d2_ohsw_1	AltaLink	+/- 50 m	Euclidean distance to power lines with one OHSW
Distance to Power Line with 2 OHSW	d2_ohsw_2	AltaLink	+/- 50 m	Euclidean distance to power lines with two OHSW
Distance to People	d2_hd_popn	Stats Canada	unknown	Euclidean distance to high density population areas (>15 dwellings per hectare)

4.4.5 Final Model Creation

The following formulae were used in ArcGIS Raster Calculator to create the final decision model.

Risk = Probability X Consequence

Where,

Probability = (habitat suitability) (likelihood for collision)

= (1 - [(0.2930)*d2_high_hab + (0.5032)*d2_prod_ba + (0.1146)*d2_h2o_std + (0.0446)*d2_h2o_mov + (0.0446)*d2_steeps]) (1 - [(0.0614)*d2_ohsw_0 + (0.5659)*d2_ohsw_1 + (0.3727)*d2_ohsw_2])

And,

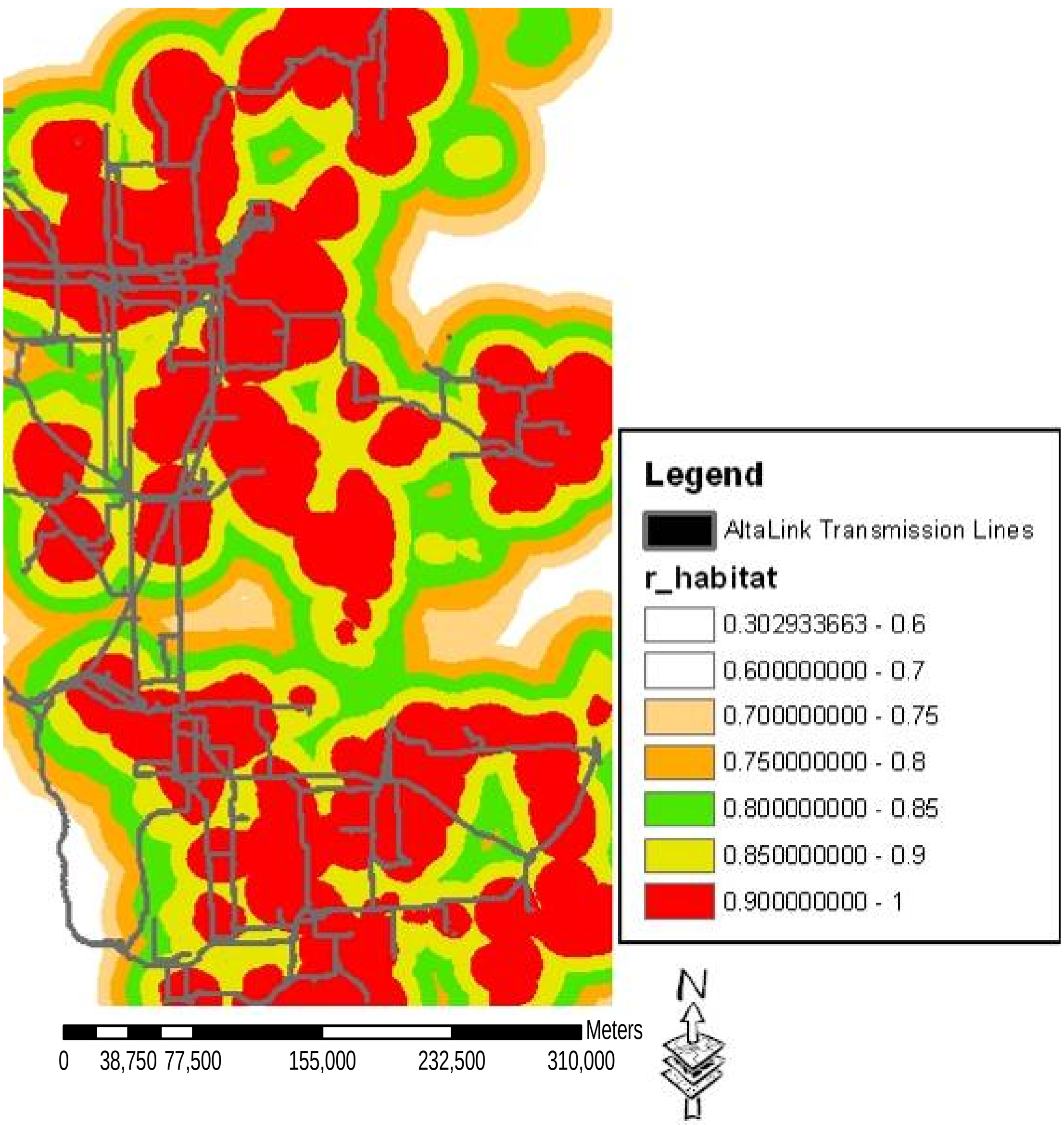
Consequence = (socio-political potential)

= 1 - [(0.4642)*d2_hd_popn + (0.2544)*d2_high_hab + (0.1839)*d2_prod_ba + (0.0975)*d2_h2o_std]

Map 4.1: Step 1 -- Probability for Suitable Bird Habitat (r_habitat)

r_habitat is the standardized (theoretically ranging from 0 to 1) bird habitat quality within the study area, as calculated using the following formula:

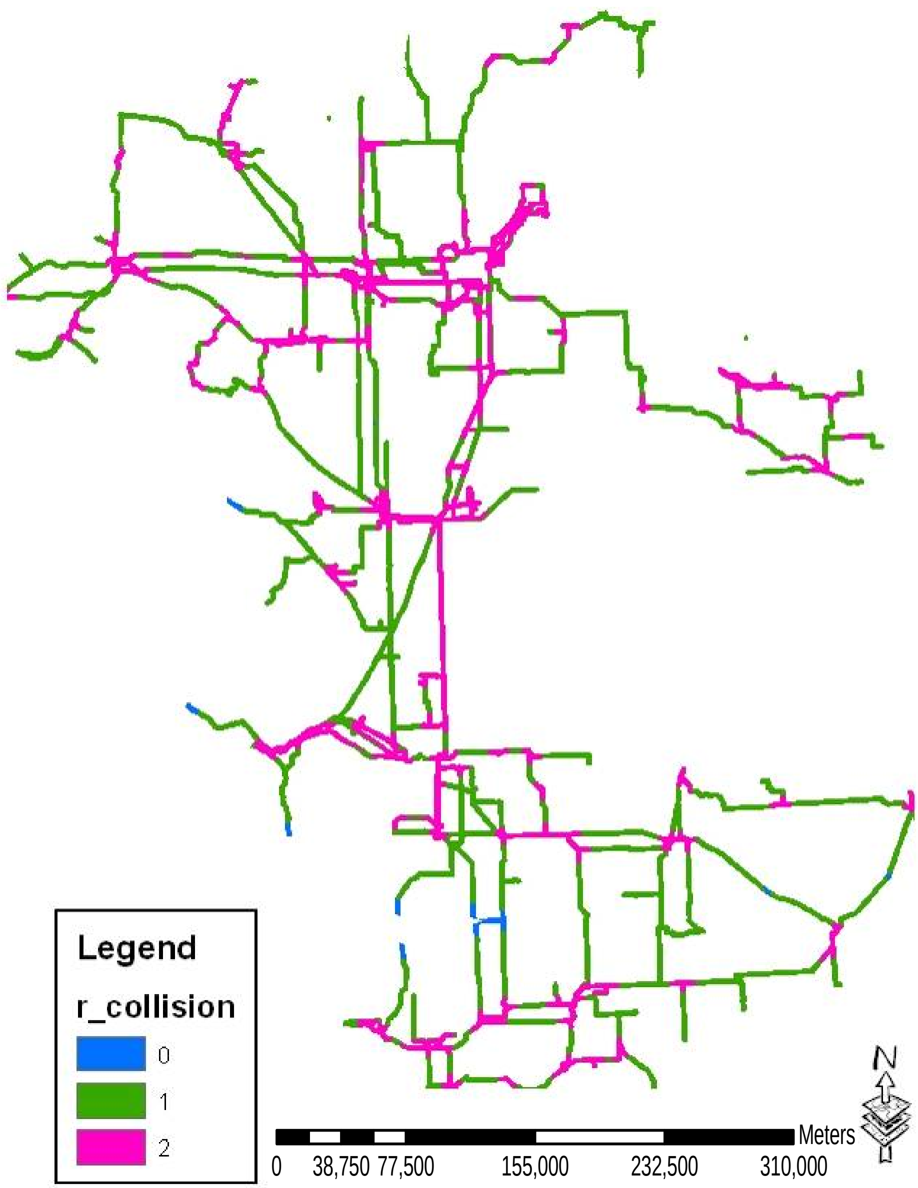
r_habitat = 1 - [(0.2930)*d2_high_hab + (0.5032)*d2_prod_ba + (0.1146)*d2_h2o_std + (0.0446)*d2_h2o_mov + (0.0446)*d2_steeps]



Map 4.2: Step 2 -- Probability for Collision (r_collision)

r_collision is the standardized (theoretically ranging from 0 to 1) risk of birds colliding with AltaLink Structures, as calculated using the following formula:

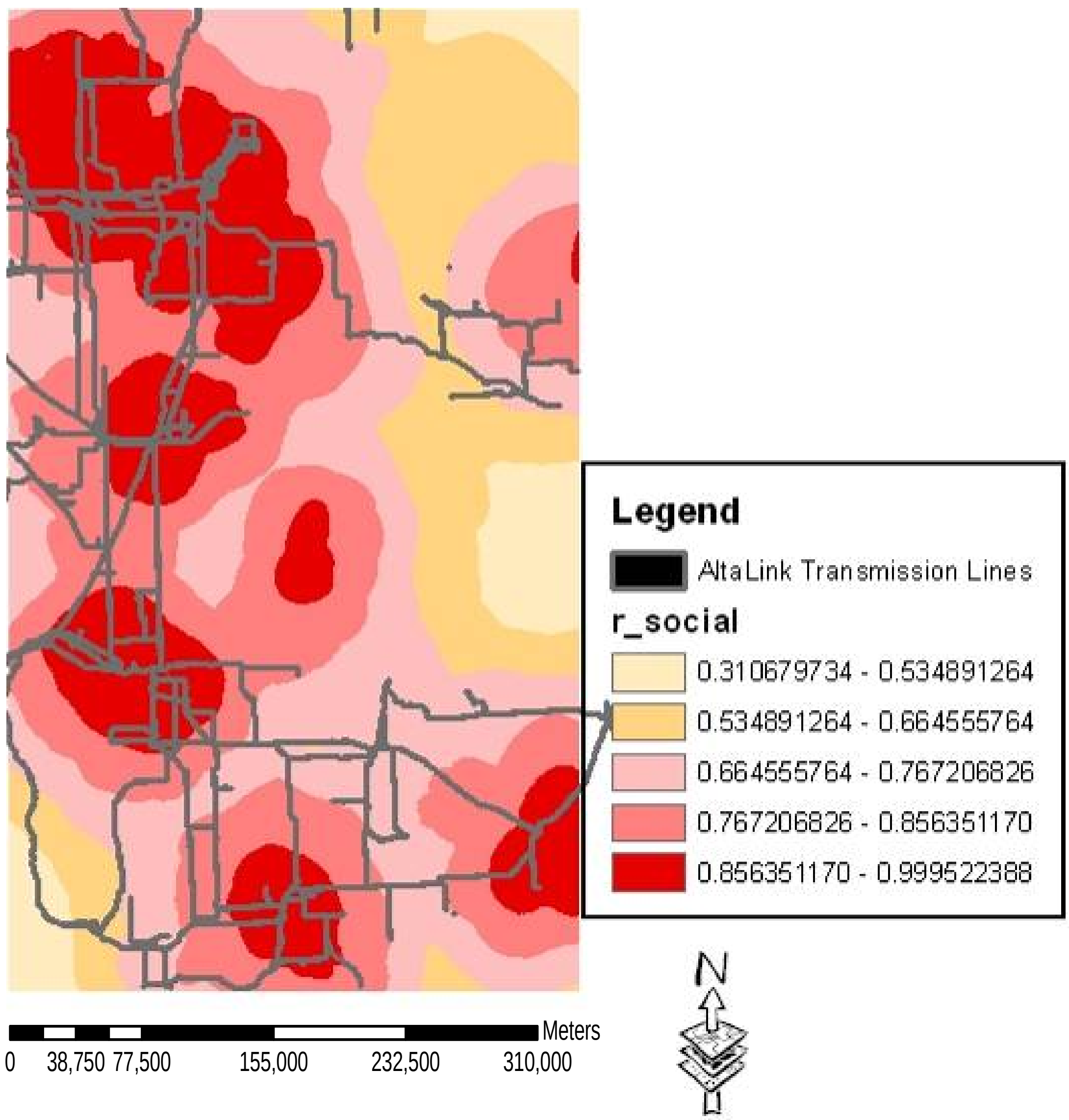
r_collision = 1 - [(0.0614)*d2_ohsw_0 + (0.5659)*d2_ohsw_1 + (0.3727)*d2_ohsw_2]



Map 4.3: Step 3 -- Probability for Social Political Consequences (r_social)

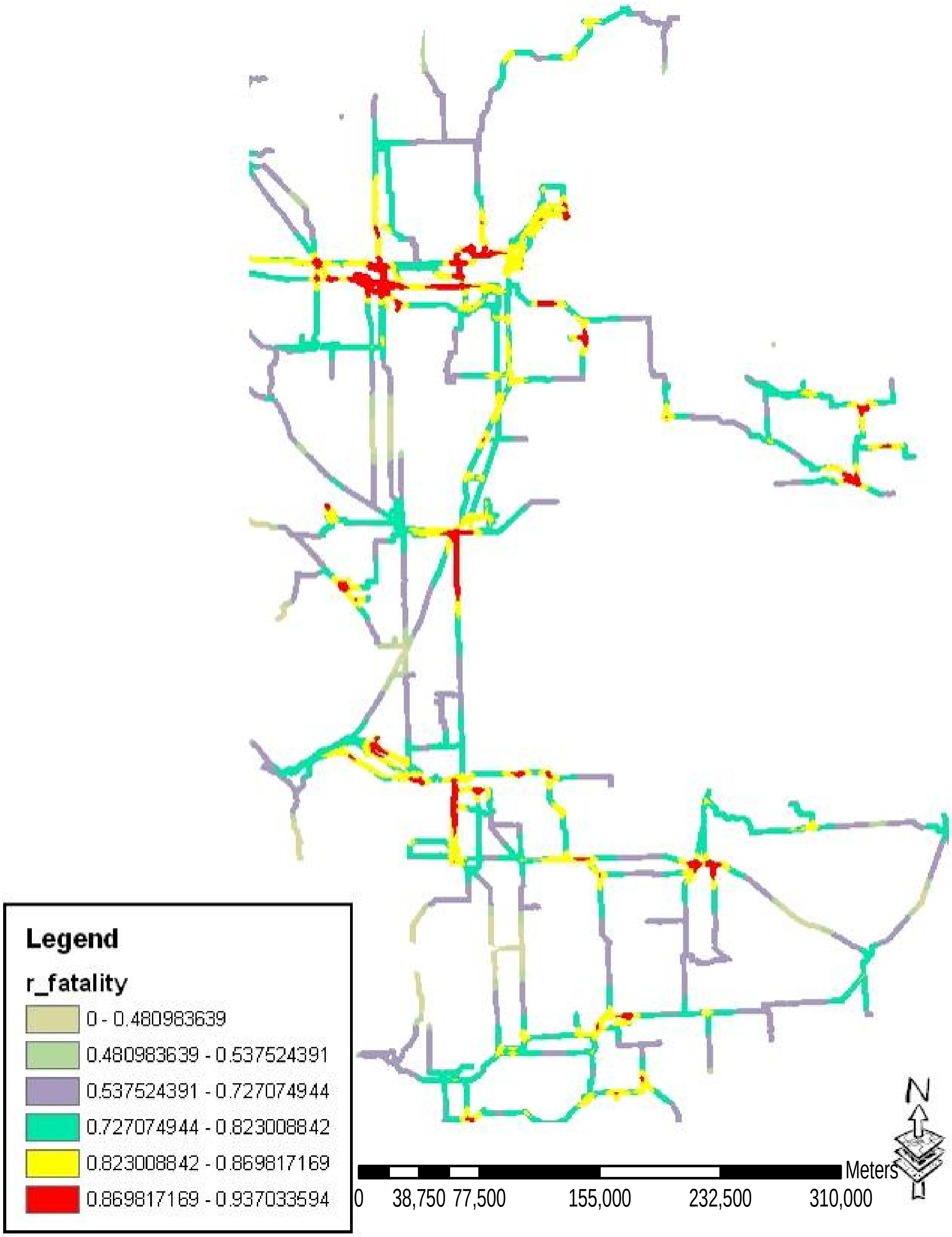
r_social is the standardized (theoretically ranging from 0 to 1) risk of sociopolitical consequences arising from bird collisions/fatalities, as calculated using the following formula:

r_social = 1 - [(0.4642)*d2_hd_popn + (0.2544)*d2_high_hab + (0.1839)*d2_prod_ba + (0.0975)*d2_h2o_std]



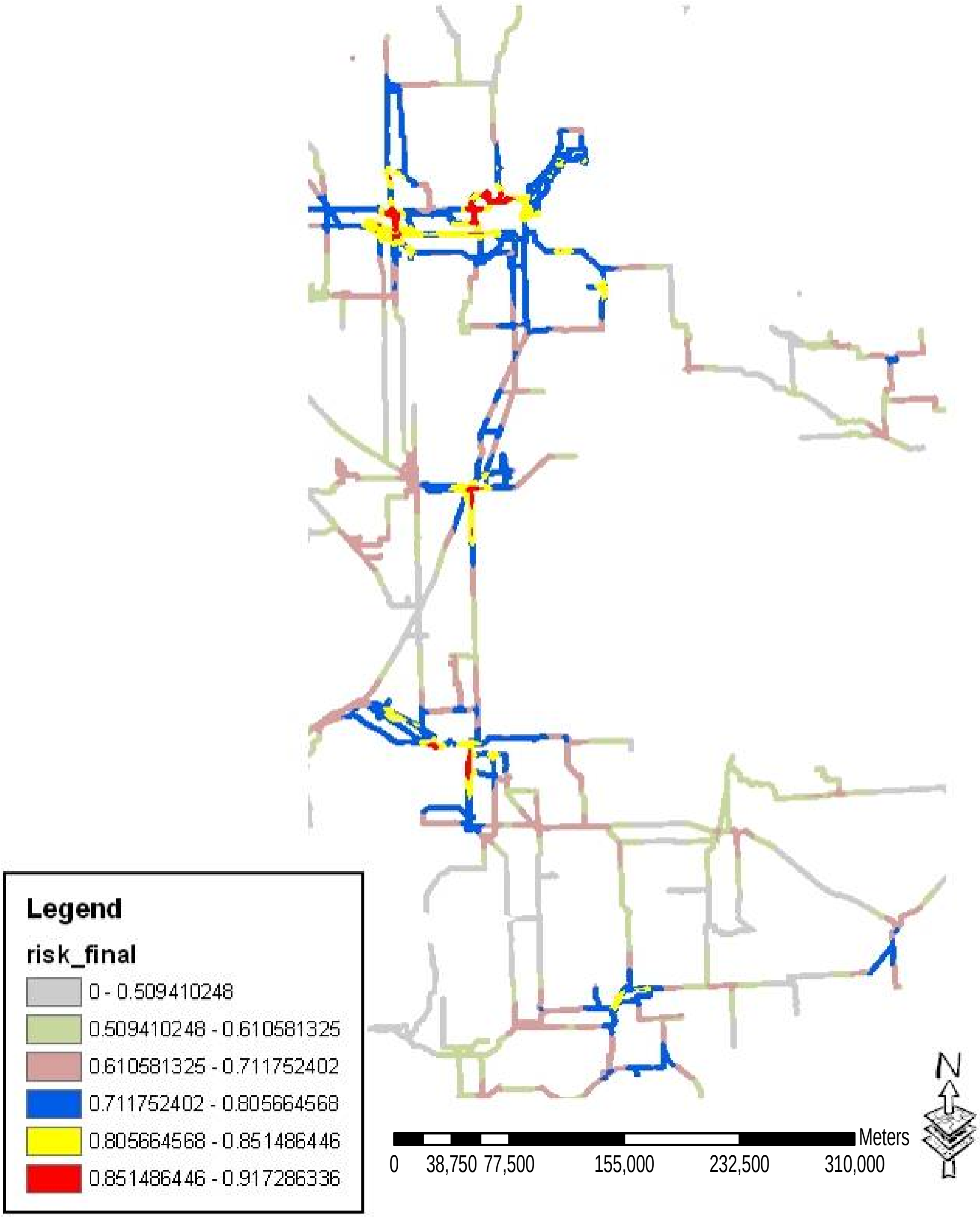
Map 4.4: Step 4 -- Probability of Fatality (r_fatality)

r_fatality = r_collision * r_habitat



Map 4.5: Step 5 -- Final Risk Model (risk_final)

risk_final = r_fatality * r_social



4.5 DISCUSSION

4.5.1 General Discussion

This chapter has described and shown how DSS and GIS were used to develop a bird–power line collision risk model. DSS is a powerful decision making tool that can greatly assist in solving complex land use type problems where a number of decision criteria are present (Eastman 1999). In this decision problem, data were lacking and the knowledge based approach was used. Past literature and professional opinion were used when comparing decision factors in the PCA. This DSS model was able to identify a number of high-risk collision risk sites that were previously unknown to AltaLink (Rasmussen 2007: personal communication).

The final model (r_final) was the result of the integration of four other models: 1. r_habitat, which represents where bird types at risk for collision are most likely to be located on the landscape; 2. r_collision, which represents where the highest risk power lines, based solely on power line characteristics, are located; 3. r_social, which represents where the highest likelihood for social-political consequences can result; and 4. r_fatality, which multiplied r_habitat with r_collision. This final model represents where the highest management value for mitigating transmission lines would occur; that is to say, where the highest risk for both collisions and chance for social-political consequences exists. R_fatality is also a useful model because if provides information on the actuarial aspects of the problem. Both r_fatality and r_final would be useful models in helping managers make decisions on which power lines to mitigate (Chapter 6).

Like other computer models, this DSS is a simplification of a complex biological system and is therefore not perfectly predictive (Van Horne 2002). However, it is still very useful as a tool for predicting where the higher risk collision areas are located. Specifically, this sort of modeling is useful in landscape-scale management.

The basis of this modeling tool could be applied to many other areas around the world and could be useful in helping other electrical utility companies predict where their high-risk collision sites are located. This is because the factors that lead to collision risk with transmission lines are consistent regardless of spatial location. Areas that attract large numbers of birds, areas that are highly used by the public and certain transmission line configurations all increase collision risk. One needs only to have available regional GIS data that can accurately represent these factors. “Empirically based wildlife-habitat models that can predict species occurrence over large spatial extents (e.g. regional areas of millions of hectares) can be very useful in developing regionally based or ecosystem-level management plans for wildlife resources” (Dettmers et al. 2002: 607).

4.5.2 Sources of Error

There are three main potential sources of error that could have affected the accuracy of this model: the researcher's ability to extrapolate the data from past studies and apply it to the current problem; accuracy and uncertainty of the GIS data; and limitations of the GIS data.

This DSS GIS model has been built on the assumptions that the researcher, through the literature review has developed a good understanding of the species – environment relationships as they relate to power line collision risk, and that the available literature is accurate and can be extrapolated to a landscape scale. It can be challenging to develop a sufficient level of understanding on these relationships for two reasons: structural uncertainty and partial observabiliity (Gutzwiller and Barrow 2001). In structural uncertainty, there may be limited understanding of the true structure of or nature of bird-landscape relations in terms of underlying biological mechanisms. Partial observability means that the knowledge of the status of bird distributions and landscape conditions, especially the magnitude and variability of parameters in space and time may be imprecise. As in Chapter 3, this source of error is controlled by using multiple peer reviewed sources for information, and thorough, careful examination of relevant information upon which informed decisions can be based

Accuracy and uncertainty in the GIS data results from availability of data, positional accuracy of data, and environmental variation in weather, habitat and disturbance (Gutzwiller and Barrow 2001). In this study, positional accuracy differs between data layers and ranges from +/- 5 to 50 m (table 4.4). This error in accuracy was compounded when the data layers were added together in the final risk calculation. It is then reasonable to assume that at some locations, positional accuracy could account for a difference of 100 m on the ground when compared to what is shown in the model. Thus, a power line defined in the model as being 500 m away from suitable bird habitat could be quite a bit closer or further when the positional accuracy of the other layers in the dataset are considered.

Random weather pattern such as heavy flooding affected the accuracy of this model because it altered the extent of some wetlands. In 2005, central and southern Alberta received records quantities of rain which led to flooding of many low areas. This flooding may have created high-risk bird collision areas that didn't previously exist. Again, some power lines were found to be closer than originally anticipated from the GIS data. For example, Clear Lake only scored a value of 0.384 (in the 0 – 0.48) category in which no collisions would be expected. This inconsistency was due to the flooding that occurred during the spring and summer of 2005, which caused the wetland to expand. This is an example of the limitations of this particular GIS model where flooding was not considered. The GIS data showed that Clear Lake was located approximately 500 m from the wetland when in actuality it was less than 60 m from the wetland. The flooding and subsequent expansion of the wetland created a collision problem where prior to this the problem may not have existed. Past research has documented these sorts of events. For example, the Broadview Marsh, located near Billings, Montana increased by 4,000 ha during a flooding event in 1980 and resulted in the death of at least 4,100 birds, primarily ducks, after colliding with a 230kV power line (Malcolm 1982). This type of accuracy error could be controlled for in future models by acquiring additional data showing the location of 100 year flood plains.

CHAPTER 5: FIELD VERIFICATION

5.1 CHAPTER OBJECTIVES

The objectives for this component of the research were to:

1. Conduct a field assessment to validate the GIS model; and
2. Verify assumptions made in the model using results from the field assessment

5.2 INTRODUCTION

Systematic sampling for avian mortality was used as an exploratory method to validate the efficacy of the model. I predicted that collisions will occur most frequently in areas that are within 500 m of a productive bird area, high habitat use area, other standing water body, other flowing water body, and areas of steep topography (>10 degrees) intersected perpendicularly by a power line and are identified by the r_fatality model as having a score between 0.72 and 1.0.

This model makes the assumption that collisions occur in areas where power lines are in close proximity to environmental features that make an area suitable to waterfowl and other water birds (i.e. productive bird areas, high habitat suitability areas, other water bodies and steep topography). The primary purpose of this field assessment was to validate this assumption.

These data were not emphasized as a major component of this project and the results are provided as exploratory. Achieving statistical significance was not the objective because even in the absence of statistically significant data, it is reasonable to assume that this model is predictive because it facilitates management decisions. Bird distribution is significantly associated with landscape features and many bird-landscape models are valid for predictive purposes (Gutzwiller and Barrow 2001).

5.2.1 Methods for Ground Truthing Bird Collisions with Power Lines

There are a number of methods available to assess collision risk (APLIC 1994). Methods include visually monitoring bird movements, collision detection system devices that can be installed on the power line, and dead bird searches (APLIC 1994). For this study, a cost effective approach that could quickly assess sites was necessary in order to survey a large enough number of sites to gain an understanding of the validity of the model.

The visual observation approach is the most common approach used by researchers because it enables observers to identify and count birds in flight and document their behaviour around the power line (APLIC 1994). Although effective, this approach is time consuming because it requires observers to conduct several partial or full-day observations starting before sunrise for each study site. The second approach is to install a collision detection system device such as the Bird Strike Indicator (BSI) or Bird Activity Monitor (BAM). The BSI, for example, is an impulse-based vibration sensing and recording tool that notifies the researcher where and when a strike occurs (EPRI 2003). This method is extremely costly and was not considered practical or feasible for this study. Dead bird searches were chosen as the method and are discussed in section 5.3.

5.3 METHODS

Dead bird searches were conducted according to APLIC (1994) in June of 2006 and 2007 during spring migration. The purpose of dead bird searches is to look for collision evidence along the power line right-of-way (ROW). Evidence of collision includes both carcasses and feather spots (Beaulaurier 1981). Feather spots are a tight cluster of feathers that are left behind when a bird is scavenged (APLIC 1994). Past research (Anderson 1978, Brown et al. 1987, Faanes 1987) has found that regular dead bird searches may only account for 26% of actual strikes. Therefore, any dead birds found under the power line indicate that collisions are taking place.

Forty-seven searches were conducted along 500 m transects (where possible) at twenty sites over two field seasons. Eighteen of these sites were in areas where the power line was situated within 1600 m of standing water, two sites where the power line crossed a river valley (slope > 10 degrees), and seven control sites were surveyed (see Appendix 3 for detailed site maps). The purpose of separating sites into these categories was to validate the assumption that power lines located close to a water body have a greater risk than do power lines located further from a water body (i.e. > 1600 m). Control sites were used to verify that dead birds found under power lines are the result of a power line collision and not some other source. Chi-square was used to test for significance of findings between site categories (Fowler and Cohen 1995).

In order to standardize between sites, and to facilitate searching, all sites had short or mixed grass and were on dry ground. Sites also had to be accessible by motor vehicle and permission had to be obtained from landowners. Finding enough sites that met these conditions proved to be challenging. Many that fit these requirements were located in southern Alberta (short grass, dry ground) and owned privately. In many cases, the landowners would not grant permission to access their land.

Searches covered the entire ROW, in a zigzag fashion to ensure that the ROW was covered systematically (APLIC 1994). Search widths were chosen according to James and Haak (1979) Raevel and Tombal (1991), and Hartman et al. (1992):

- 500kV line: out to 50 m from the outer conductor on either side
- 230kV line: out to 45 m from the outer conductor on either side
- 115kV line: out to 20 m from the outer conductor on either side

When dead birds or feather spots were found, the following data was recorded (if possible):

- Map position of each dead bird
- Species
- Sex
- Physical condition (e.g. broken bones, blood, decomposition, feeding damage by scavengers)

5.4 RESULTS

During the forty-seven site searches 32 ducks, 2 pelicans, 11 medium to large water birds, 43 gulls, 3 passerines, and 14 unknown birds, all believed to be power line collision victims, were found. These birds were found in various stages of decomposition. Typical findings include feather patches (figure 5.4), wings (figure 5.3), bones (figure 5.1) and full carcasses (figure 5.2).

Figure 5.1: Photo showing extensively decomposed remains typically found under power lines.

Figure 5.2: Photo showing typical bird remains from power line collisions.

Figure 5.3: Photo showing difficulty in searching for power line collision victims. Dead birds can be difficult to spot, especially in long grass and brush.

Figure 5.4: Photo showing typical power line collision victim findings. Often only clumps of feathers are found, indicating that the bird has been scavenged (Beaulaurier 1981, APLIC 1994).

Dead birds were found at nine out of fourteen sites where collisions were expected and no dead birds were found in two out of five areas where no dead birds were expected. No dead birds were found at any of the seven control sites. Results of the dead bird search are summarized in the following tables.

Table 5.1: Results of Dead Bird Searches According to r_fatality Model Scores

Site Name	**Power Line Number**	**Model Score (0-1 with 1 being highest risk)**	**Dead Birds found (Yes = 1; No= 0)**	**Dead Birds Expected (Yes = 1; No= 0)**
Big Lake	747L	0.86 – 0.93	1	1
Chin Lake	820AL	0.53 – 0.72	0	0
Clear Lake	197L	0 – 0.48	1	0
Dalmead Lake	924L	0.82 – 0.86	1	1
Eagle Lake	733L	0.72 – 0.82	0	1

Elbow River	916L	0.86 – 0.93	1	1
Frank Lake	1201L	0.72 – 0.82	1	1
EID Site	Confidential	0.72 – 0.82	0	1
EID Site	Confidential	0.72 – 0.82	1	1
Lethbridge Coulee	725L	0.82 – 0.86	0	1
Little Bow Lake Reservoir	923L	0.53 – 0.72	0	0
Longhurst Lake	1202L	0.53 – 0.72	Conditions too poor to search	0
Ministik Lake	174L	0.86 – 0.93	Conditions too poor to search	1
EID Site	Confidential	0.72 – 0.82	1	1
EID Site	Confidential	0.72 – 0.82	1	1
St. Mary's Reservoir	225L	0.72 – 0.82	1	1
Taber Lake	172L	0.72 – 0.82	1	1
Traverse Reservoir	923L	0.53 – 0.72	1	0
Unnamed Lake (south of Red Deer)	925L	0.86 – 0.93	Conditions too poor to search	1
Yellow Lake	722L	0.53 – 0.72	1	0
Controls (No Power Line)	**Power Line Number**	**Model Score**	**Dead Birds found (Yes/No)**	**Dead Birds Expected (Yes/No)**
Traverse Reservoir	N/A	N/A	0	0
Elbow River Valley	N/A	N/A	0	0
Frank Lake	N/A	N/A	0	0
Yellow Lake	N/A	N/A	0	0
Dalmead Lake	N/A	N/A	0	0
Rolling Hills Lake	N/A	N/A	0	0
Chin Lake	N/A	N/A	0	0

Sites were categorized according to how close a power line came to a water feature. This was used to validate the assumption that the distance of a power line to a high risk feature is critical in determining the level of risk.

1. Power line within 60 m of water;
2. Power line 60 m to 500 m of water;
3. Power line 500 m to 1600 m of water; and
4. Power line crossing perpendicular to a river valley with a steep slope.

Dead birds found at each site were standardized to dead birds per 100 m. Two-thirds of all dead birds found were in areas where the power line was situated within 60 m of a water body. These results show that there is a significant difference ($p = 0.0012$, $df = 3$) between levels of risk for the different categories of sites.

Table 5.2: Search Results Showing Categories of Study Sites Standardized to Dead Birds per 100 m

Wetland Sites			
Location	**Site Description**	**Distance Category**	**Dead Birds per 100m**
Eagle Lake	RD, S, F	1600 m	0
Little Bow Lake Reservoir	H, S	1600 m	0
Dalmead Lake	W, S	500 m	1.2
EID Land	OG, AG, F, G, S	500 m	0
EID Land	OG, R, S, F	500 m	0.48
EID Land	RD, S, F	500 m	0.38
St. Mary's Reservoir	L, F	500 m	0.25
Taber Lake	RD, M, F	500 m	0.63
Traverse Reservoir	H, S, R	500 m	0.76
Yellow Lake	H, M, AG	500 m	1.33
Chin Lake	H, S, G,	60 m	0
EID Land	OG, H, G, M, MR, RD, W	60 m	0.47
Clear Lake	MA, M, G, RD	60 m	2.4
Frank Lake	MA, M,	60 m	1.3
Yellow Lake	AG, H, MR, G, S	60 m	5.26

Topographical Depression Sites			
Location	**Site Description**	**Distance Category**	**Dead Birds per 100m**
Elbow River Valley	UR, ST, R, M	N/A	0.4
Lethbridge Coulee	UR, ST, M	N/A	0

Control Sites			
Location	**Site Description**	**Distance Category**	**Dead Birds per 100m**
Traverse Reservoir	H, S, R	N/A	0
Elbow Park	UR, F, R, M	N/A	0

Frank Lake	MA, M,	N/A	0
Dalmead Lake	AG, Fl, MR, W, M	N/A	0
Rolling Hills Lake	OG, R, H, S	N/A	0
Chin Lake	AG, H, G, S	N/A	0

Legend	
Site Descriptions	
Description	**Abbreviation**
In urban area	UR
Oil and gas activity	OG
Recreational Area	R
Agricultural Land	AG
Flat terrain	Fl
Hilly terrain	H
Steep terrain	ST
Marsh	MR
Interspersed small wetlands present	W
Along road	RD
Along fence line	F
Grazing Area	G
Short grass	S
Mixed grass	M
Long grass	L
Thick brush	TB

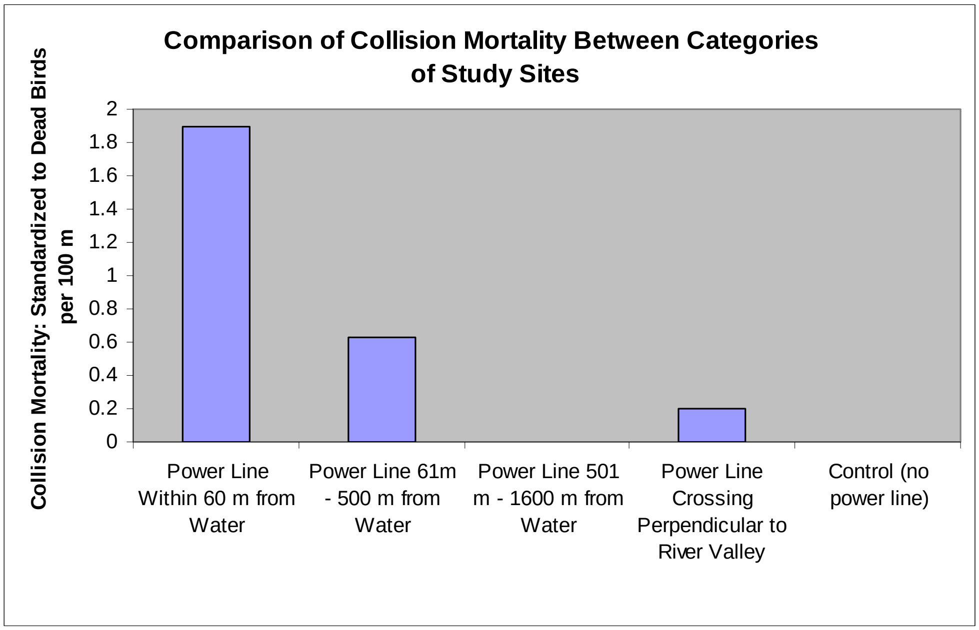


Figure 5.5: Comparison of collision mortality between categories of study sites. Greatest evidence of collision mortality was seen at sites where the power line came within 60m of water.

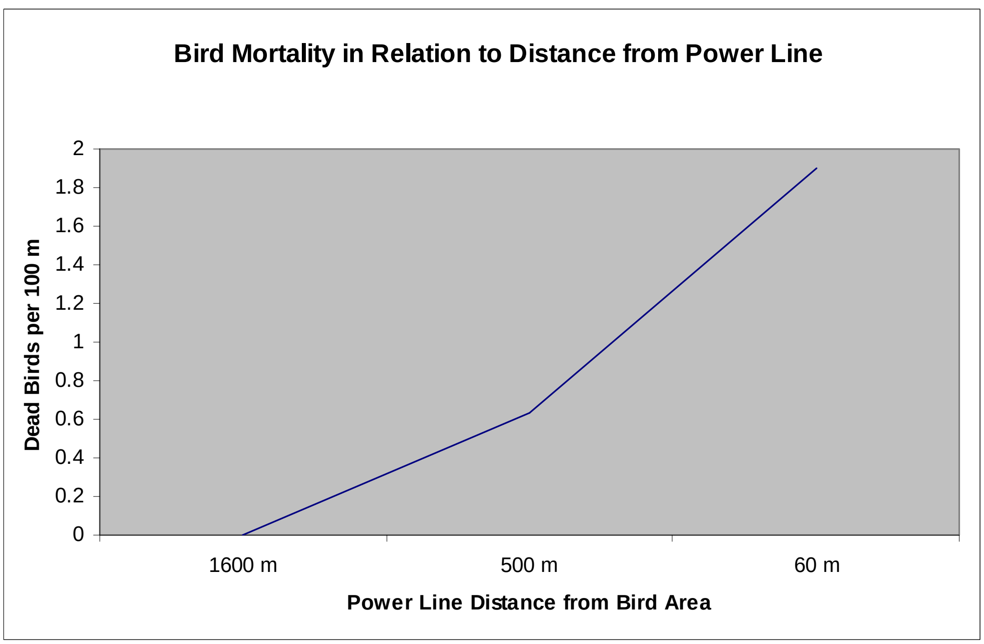


Figure 5.6: Bird mortality in relation to distance from power line. Power lines situated further from standing water have a lesser effect on birds than do power lines situated closer to standing water.

5.5 DISCUSSION OF RESULTS

5.5.1 General Discussion

Collision risk was predicted to be greatest in areas that are within 500 m of a productive bird area, high habitat use area, other standing water body, other flowing water body, and areas of steep topography (>10 degrees) intersected perpendicularly by a power line and are identified by the model as having a score between 0.72 and 1.0. The results of this study were found to support this prediction. The results also show a trend in more dead birds when the power line is within 60 m of a bird area ($p = 0.0012$, $df = 3$) (figure 5.6). This trend is consistent with findings published in APLIC (1994) and validates the assumption that high-risk bird collision areas are associated with environmental factors.

During the forty-seven site searches 32 ducks, 2 pelicans, 11 medium to large water birds, 43 gulls, 3 passerines, and 14 unknown birds, all believed to be power line collision victims, were found. It is important to note that 35 of the 43 gulls were discovered at Yellow Lake, all within 200 m of each other. At this location, the power line was located in between a private landfill and a wetland. This is an example of how an industrial feature, unrelated to the power line, can create unusually high collision risk. The gulls here were observed in high numbers flying back and forth between the wetland and the landfill. One gull was seen colliding with the shield wire during the survey. This type of scenario cannot be accounted for in the GIS models. If those 35 gulls are removed from the results, then the findings do support past research by Beaulaurier (1981), Faanes

(1987), Bevanger (1998), Bevanger and Brøseth (2004) where it was found that gulls collide with power lines much less frequently than do waterfowl and other medium to large water birds.

When analyzing results from a model such as this, it should be kept in mind that the purpose of the model is to predict areas of higher risk compared to all other areas across the landscape. There will always be areas that do not show up as high-risk but where collisions do actually occur. "Habitat models are a means of quantitatively assembling best knowledge of animal-habitat relationships to make informed decisions possible, rather than expecting the models to be perfectly predictive with $P < 0.05$" (Van Horne 2002: 72).

5.5.2 Sources of Error

Sources of error associated with this research include assumptions made in the ground truthing methodology and detection bias.

To ground truth, all carcasses and feather patches found under a transmission line were assumed to be evidence of collisions (as per Beaulaurier 1981) and not from some other source, such as vehicle collisions or natural death. To be absolutely sure that the cause of death was from power line collision, a necropsy must be performed. This was not possible in this study because in many cases, the carcasses were so decomposed that a necropsy would not have been possible. Furthermore, this carcass search differed somewhat from others. Past studies have focused on specific sites where the researcher spends several days, weeks or months monitoring the same site and conducts regular, daily carcass searches. This allows for fresh carcass collection upon which a necropsy can be performed. In this study it was assumed that past research was accurate and that power lines situated in close proximity to productive bird areas and other areas supporting significant waterfowl populations would have collisions. Under this assumption, it would then be logical to assume that dead birds and feather spots were indications of collisions. The result of the control searches, where no power line was present, no dead birds or their parts were found. This supports the assumption that all dead birds under power lines are the result of power line collisions.

Detection bias was another potential source of error in this study. Detection bias is the researchers ability to detect dead birds on the ground underneath a power line. Beaulaurier (1981) recommends correcting for this mortality estimate in order to obtain an accurate assessment of mortality rate at a given site. Because this dead bird search was only looking for evidence of collisions (not collisions rate), and that it was assumed that the searchers ability to detect carcasses would remain constant between study sites, detection bias correction was determined to be unnecessary for the purpose of this assessment.

5.5.3 Future Work

Future work of a similar nature to the fieldwork conducted in this study is planned to occur annually at AltaLink. This will allow the dead bird data set to grow along with additional years of field surveys. Uncertainty about the true structure of bird-landscape relations can be reduced by ensuring that models meet important statistical assumptions, such as improving model accuracy through continued field sampling and model fitting (Gutzwiller and Barrow 2001). The data presented in tables 5.1 and 5.2 is expected to change slightly as more data is collected.

CHAPTER 6: DISCUSSION AND RECOMMENDATIONS

6.1 GENERAL DISCUSSION

6.1.1 Species and Power Line Collision Patterns

The extent and impact of bird mortality from overhead transmission lines is not well understood (Faanes 1987, Bevanger 1998). The majority of transmission lines are located in remote areas, away from the public eye and therefore reported bird losses from collisions are considered a superficial measure of occurrence (Faanes 1987, Bevanger 1998). As the human population grows, energy demands will increase and more power lines will be built (APLIC 2006). Therefore it is imperative that effective methods for reducing collisions be identified and understood. This research has presented a method for assessing collision risk on existing electric power transmission lines. It takes a population-scale management approach with the aims of reducing overall bird-power line collisions. It considers biological, social-political and economic risk factors and consequences.

Since the early 1990s, risk assessment has become a common approach to dealing with environmental problems (Kirkland and Thompson 2002). Remotely sensed data is becoming increasingly accessible and can be used as a practical alternative to comprehensive ecological research studies when time and funding is limited (Logan 2003). Waterfowl and water birds are at highest risk for colliding with transmission lines. Transmission lines situated in close proximity to important waterfowl and water bird habitat create high-risk situations for collisions. Transmission lines situated near this important habitat that are also near populated and recreational areas should be considered high-risk because of the potential for negative public response to observed mortality. This research has shown how high-risk environmental, power line and social–political factors can be compared, ranked and categorized in a risk assessment and GIS model. The potential for economic consequences is always present because the chance for fines resulting from non-compliance with legislation exists at every site. Utility operators can use a risk assessment approach for mitigating power lines as a means to show due diligence, and thus, effectively reduce the chance for economic repercussion.

6.1.2 So What?

Approximately 85% of Alberta's population resides in southern and central Alberta (AltaLink 2004), within the Pacific and Central migratory flyways and the prairie pothole region. There is approximately 12,000 km of existing transmission line in this area. If the population in Alberta continues to grow as expected, it is anticipated that $3.5 billion in transmission upgrades will be required in the next ten years (AESO 2007b). This projected growth in transmission will inevitably lead to more bird collisions. This research and risk assessment can be used as an assessment tool for prioritizing transmission lines for mitigation as part of an Avian Protection Plan, in identifying study sites for conducting research and testing mitigation devices, and for developing guidelines for new transmission lines.

6.1.2.1 Avian Protection Plans

An Avian Protection Plan (APP) is a management system for electric utilities that is specific to birds, designed to reduce the operational and avian risks that result from avian interactions with electric utility facilities (APLIC and USFWS 2005). The framework was developed jointly by APLIC and USFWS (2005) and although not a legislated requirement, has been widely adopted by utilities in the USA. To date, no Canadian utilities have implemented an APP.

APP's require the following principles / deliverables: corporate policy; training, construction design standards; nest management; avian reporting system; a risk assessment methodology; mortality reduction measures; quality control; and the identification of key resources (APLIC and USFWS 2005). In order to have the greatest impact on reducing avian mortality, a risk assessment is undertaken as part of the APP process (APLIC and USFWS 2005). Risk assessment methods have been developed to address avian electrocution, but not for collisions. The likely reason for this is the lack of reporting and general difficulties in identifying collision areas. Because electrocution results in a power outage, it is easier for companies to identify and monitor high-risk electrocution sites.

APLIC currently recommends that a two-year, four-season study be carried out to determine the extent of the collision problem (Bridges and Anderson 2002). When a great number of sites are suspected of having collision risk, this recommendation becomes unfeasible. When resources are limited, this certainly is not a viable solution. The risk assessment and GIS model presented in this study could be used as a method for carrying out a risk assessment for collisions.

6.1.2.2 Identifying Sites for Research opportunities

This model can be used as a method for selecting study sites for site specific research. Because collisions are not a well understood issue, it would be useful to perform studies that served to develop a better understanding of high-risk sites, low-risk sites, and sites where the public could be impacted. Sites for testing mitigation devices can also be identified.

6.1.2.3 Making Recommendations for New Transmission Lines

In addition to identifying high-risk areas on the existing transmission system, results from the literature review can be extrapolated to make recommendations for the construction of new transmission lines. In particular, the model makes it possible to identify and subsequently avoid or mitigate high-risk areas.

6.2 MANAGEMENT RECOMENDATIONS

6.2.1 Methods for Mitigation Bird Collisions with Transmission Lines

Mitigation options were identified through a comprehensive literature review. Mitigation options for retrofitting existing power lines include modification of habitat near power lines, burial, removal of overhead shield wire, and line modification. When considering each option, it is important to remember that the purpose of the facility is to transmit electricity (Bridges and Anderson 2002). Any solutions being considered must take this into account by ensuring that reliable electrical transmission always be the first priority for the utility.

6.2.1.1 Habitat Modification

Habitat modification is a voluntary environmental management initiative that could be used to reduce the chance for collisions. According to APLIC (1994), there are two land modification options that can be considered:

1. Modify habitat near power lines to change the attractiveness to birds. For example, plant trees that will grow near or above the height of power lines. This will cause birds to gain altitude to clear the tree line and subsequently also clear the power line (figure 2.6); and
2. Modify land use to reduce disturbance to birds around the power line. For example, create feeding habitat on the same side of the power line as resting habitat so that birds have less of a reason to cross the power line.

These types of initiatives would be most feasible in parks or other areas such as Ducks Unlimited wetlands where conservation is the primary goal. Electric utilities could work with these organizations to modify ROWs in a manner that would reduce the risk to birds. Benefits to the company would result from being an environmentally responsible neighbor and would include positive relations with the public, ENGO's and regulators (Thompson 2002).

However, habitat modification may not always be feasible. In Alberta, power line ROWs are often located along road allowances or private property and it is difficult to obtain enough ROW width to make this possible (Rasmussen 2007: personal communication). Typical widths are 30 to 45 m (Rasmussen 2007: personal communication). Agriculture is the dominant land use in southern Alberta and therefore habitat modification could mean reducing crop or grazing areas. In addition, it may not be desirable to modify habitat in areas with rare, sensitive or significant native habitats.

6.2.1.2 Burial

The burial of transmission lines will eliminate bird collisions. However, this is currently not a feasible option for transmission line companies (APLIC 1994). Installing lines underground becomes more impractical as the voltage of the line increases; even with lower voltage lines, burial is often not technically or financially feasible. Depending on site conditions, burial costs vary from 3 to 20 times as much as an overhead line (APLIC 2006). Burial must consider the voltage, cable and insulation type, where other underground utilities are located, soil conditions, surrounding regulatory atmosphere, the potential for water contamination, and how utility personal can access the power line in the event of an outage (APLIC 1994).

6.2.1.3 Overhead Shield Wire Removal

Up to 90% of collisions may occur on the overhead shield wire because its narrow diameter makes it difficult to see in low light, fog and other poor visibility conditions (APLIC 1994). A recent study by Bevanger and Brøseth (2001) found that when the shield wire was removed, collisions decreased by half. Although a viable option for reducing collisions, shield wire removal will render the power line more susceptible to lightning damage (Kurtz and Shoemaker 1986). Therefore, removal of this wire is not always a viable option, especially in areas where lightning is common.

6.2.1.4 Power Line Modification

Power line modification is the process where steps are taken to make the power line more visible to birds in flight. Marking the conductors and / or shield wires is the most common response by electric utility companies is to modify the power line (Alonso et al. 1994, APLIC 1994). On transmission lines, marking the shield wire has received particular focus because it appears to be the one most often struck by birds in flight (Scott et al. 1972, Willard and Williard 1978, Brown et al. 1987, and Faanes 1987). Alonso et al (1994) found that both collisions and flight intensity decreased by 60% after shield wires were marked. Beaulaurier (1981) summarized the results from 18 studies and found that, on average, marking the shield wires or conductors resulted in collisions decreasing by 45%. Marking has been shown to have the same effectiveness as shield wire removal (Beaulaurier 1981).

There are numerous types and variations of markers available on the market. There has been a tremendous amount of research conducted on marking power lines and the effectiveness of marking power lines although few studies have been able to verify the actual effect of certain devices (Bevanger and Brøseth 2001). Marking with the wrong color or wrong type of device may not be effective at solving the problem, may become a maintenance problem for the power company, and may even cause lines to go down in extreme cases (Bridges and Anderson 2002). Therefore, it is imperative that effective devices are used to mark power lines.

When choosing markers, local climatic conditions must be considered. In Alberta, the wind is strong and winters are cold. Therefore, utilities must consider wind and ice loading prior to installing markers. For example, swan flight diverters (SFDs) have been used successfully in Spain and the USA (Harness 2006: personal communication) should not be used in Alberta because of ice loading concerns.

Two devices that have shown good success and are recommended for the Alberta climate are the Firefly Bird Flapper / Flight Diverter (Firefly) and the Bird Flight Diverter (BFD) (figure 6.1). The Firefly has the advantage over other devices in that it is visible in low light conditions, the time when collisions are most common because of its ability to reflect UV light (Chervick 2006: personal communication). The devices also glow at night for up to 10 hours and can therefore provide a visual cue to night migrants and other birds that are active at night (Chervick 2006: personal communication). To date there have not been any published peer reviewed scientific studies to validate the effectiveness of the Firefly, only personal accounts from companies that have been using the device. A soon to be published study by Yee (2007) found that the Firefly reduced collisions by 60% for sandhill cranes. Another concern on the Firefly is its ability to withstand stress caused by high winds. In windy areas, the marker plates do not last (Heck 2007) and therefore become a maintenance concern for the utility operator and become less effective in protecting birds.

Like the Firefly, the BFD provides a visual image that helps migratory birds avoid collisions with utility power lines. APLIC (1994) reported that BFD's installed every 10 m can reduce collisions up to 58%. However, they may be less effective than the Firefly marker in poor light conditions (e.g. fog, dusk, night) because they do not reflect UV light and do not glow in the dark. They are however much more durable in windy conditions. The most effective method for marking power lines may be to stagger Firefly's with BFD's along the overhead shield wire in areas with mild to moderate winds. This would allow for an occasional missing device while still increasing the line's profile and make it while continuing to protect birds, even in poor visibility conditions. In very windy areas, the BFD should be used exclusively.

Markers should be installed every 10 meters on the overhead shield wire(s) (OHSW) (APLIC 1994). If more than one shield wire is present, then markers are placed at 10 m intervals, on alternating wires (figure 6.2). Brown and Drewian (1995) found that this staggered arrangement produces a visual equivalent of 27.6% coverage even though individual wires only had 9.2% coverage.

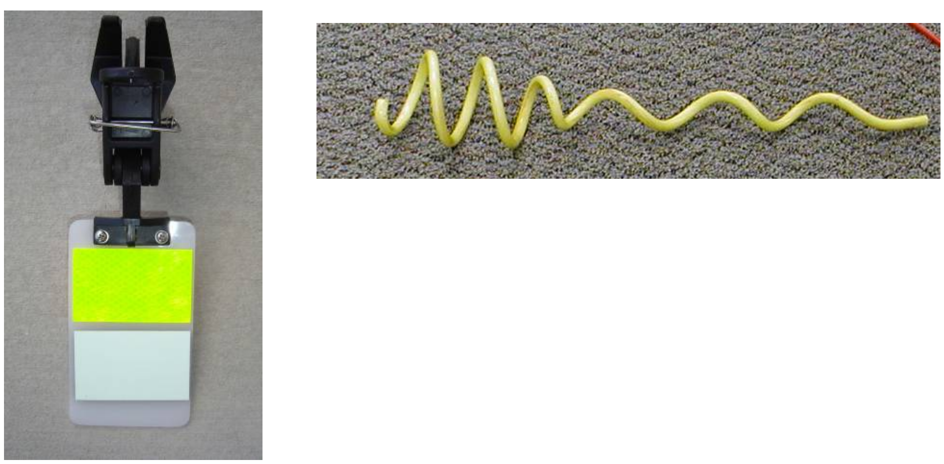


Figure 6.1: Photos showing bird markers. Left: Firefly bird marker; right: Bird Flight Diverter (BFD)

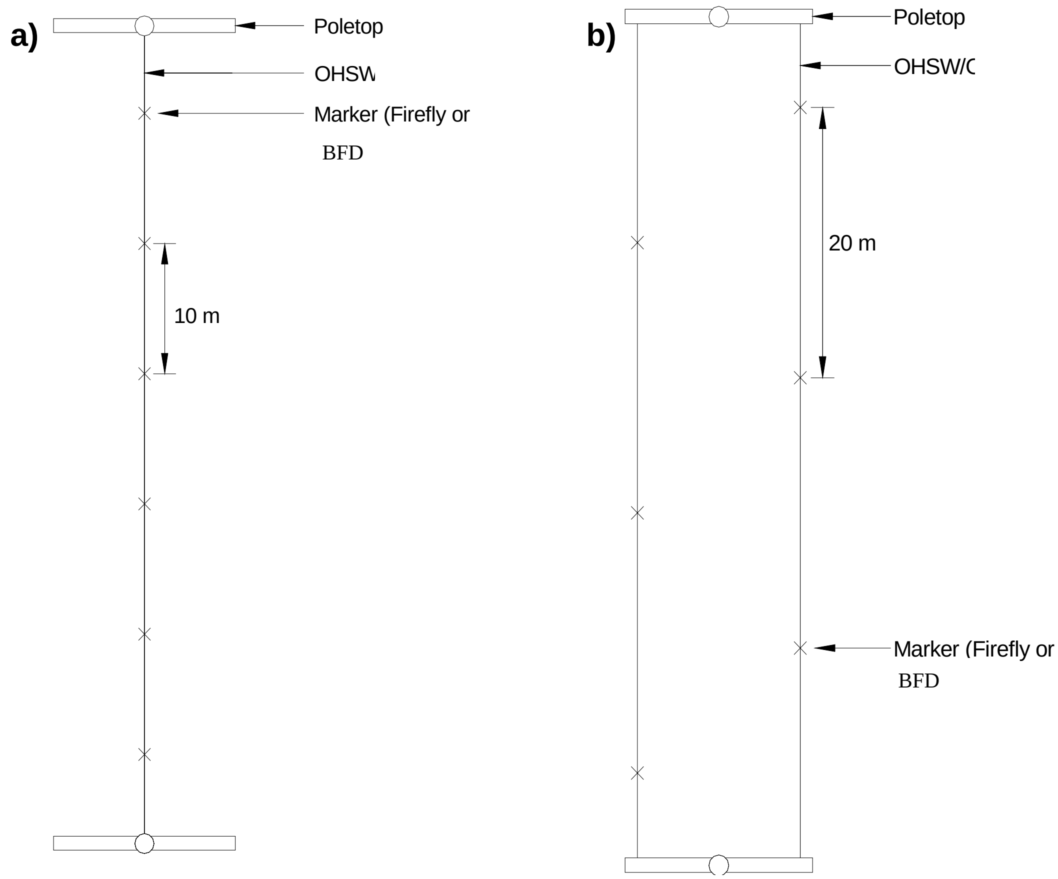


Figure 6.2: Plan view showing method for installing bird markers on power lines where one (a) and two (b) OHSW is present.

6.2.2 Mitigating Existing Transmission Lines

The areas identified as being higher risk for bird – power line collisions should be retrofitted to reduce overall risk. Because these lines are already built, the most practical and economical approach to reduce risk would be modify the power lines by installing bird markers on the shield wire. It is important to note that marking the shield wire is not going to completely solve the problem. Past research has shown that marking decreases collisions by 60% on average, depending on the types of markers used and types of birds present (APLIC 1994). Often this is considered acceptable from a management perspective because it is a simple, cost effective mitigation approach that takes care of a large percentage of the problem. Areas should be prioritized so that the higher risk areas are retrofitted first.

Sites can be prioritized through a combination of two methods, a desktop assessment and a field assessment. The desktop assessment will utilize the risk assessment and GIS model(s) presented in this study. The field assessment will further rank sites based on environment and power line features that could not be identified in the model(s).

6.2.2.1 Part 1: Desktop Assessment

The results of the model have been used to separate areas into risk categories (table 6.1). For the purpose of the desktop assessment, category 1 areas are considered to have the greatest risk and category 5 to have the lowest. Sites scoring lower than category 5 are not considered here even though they may also have risk. As previously stated, this is because mitigation will take a landscape-scale approach. Once category 1 through 5 areas have been evaluated and mitigated, further areas can be considered.

Two GIS models were considered when ranking sites, r_fatality and r_final. In r_fatality, where the social political consequence is not considered, more areas with a high probability for collision were identified. In the r_final model, only those sites with high probability and high consequence for collisions score very high (0.80 – 0.92). Both models were considered in the ranking because companies should retrofit sites with high collision mortality, even when they are located far away from the public eye.

Table 6.1: Risk Categories for Bird Collision Areas

Risk Category	Risk Description	Description	Risk Model	Risk Score	Number of Areas
1	High Probability, High Consequence	Red areas in final model	R_Final	0.85 – 0.92	12
2	High Probability, Moderate Consequence	Yellow areas in final model	R_Final	0.80 – 0.84	22
3	High Probability, Low Consequence	Red areas in fatality model, not identified as red or yellow in final model	R_Fatality	0.87 – 0.94	20
4	Moderate Probability, Low Consequence	Yellow areas in fatality model, not identified as red or yellow in final model	R_Fatality	0.82 – 0.86	22
5	Low-Moderate Probability, Low Consequence	Third highest category in both models	R_Final and R_Fatality	0.71 – 0.80 and 0.72 – 0.82 respectively	124

6.2.2.2 Part 2: Field Assessment

For the field assessment, environment and power line features that can not be evaluated through the GIS model are identified. For categories 1 – 4, a site visit and dead bird search (as presented in Chapter 5) should be carried out. Due to the high number of sites identified in category 5, a helicopter evaluation during an annual patrol should be conducted. Site and power line characteristics including the presence of dead birds (only possible from a site survey), vegetative characteristics, wetland edge, conductor configuration, and any other features that may be an attractant to birds (e.g. landfill) should be noted.

When evaluating each site, the following questions should be asked (from APLIC 1994: 12):

- What kinds of habitat occur on each side of the line?
- What species occupy these habitats?
- What is the behaviour of the species using the habitat (feeding, roosting, courtship, etc)?
- When does the species use the habitat (time of day, season)?
- Does the species behaviour and the timing of behaviour predict a substantial risk of collisions in this habitat?
- What other factors may influence bird flight / behaviour (e.g. hunting, flushing, etc.)?

In addition to those listed above, I would recommend adding the following questions:

- Was there evidence of collisions at the site (i.e. carcasses, feather spots)?
- Do threatened or endangered species occur here?
- Is there emergent vegetation near the power line that offers good nesting, brooding and molting habitat?
- Is there tall vegetation at the same height or above the conductors and shield wire between the power line and the water body?
- Are there any industrial areas near the power line that may attract water birds (e.g. landfill, cooling ponds at electric generating stations, sewage ponds, settling ponds at mines)?
- Does the power line have vertical or horizontal conductor configuration (figure 6.3)?
- Does this area experience extreme winds? What is the orientation of the power line in relation to prevailing wind direction during the spring and fall?

The answers to these questions will help decision makers address the bird collision problem for existing transmission lines. From here, management options are evaluated (section 6.2.1) and a strategy for carrying out these options is developed.

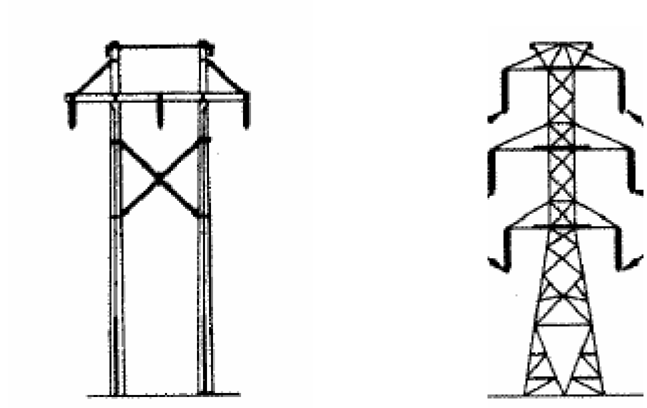


Figure 6.3: Diagram showing two types of conductor configuration. Left: horizontal; right: vertical conductor configuration.

6.2.3 Management Recommendations for New Power Lines

During the siting and planning stages of new power lines, utility companies have the opportunity to plan and design in a way that minimizes avian collisions. Recommendations based on the results of this study have been developed here to proactively minimize bird collision risk for new transmission lines.

6.2.3.1 Power Line Siting Priorities

The following priorities should be taken into account during power line siting.

- All new power lines should be sited 500 m from designated wetlands[1]. Faanes (1987) found that avoiding areas of known water bird

[1] Designated wetlands are those designated as having high value by Ducks Unlimited, BirdLife International, and the Alberta Conservation Association. They also include top birding sites, and wildlife viewing areas.

concentration areas during the route planning stage is probably the most cost effective method of lowering avian mortality levels.

- New power lines should not cross directly overtop of wetlands (class III, IV or V), lakes or reservoirs.
- New power lines should not cross perpendicular to major flight corridors. These typically include steep (>10 degrees) linear features such as river valleys.
- New power lines should not come within 200 m of wetlands (class III, IV or V), lakes or reservoirs that are within protected areas (parks, conservation areas ecological reserves, federal lands) or high use public areas such as campgrounds, golf courses, municipal parks, and off-leash parks).

6.2.3.2 Power Line Design Priorities

Understandably it is not always possible to site power lines away from important bird habitat. Where possible, an overhead shield wire should not be installed on the portion of line that crosses directly overtop of a wetland (class III, IV or V), lake, reservoir, river or coulee valley > 10 degrees, or river. Alternatively, markers can be installed on the overhead shield wire of power lines located in the following areas:

- <u>Spanning a Water Body</u>: Power lines that span or are within 30 m of, Class III, IV, or V wetlands, lakes, and reservoirs.

- Proximity to Designated Wetlands: Power lines that are within 500 m of a bird area that have been designated as having high value (figure 6.4).
- Rivers and River Valleys: Power lines that cross a primary river valley with a slope on either side that is greater than 10 degrees (figure 6.6), coulee valleys with a slope on either side greater than 10 degrees (figure 6.6) and all spans crossing directly over a primary river with shallow slopes (figure 6.5).
- Public Use Areas: Power lines with an overhead shield wire that are located within a public use area and are within 200 m of a Class III, IV, or V wetland, lake, or reservoir. Public use areas include, for example (but are not limited to), campgrounds, golf courses, municipal parks, and off-leash parks.
- If a proposed power line is sited 30 – 500 m from a Class III, IV, or V wetland, lake, or reservoir that is located within a designated conservation area (e.g. ecological area, conservation area, wildlife reserve, Provincial Park, National Park, or federal land), or other sites that may be identified by Regulators as having the potential to be of high value to bird species the following areas, then an environmental assessment (EA) should be conducted to determine if bird markers are necessary:

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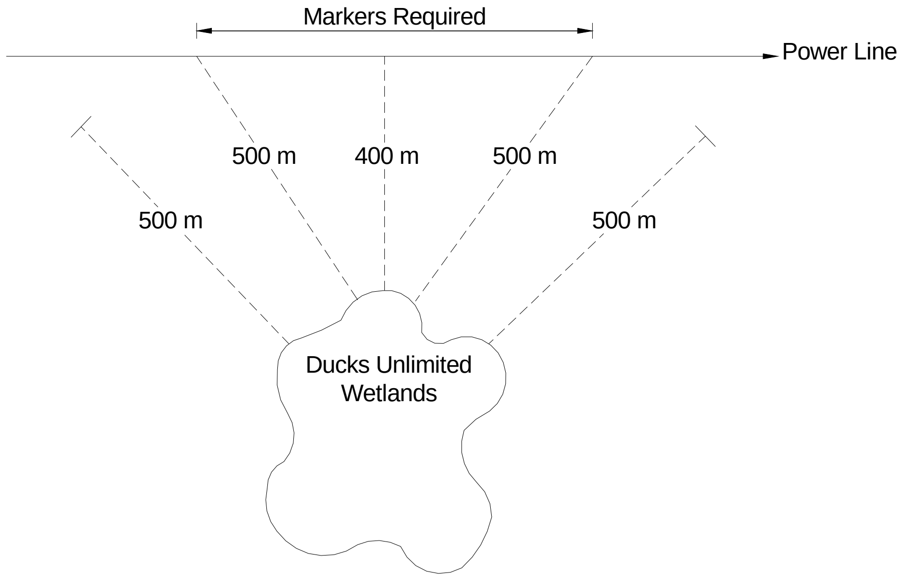

Figure 6.4: This figure shows an example of a power line that is within 500 m of a designated wetland. In this example the closest point of the wetland is 400 m from the power line. When we triangulate out from the points of the wetland, we find the area of the line that require markers.

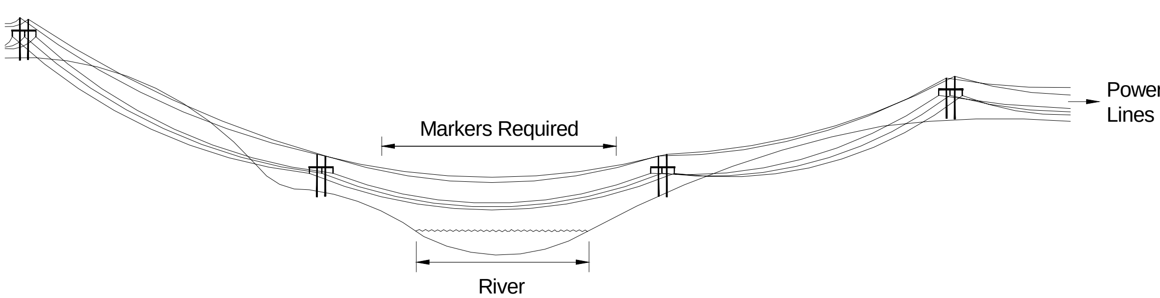

Figure 6.5: This figure shows a river valley in cross section where the slope of each side is less than ten degrees. In these situations, markers are required where the power line spans the water plus 30 m out on either side.

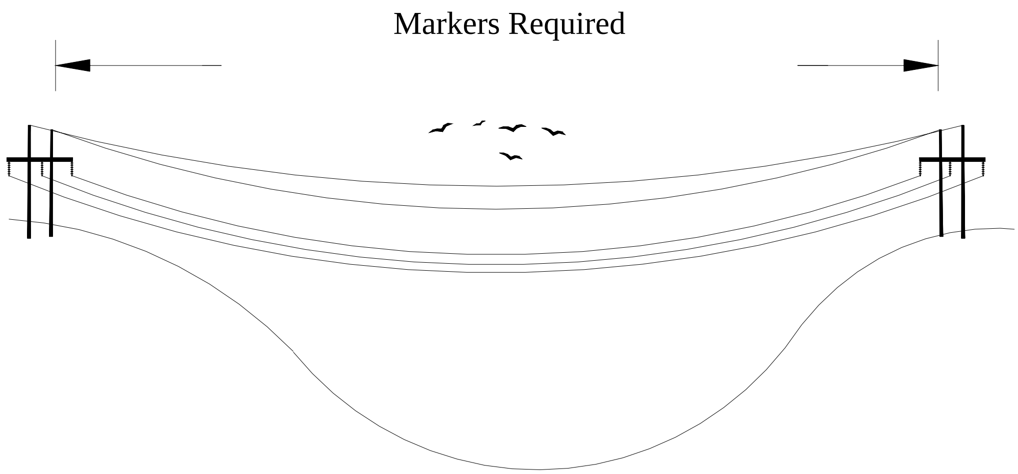

Figure 6.6: This figure shows a river or coulee valley in cross section where the slope of each side is greater than ten degrees. In these situations, markers are required from bank to bank.

6.3 FUTURE WORK EFFORTS AND RESEARCH NEEDS

The risk assessment method and model presented in this study is the first to have been developed that assess the risk of bird collisions with transmission lines at a landscape scale. Prior to being implemented in other electrical transmission service regions, it should be further scientifically tested and adjusted if needed. Although this model was validated in the field, rigorous testing was beyond the scope of this study.

This model should also be assessed for completeness. One of the limitations in this study was availability of quality GIS data. As data becomes more accessible, further layers may be added. For example, a higher risk category that identifies where endangered, threatened, and other sensitive species are present would be useful. This model should also be assessed to determine how much collisions would decline if all the high-risk areas were mitigated. For electrocutions on distribution structures, past studies have found that by modifying 3% of poles can prevent 90% of raptor electrocutions when the highest risk poles are identified and retrofitted (Platt 2005). Because transmission lines, like distribution lines, are large, geographically dispersed industrial systems, it is logical to hypothesize that this same statement could be made for collisions. Future studies could evaluate this hypothesis.

6.4 APPLICABILITY TO OTHER PROBLEMS

Bird collisions are one issue out of a group known as ‘avian impacts from energy facilities’ (APLIC 2006). Energy facilities include transmission power lines, distribution power lines, electrical substations, communication towers, and wind turbines, all of which have very different associated impacts:

- Transmission power lines: bird collisions (as presented in this study)
- Distribution power lines: raptor electrocution (APLIC 2006)
- Electrical substations: electrocution of numerous species; most common in Alberta are ravens and owls (Niles 2006: personal communication, Harness 2007: personal communication)

- Communication towers: bird collisions (especially night migrants) (Erickson et al. 2005, APLIC 2006)
- Wind turbines: bird and bat collisions (numerous species) (Erickson et al. 2005)

This sort of risk assessment methodology using GIS modeling could be applied to these problems. So long as sufficient literature exists on the species involved, that species' distribution, environmental attractants, and hazardous structure configurations, then presumably, a similar risk model could be developed.

Figure 6.7: Photos showing electrical facilities with avian impacts. Clockwise from top left: transmission power line, distribution power line, electrical substation, communication tower, wind turbine.

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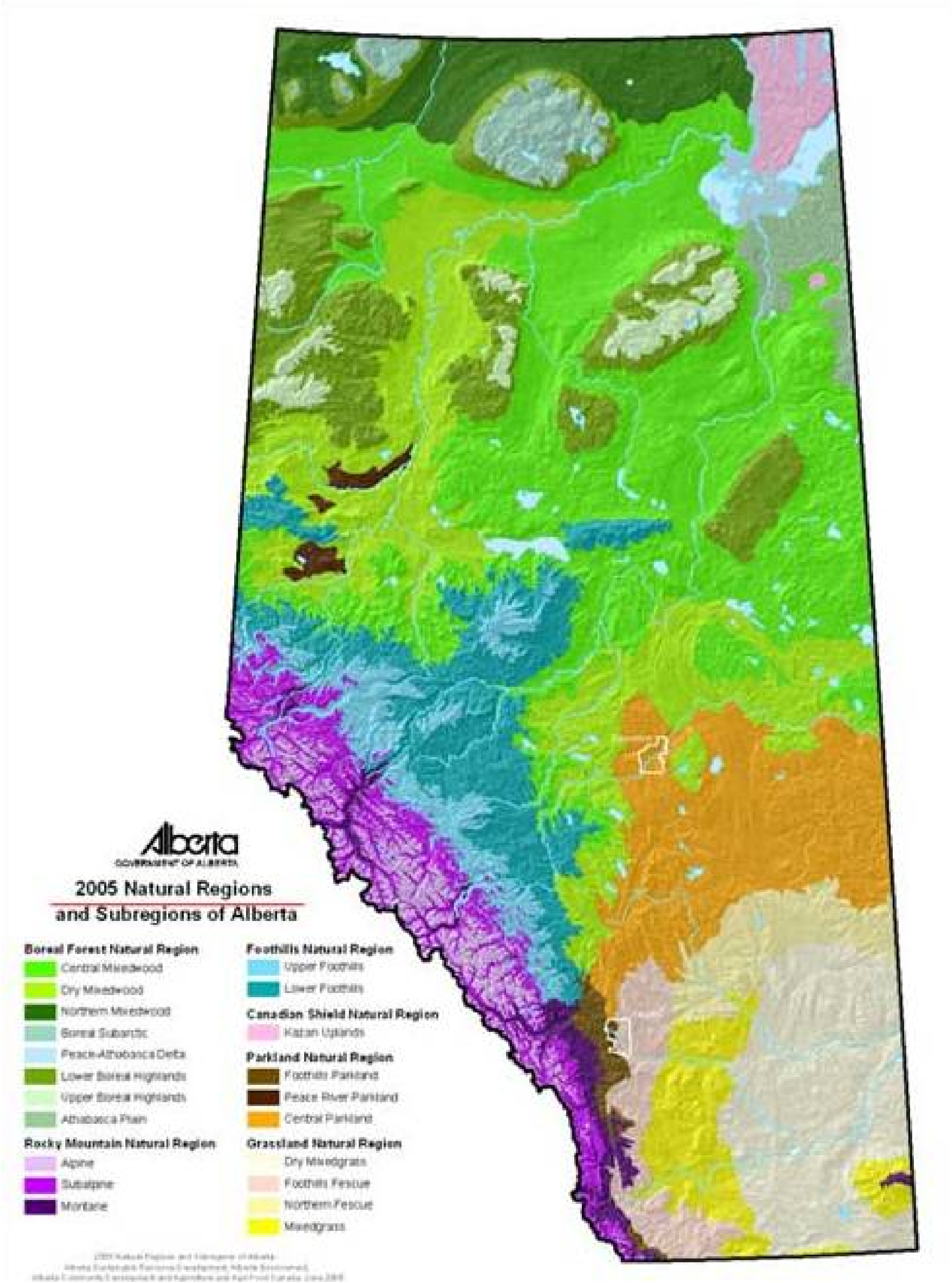
APPENDICES

APPENDIX 1:

Alberta Natural Regions



Source: http://www.cd.gov.ab.ca/preserving/parks/anhic/natural_regions_map.asp

APPENDIX 2:

Species Documented to Have Collided with Power Lines

Source: Hunting 2002

This table summarizes species that have been documented colliding with power lines.

Order, Family	***Locations***	***Researchers***
Podicipediformes, podicipedidae (Grebes)	North Dakota, Montana, California	Cassel et al. 1989, Faanes 1987, Hartman et al. 1993, Krapu 1974, Malcolm 1982, McKenna and Allard 1976
Procellariiformes, Diomedeidae (Albatrosses)	Laysan Island, Kauai Hawaii	Bailey 1929, Byrd et al. 1978
Pelecaniformes, Pelecanidae (Pelicans)	Venezuela, North Dakota	Faanes 1987, McKenna and Allard 1976, McNeil at al. 1985
Pelecaniformes, Phalacrocoracidae (Cormorants)	Venezuela, North Dakota	Faanes 1987, McKenna and Allard 1976, McNeil at al. 1985
Ciconiiformes, Ciconiidae (Storks)	Europe, Germany, Rhodesia, South Africa, Uganda Africa, Australia	Council of Europe 1981, Haas 1980, Harwin 1971, Jarvis 1974, Pomeroy 1978, Riegel and Winkel 1971, Rix 1970, Somerset 1972.
Ciconiiformes, Ardeidae (Herons, Egrets)	Denmark, Arkansas, Venezuela, England, North Dakota, California, Spain	Alonso and Alonso 1999, Anderson and Block 1972, Faanes 1987, Lano 1927, Ledger et al. 1993, McNeil et al. 1985, Pearson 1993, Scott et al. 1972.
Phoenicopteriformes, Phoenicopteridae (Flamingos)	Africa	Ledger et al. 1993
Anseriformes, Anatidae (Ducks, Swans)	Denmark, Illinois, California, Montana, Manitoba, Britain, England, North Dakota, Saskatchewan, South Africa, Oregon, Texas, New Mexico, South Dakota, Wisconsin, Missouri, Delaware, Washington, Wyoming, Minnesota, Spain, Sweden	Alonso and Alonso 1999, Anderson and Block 1972, Anderson 1978, Arend 1970, Banko 1960, Blokpoel and Hatch 1976, Boso 1965, Boyd and Ogilvie 1964, Cassel et al. 1989, Cohen 1896, Cornwell and Hochbaum 1971, Cornwell 1968, Dedon et al. 1990, Eltringham 1963, Faanes 1987, Gollop 1965, Harrison 1963, Hobbs and Ledger 1986, Hodson and Snow 1965, Hugie et al. 1993, Krapu 1974, LaBerge 1976, Ledger et al. 1993, Lee 1978, Malcolm 1982, Mathiasson 1999, McDonald 1979, McKenna and Allard 1976, Meyer 1978, Meyer and Lee 1979, Ogilvie 1967, Owen and Cadbury 1975, Pangburn 1945, Pearson 1993, Perrins and Reynolds 1967, Peterson and Glass 1946, Sanderson and Anderson 1981, Schorger 1952, Schroeder 1977, Scott et al. 1972, Siegfried 1972, Sisson 1975, Rasmussen 2001, Thomas 1977, Trauger et al. 1971, Weaver and Ores 1974, Wiese 1979, Wildan Associates 1982, Wilmore 1974, Willard et al. 1977

Falconiformes, Cathartidae (Vultures, Condor)	California, Spain	Alonso and Alonso 1999. Rees 1989, Scott and Jurek 1985
Falconiformes, Accipitridae (Eagles, Hawks, Accipiters)	Utah, California, Spain, Britain, South Africa, Sweden, Norway, Colorado, Nebraska, South Dakota, Florida, England, Ohio, Mississippi, Montana	Alonso and Alonso 1999, Anthony et al. 1994, Austin-Smith et al. 1983, Baldrige 1977, Bromby 1981, Dawson 1974, Faanes 1987, Fernandez and Insausti 1990, Ferrer and De La Riva 1987, Ferrer et al. 1991, Garzon 1977, Glue 1971, Hartman et al. 1993, Hobbs and Ledger 1986, Hugie et al. 1993, Marion and Ryder 1975, Olsen and Olsen 1980, Olsson 1958, Pearson 1993, Platt 1976, Scott et al. 1972, Smith 1985, Snow 1973, Vian 1971, Walker 1916, Zimmerman 1976.
Falconiformes, Falconidae (Falcons)	England, Iceland, California, Colorado, Spain, Britain, U.S., South Africa, Australia	Brown 1976, Clausen and Gudmundsson 1981, Drager and Linthicum, eds. 1985, Enderson and Kirven 1979, Ferrer et al. 1991, Garzon 1977, Glue 1971, Herren 1969, Hobbs and Ledger 1986, Newton 1979, Pearson 1993
Galliformes, Phasianidae (Pheasants, Grouse)	Utah, North Dakota, Finland, Norway	Bevanger 1993, Borell 1939, Cassel et al. 1989, Faanes 1987, Heye 1963
Gruiformes, Rallidae (Rails)	California, North Dakota, Texas, Virginia, Britain, Montana, Philadelphia, Spain	Alonso and Alonso 1999, Arnold 1960, Cassel et al. 1989, Dedon et al. 1990, Faanes 1987, Graham 1916, Lemmon 1898, Malcom 1982, Potter and Murray 1949, Scott et al. 1972
Gruiformes, Gruidae (Cranes	Idaho, Kansas, Saskatchewan, Texas, Oklahoma, Nebraska, Florida, California, North Dakota, Spain, South Africa	Alonso and Alonso 1999, Drewien 1973, Goodland Daily News 1965, Faanes 1987, Howe 1989, Ledger et al. 1993, Lewis 1974, Nesbitt and Gilbert 1976, Pogson and Lindstedt 1988, McCann 2001, Russell Daily News 1968, Tacha et al. 1978, Walkinshaw 1956, Wheeler 1966
Charadriiformes, Charadriidae (Killdeer) – Recurvirostridae (Avocet)	Denmark, Montana	Andersen and Block 1972, Malcolm 1982
Charadriiformes, Recurvirostridae (Shorebirds)	Denmark, North Dakota	Andersen and Block 1972, Pearson 1993, McKenna and Allard 1976
Charadriiformes, Scolopacidae (Shorebirds)	Unknown, California, New York, Saskatchewan, Oregon, North Dakota, Washington, Montana, Florida, Spain	Bailey 1929, Cohen 1896, d'Ombrain 1945, Emerson 1904, Faanes 1987, Farnham 1971, Gerstenberg 1972, Gollop 1965, Griepentrog 1929, Hartman et al. 1993, Frapu 1974, Lee 1978, Malcolm 1982, McKenna and Allard 1976, McNeil et al. 1985, Meyer and Lee 1979, Scott et al. 1972, Weston 1966, Willard et al. 1977
Charadriiformes, Laridae (Terns, Gulls)	Denmark, North Dakota, Britain, Ireland, Quebec, Oregon, Venezuela, California, Englan,	Alonso and Alonso 1999, Andersen and Block 1972, Cassel et al. 1989, Faanes 1987, Flegg and Cox 1975, Gosselin 1978, Griepentrog 1929, Hartman et al. 1993, Krapu 1974, Lee 1978,

	Washington, Montana, Florida, Spain	Malcolm 1982, McKenna and Allard 1976, McNeil et al. 1985, Meyer and Lee 1979, Scott et al. 1993, Weston 1966, Willard et al. 1977
Strigiformes, Strigidae (Owls)	Denmark, Europe, Washington, Idaho, Switzerland, Sweden, Norway, New Jersey, U.S., California, Oregon, Montana, Spain	Alonso and Alonso 1999, Andersen and Block 1972, Counsil of Europe 1981, Fitzner 1975, Hartman et al. 1993, Herren 1969, Hugie et al. 1993, Olsson 1958, Pearson 1993, Potter and Murray 1949, Stewart 1969, Willard et al. 1977
Strigiformes, Tytonidae (Owls)	England, Pennsylvania, California, Spain, Canada	Alonso and Alonso 1999, Hartman et al. 1993, Houston 1978, Potter and Murray 1949, Scott et al. 1972
Columbiformes, Columbidae (Pigeons, Doves)	North Dakota, Oregon, Britain, Colorado, Washington, Spain	Alonso and Alonso 1999, Cassel et al. 1989, Faanes 1987, Griepentrog 1929, Meyer and Lee 1979, Scott et al. 1972, Stahlecker 1975
Apodiformes Trochilidae (Hummingbirds)	Arizona, California	Colton 1945, Hendrickson 1949
Piciformes, Picidae (Woodpeckers)	North Dakota	Faanes 1987
Passeriformes, Tyrannidae (Flycatchers)	Saskatchewan	Gollop 1965
Passeriformes, Laudidae (Larks)	North Dakota, Wyoming, Colorado, California, Spain	Alonso and Alonso 1999, Cassel et al. 1989, Coues 1976, Dedon et al. 1990, Stahlecker 1975
Passeriformes, Hirundinidae (Swallows, Martins)	Arizona, Britain	Anderson 1933, Mead 1979
Passeriformes, Corvidae (Ravens, Crows)	England, Spain	Alonso and Alonso 1999, Holyoak 1971
Passeriformes, Turdidae (Thrishes), Turdidae, Tyrannidae (Kingbirds), Sylviidae (Gnatcatchers)	Denmark, North Dakota, Saskatchewan, Britain, Oregon, Washington	Andersen and Block 1972, Cassel et al. 1989, Gollop 1965, Meyer and Lee 1979, Scott et al. 1972
Passeriformes, Sturnidae (Starlings)	Denmark, North Dakota, Britain, California, Oregon, Washington, Spain	Alonso and Alonso 1999, Andersen and Block 1972, Cassel et al. 1989, Meyer 1978, Meyer and Lee 1979, Scott et al. 1972
Passeriformes, Parulidae (Wood Warblers)	North Dakota, Saskatchewan	Cassel et al. 1989, Gollop 1965
Passeriformes, Thraupidae (Tanagers)	Saskatchewan	Gollop 1965
Passeriformes, Emberizidae (Warblers, Tanagers,	Denmark, Washington, North Dakota,	Andersen and Block 1972, Beaulaurier 1981, Dedon et al. 1990, Faanes 1987, Hartman et al. 1993,

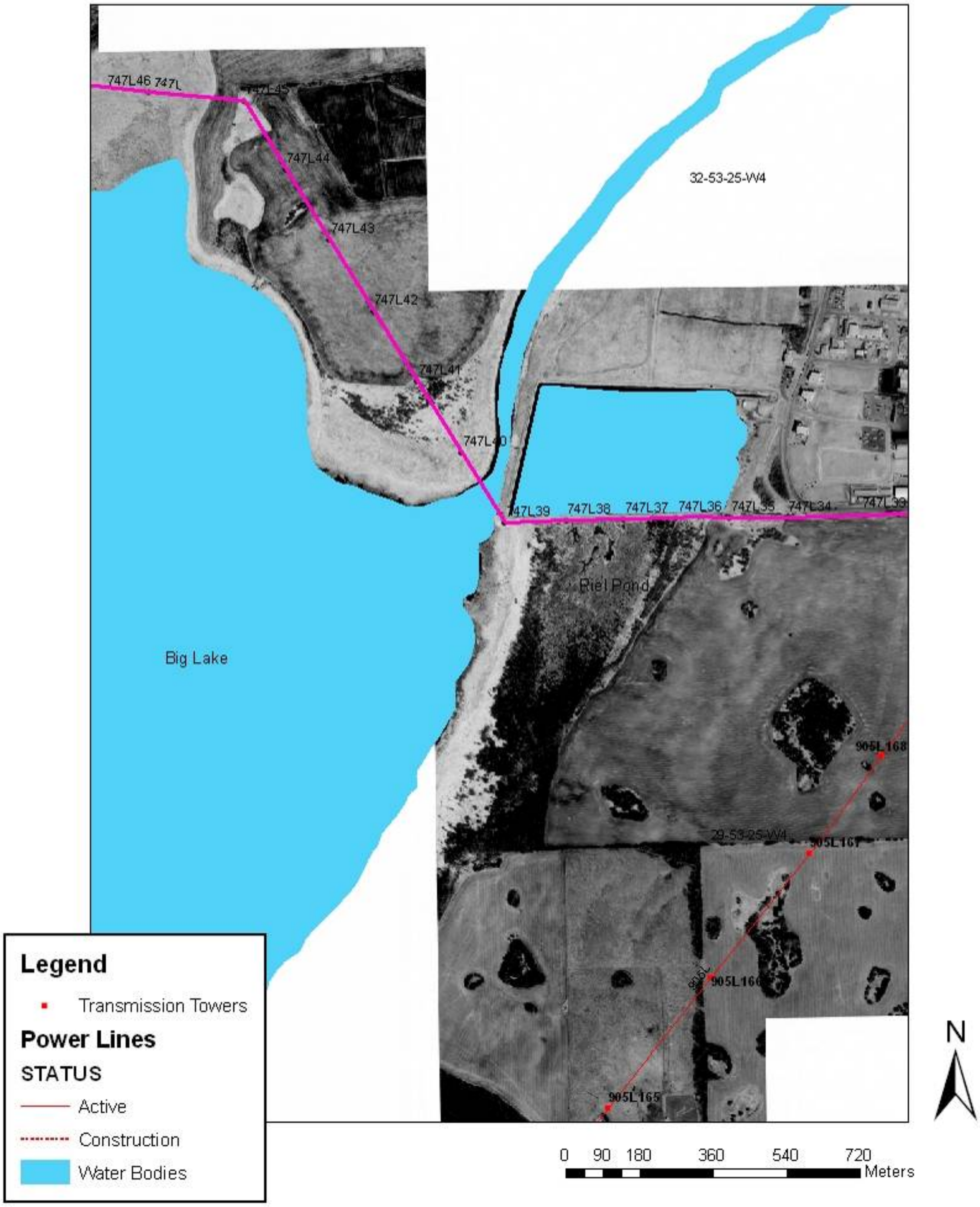
Cardianls, Grosbeaks, some Sparrows)	Saskatchewan	Malcolm 1982, McKenna and Allard 1976, Meyer 1978, Meyer and Lee 1979, Pearson 1993
Passeriformes, Passeridae (Old World Sparrows)	North Dakota	Cassel et al. 1989
Otitidae	Germany	Kretzschmar 1970
Non-specific Collision Accounts		Benton 1954, Biosystems Analysis 1990, Dunbar 1954, Jennings 1961, Meyer 1978, Peterson and Glass 1946, Quortrup and Shillinger 1941, Scott 1950, Scott and The Wildfowl Trust 1972, Stout 1967, Stout and Cornwell 1976, Weir 1971

APPENDIX 3:

Study Site Maps

Site maps are presented in alphabetical order. Sites that are owned by the Eastern Irrigation District are not included because of a prior confidentially arrangement.

Big Lake



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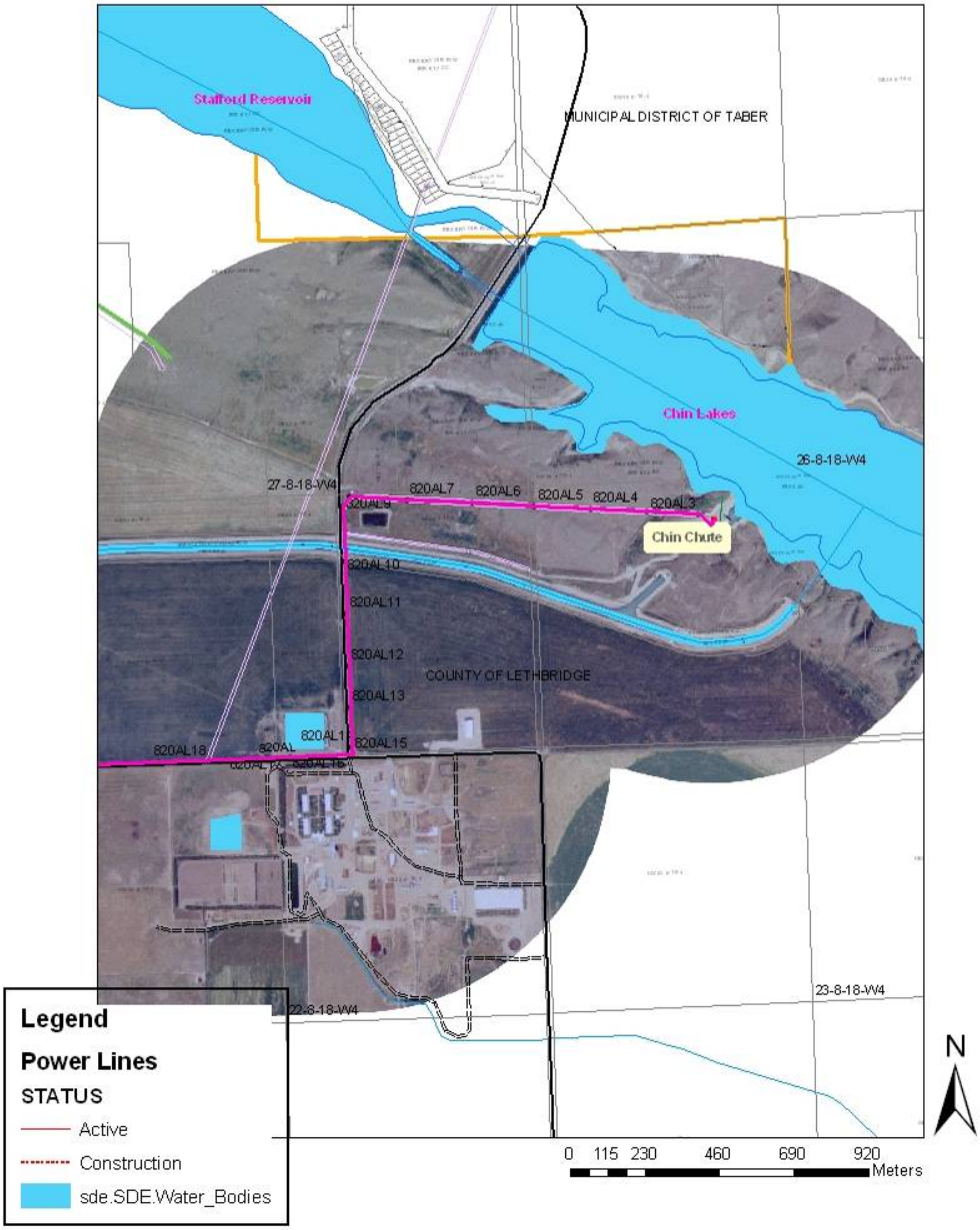
747L38
747L37
747L36
747L34
32-53-25-W4
Piel Pond
Big Lake
905L168
905L167
905L166
905L165
Legend
Transmission Towers
Power Lines
STATUS
Active
Construction
Water Bodies
N
0 90 180 360 540 720
Meters

Chin Lake



Stafford Reservoir
MUNICIPAL DISTRICT OF TABER
Chin Lakes
26-8-18-W4
27-8-18-W4
820AL7
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820AL3
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Chin Chute
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820AL12
COUNTY OF LETHBRIDGE
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22-8-18-W4
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Construction
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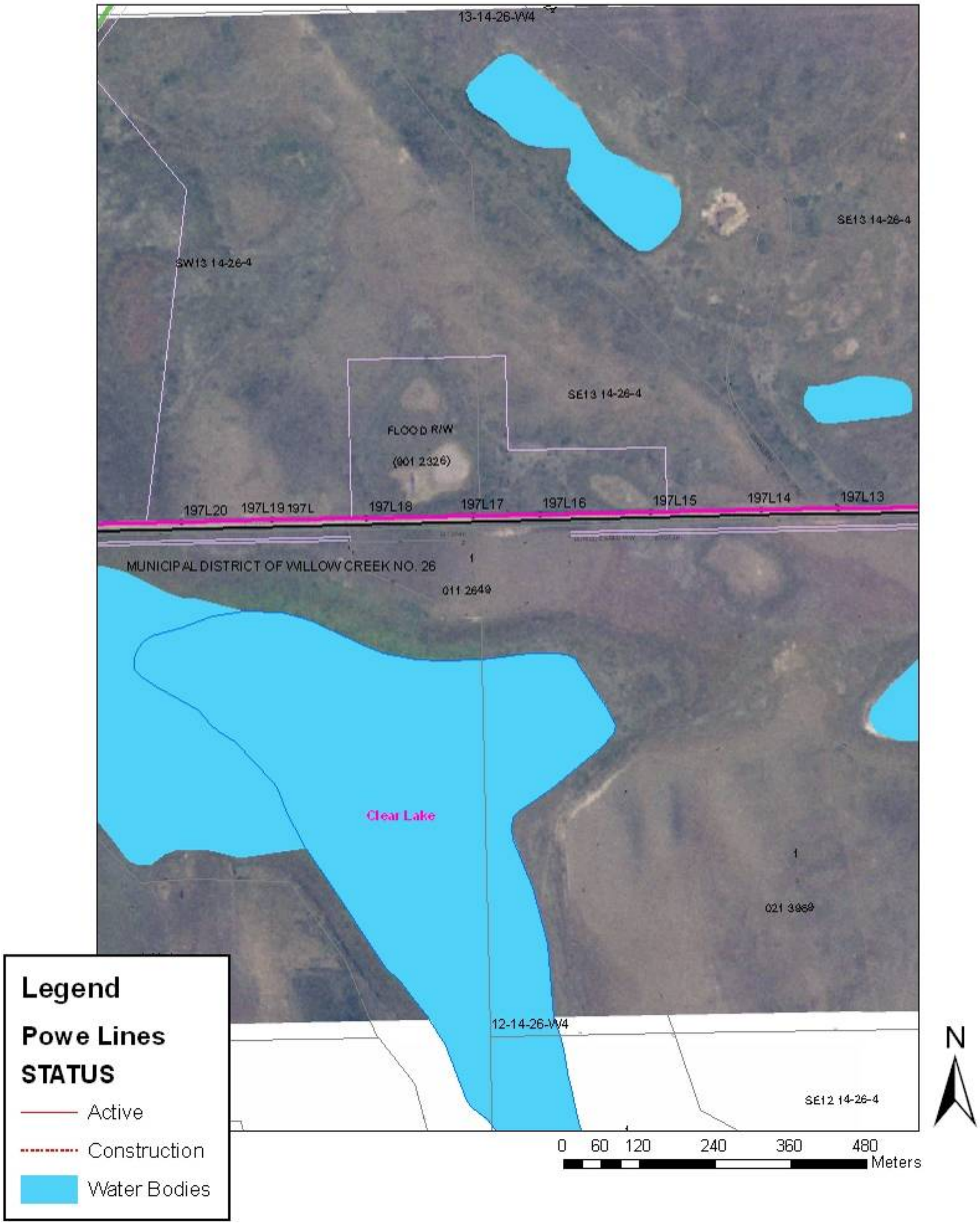
Clear Lake



13-14-26-W4
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SW13 14-26-4
SE13 14-26-4
FLOOD R/W
(901 2326)
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197L19 197L
197L18
197L17
197L16
197L15
197L14
197L13
MUNICIPAL DISTRICT OF WILLOW CREEK NO. 26
1
011 2649
Clear Lake
1
021 3969
12-14-26-W4
SE12 14-26-4
Legend
Powe Lines
STATUS
Active
Construction
Water Bodies
0 60 120 240 360 480
Meters
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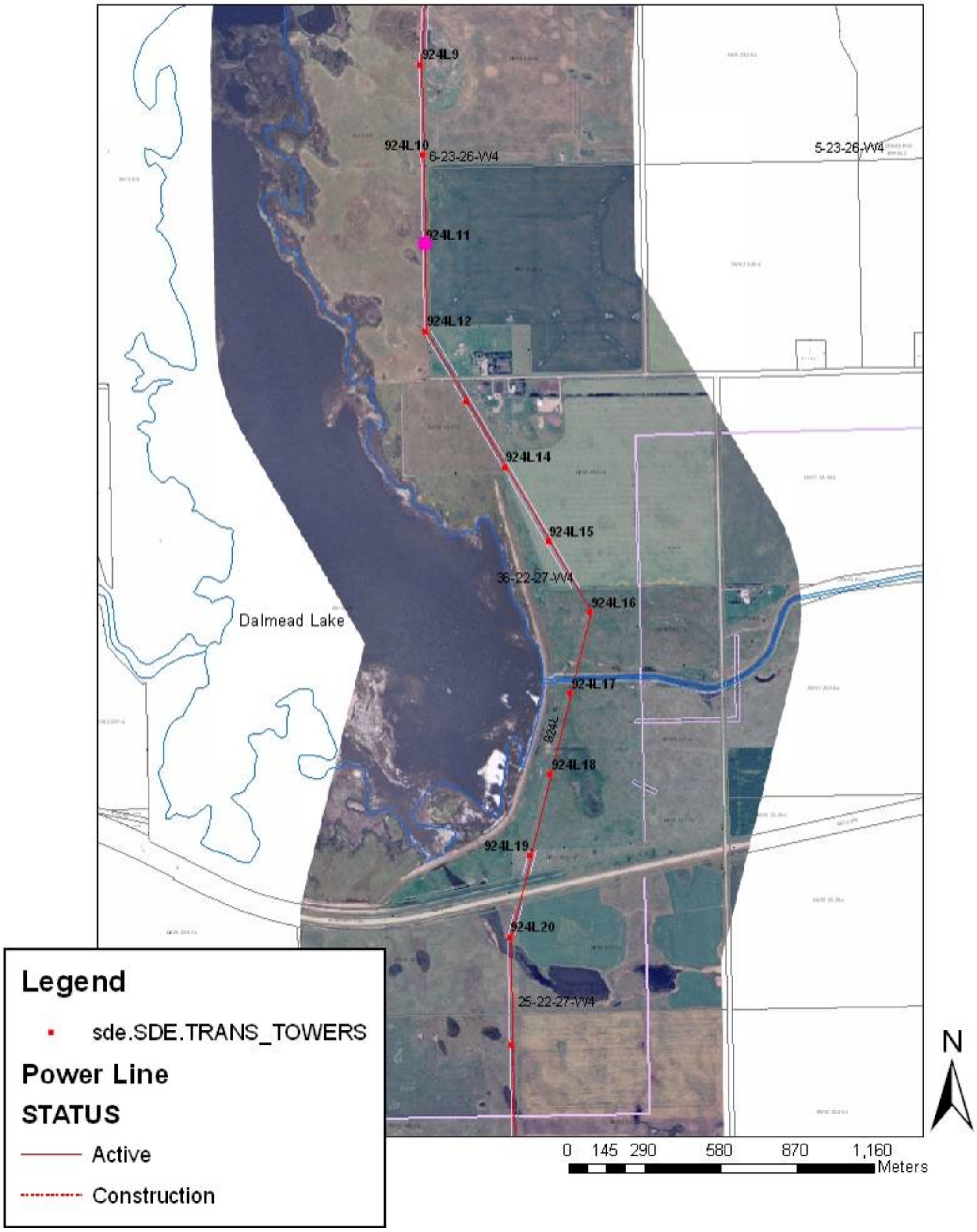
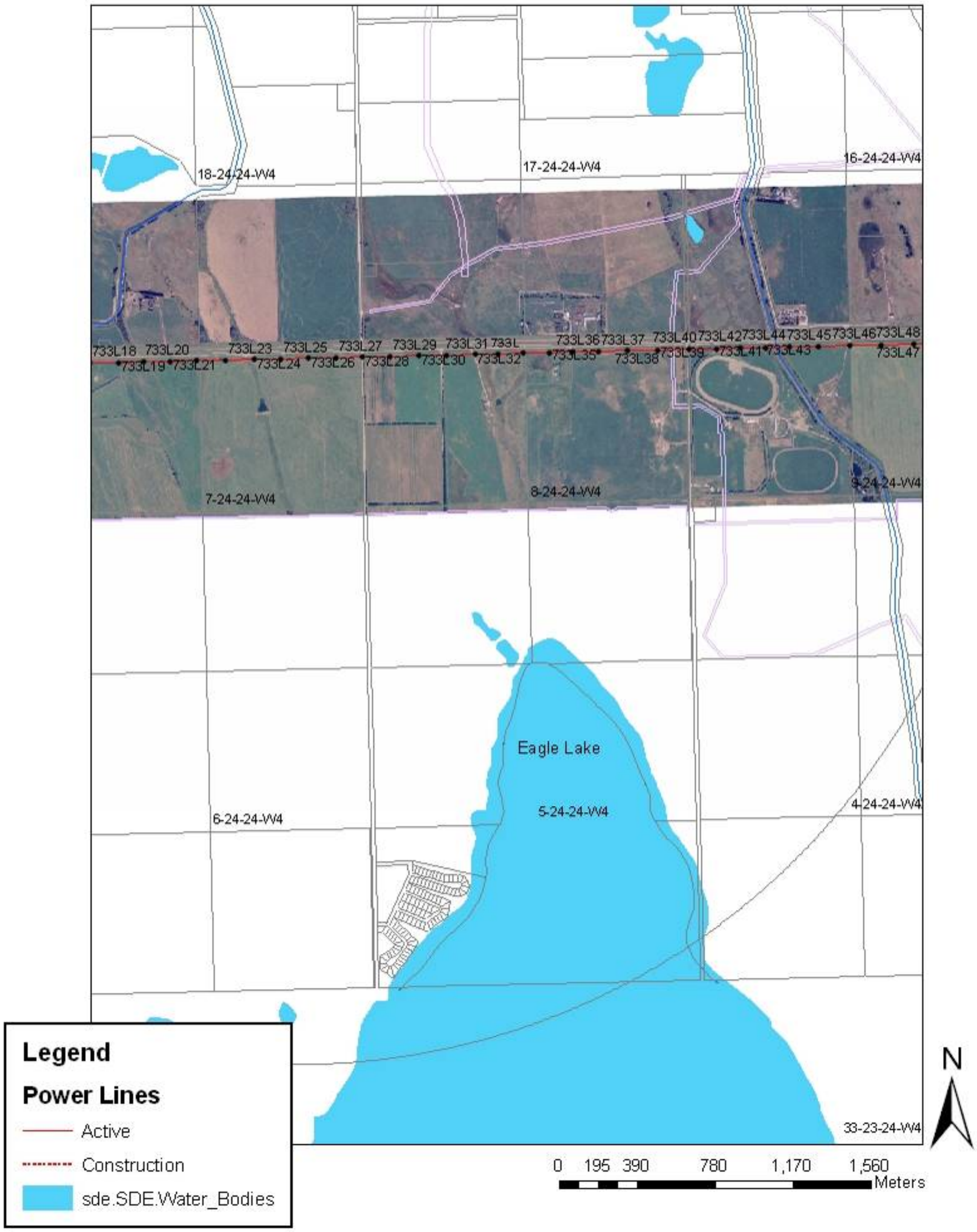
Dalmead Lake



Eagle Lake



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733L46
733L47
733L48
7-24-24-W4
8-24-24-W4
9-24-24-W4
Eagle Lake
5-24-24-W4
6-24-24-W4
4-24-24-W4
33-23-24-W4
Legend
Power Lines
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Construction
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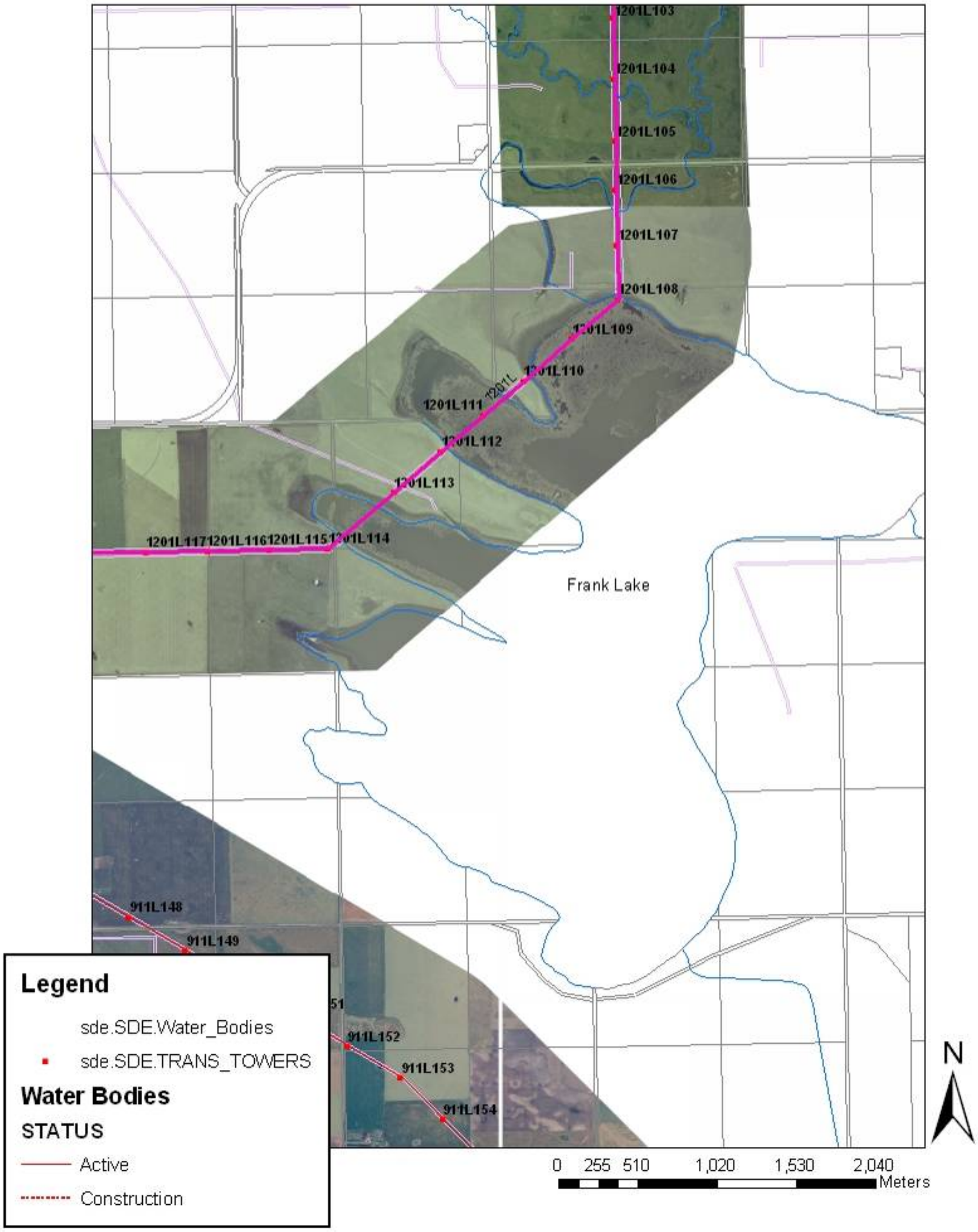
Meters

Elbow River Valley

Frank Lake



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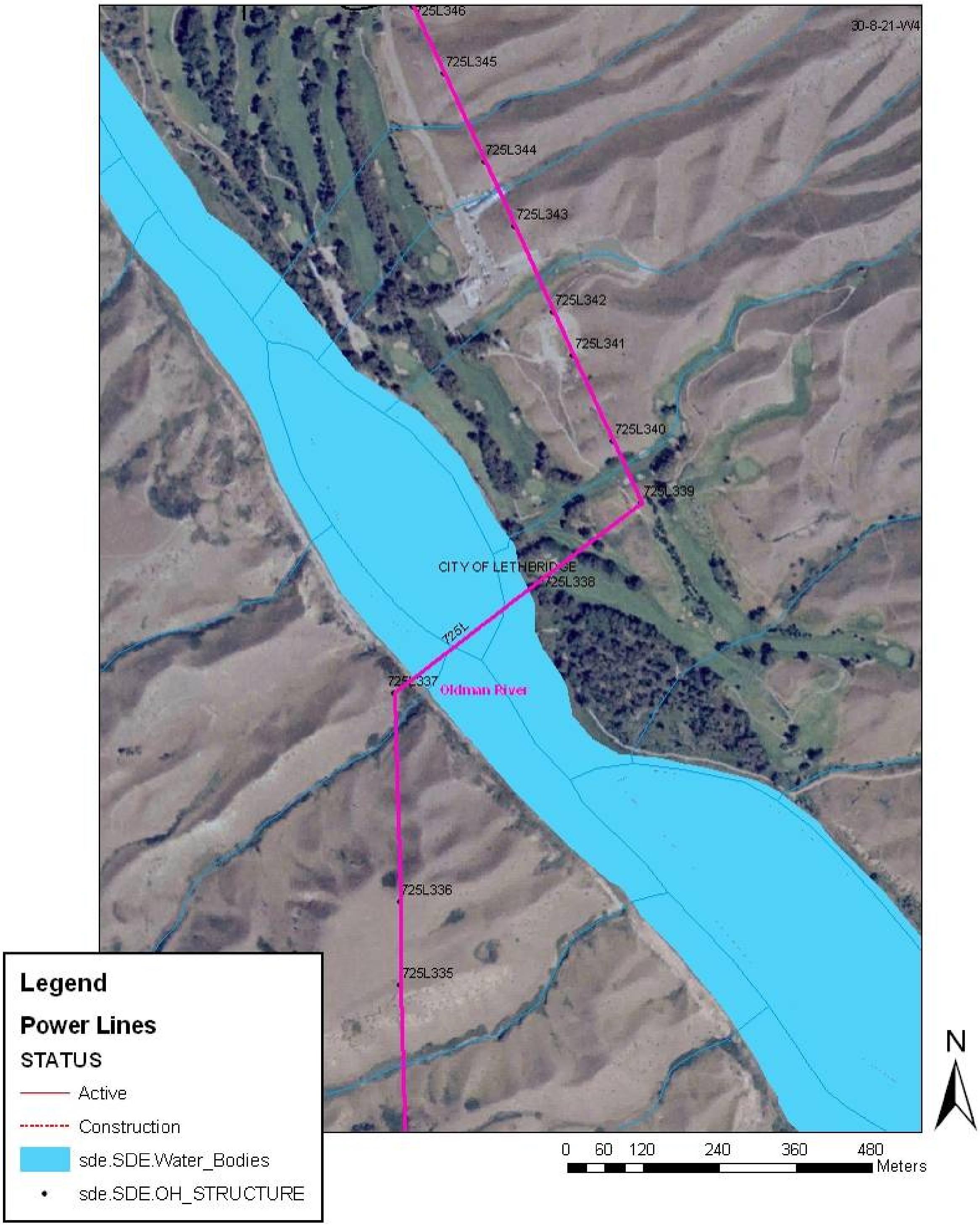
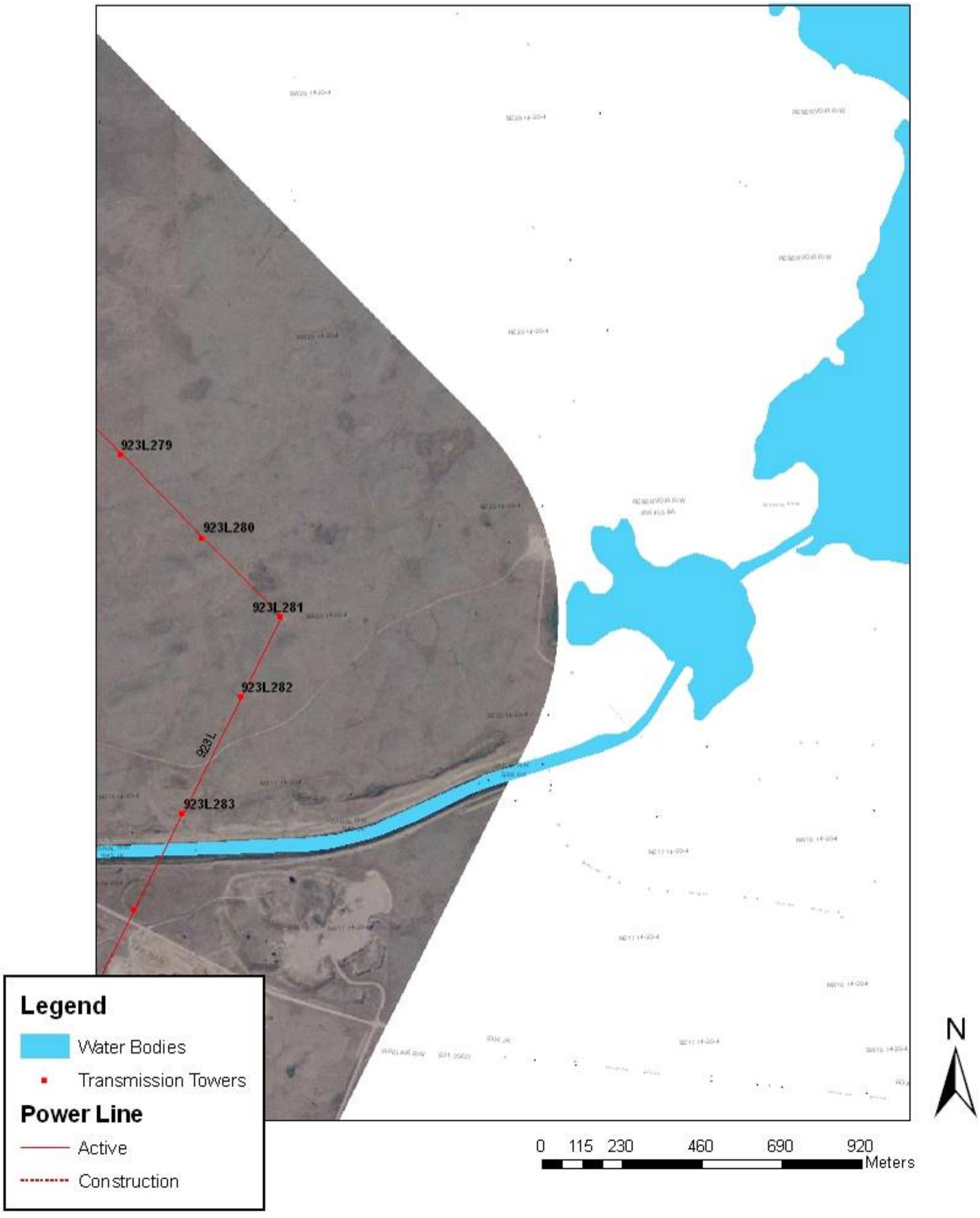
Frank Lake
911L148
911L149
911L152
911L153
911L154
Legend
sde.SDE.Water_Bodies
sde.SDE.TRANS_TOWERS
Water Bodies
STATUS
Active
Construction
N
0 255 510 1,020 1,530 2,040
Meters

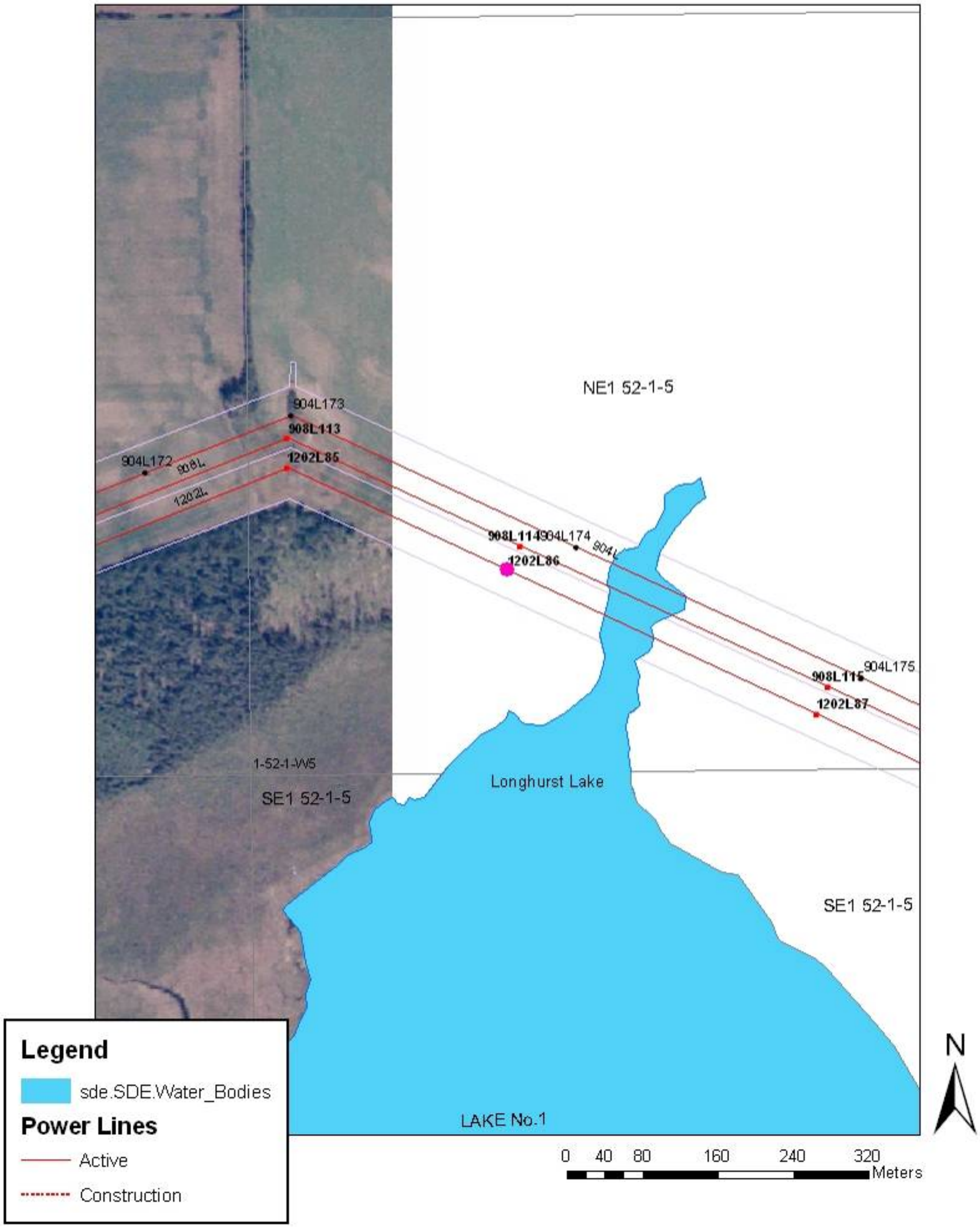
Lethbridge River Valley



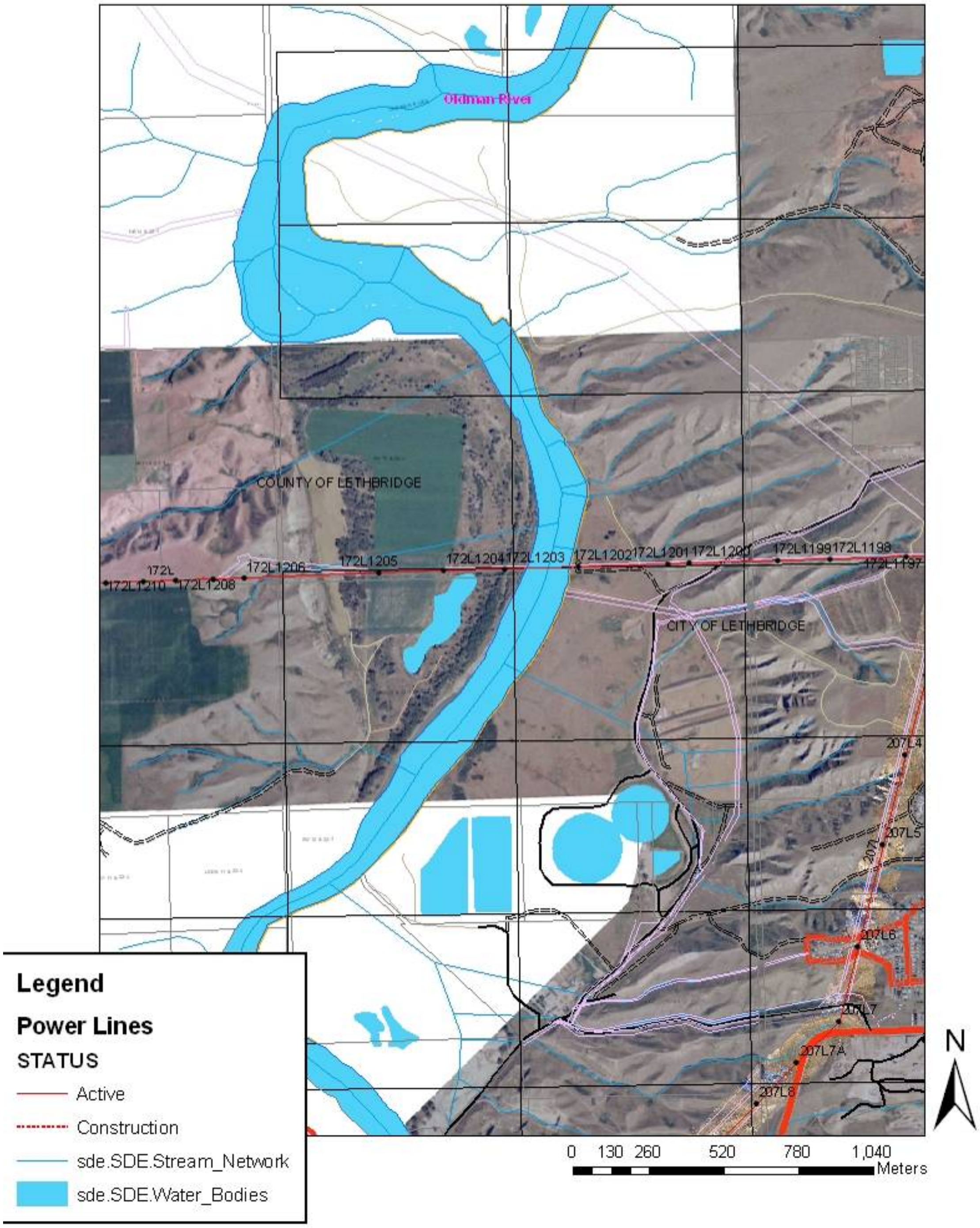
Little Bow Reservoir



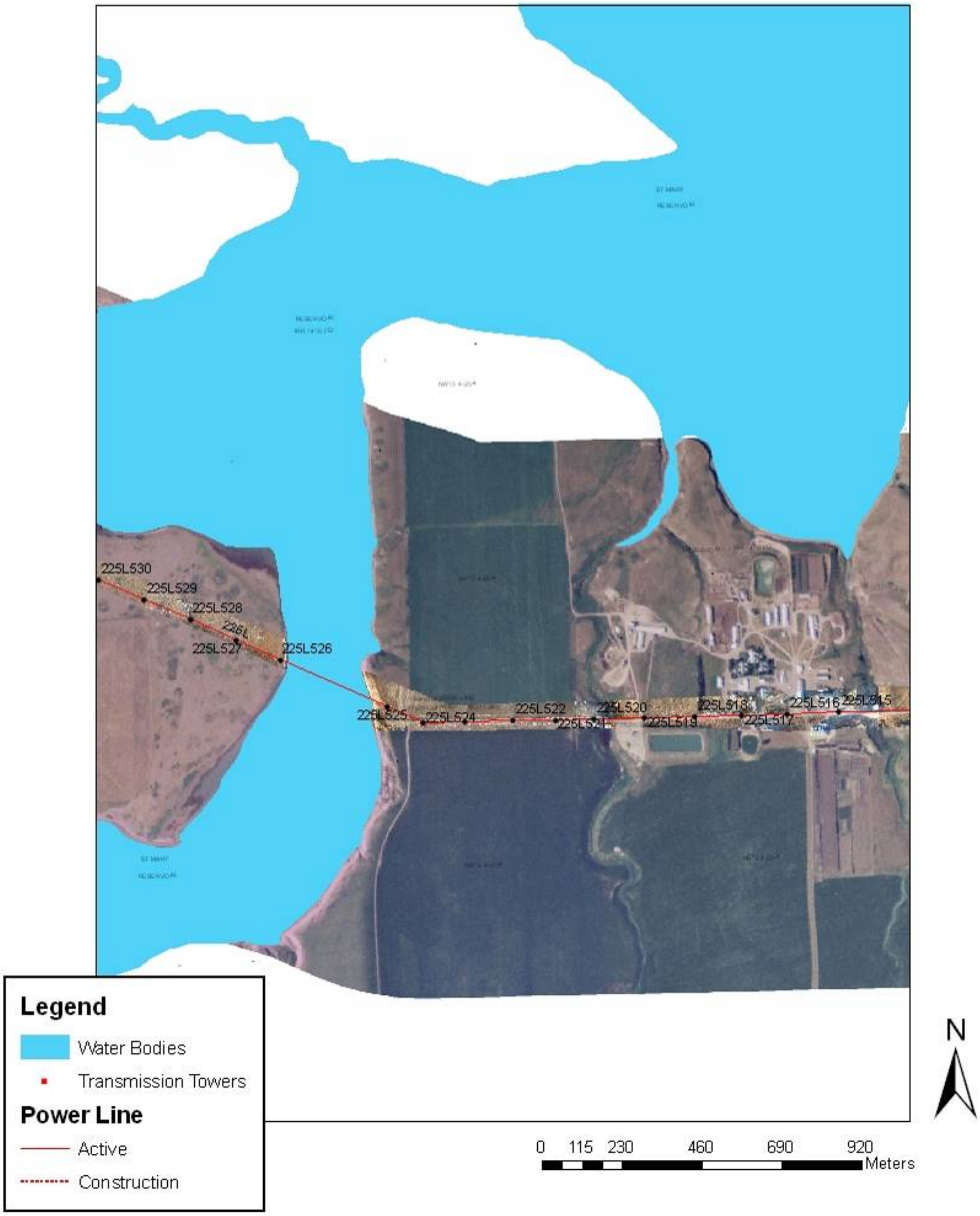
Longhurst Lake



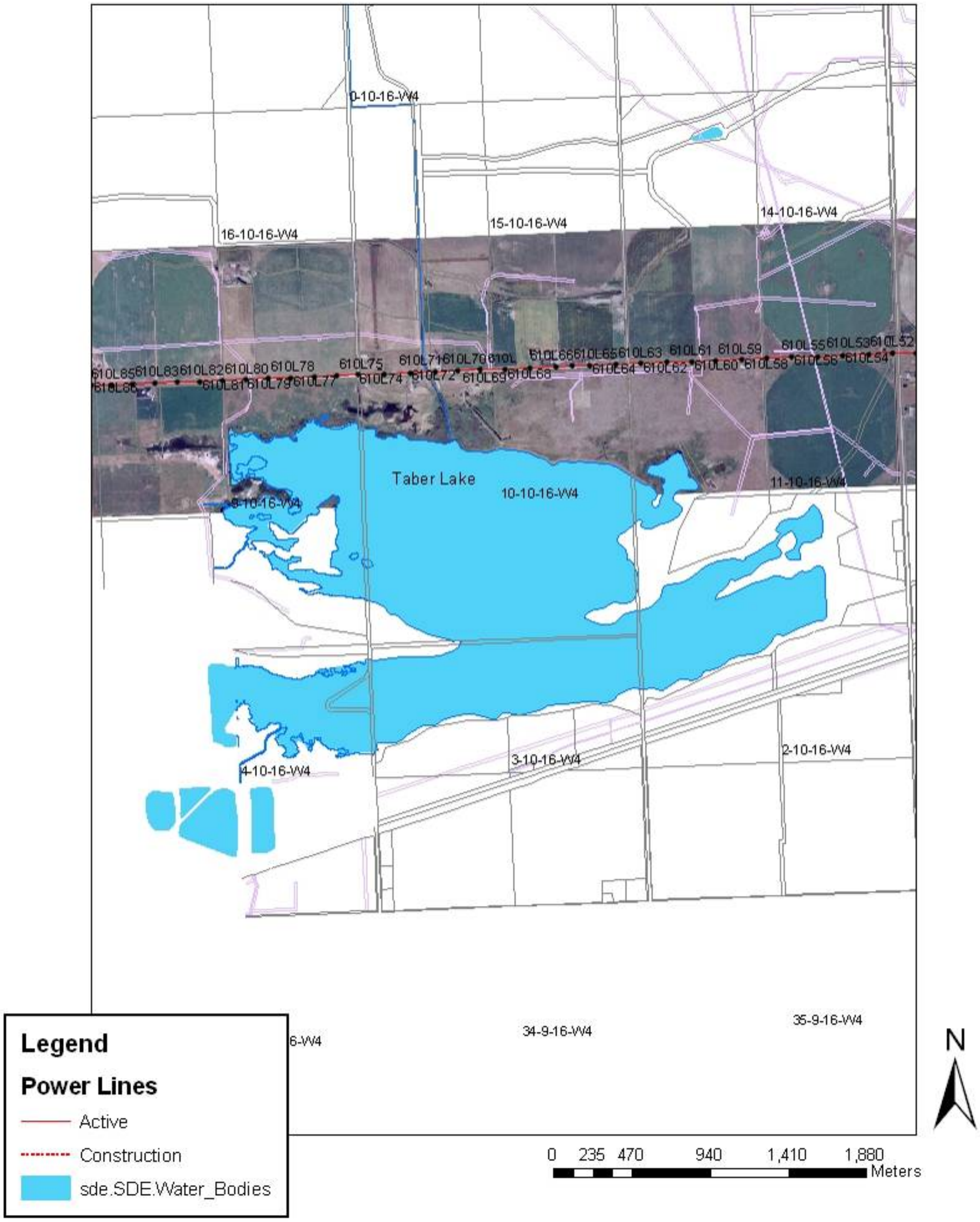
Oldman River Valley



St. Mary's Reservoir



Taber Lake



0-10-16-W4
15-10-16-W4
14-10-16-W4
16-10-16-W4
Taber Lake
10-10-16-W4
11-10-16-W4
4-10-16-W4
3-10-16-W4
2-10-16-W4
6-W4
34-9-16-W4
35-9-16-W4
Legend
Power Lines
Active
Construction
sde.SDE.Water_Bodies
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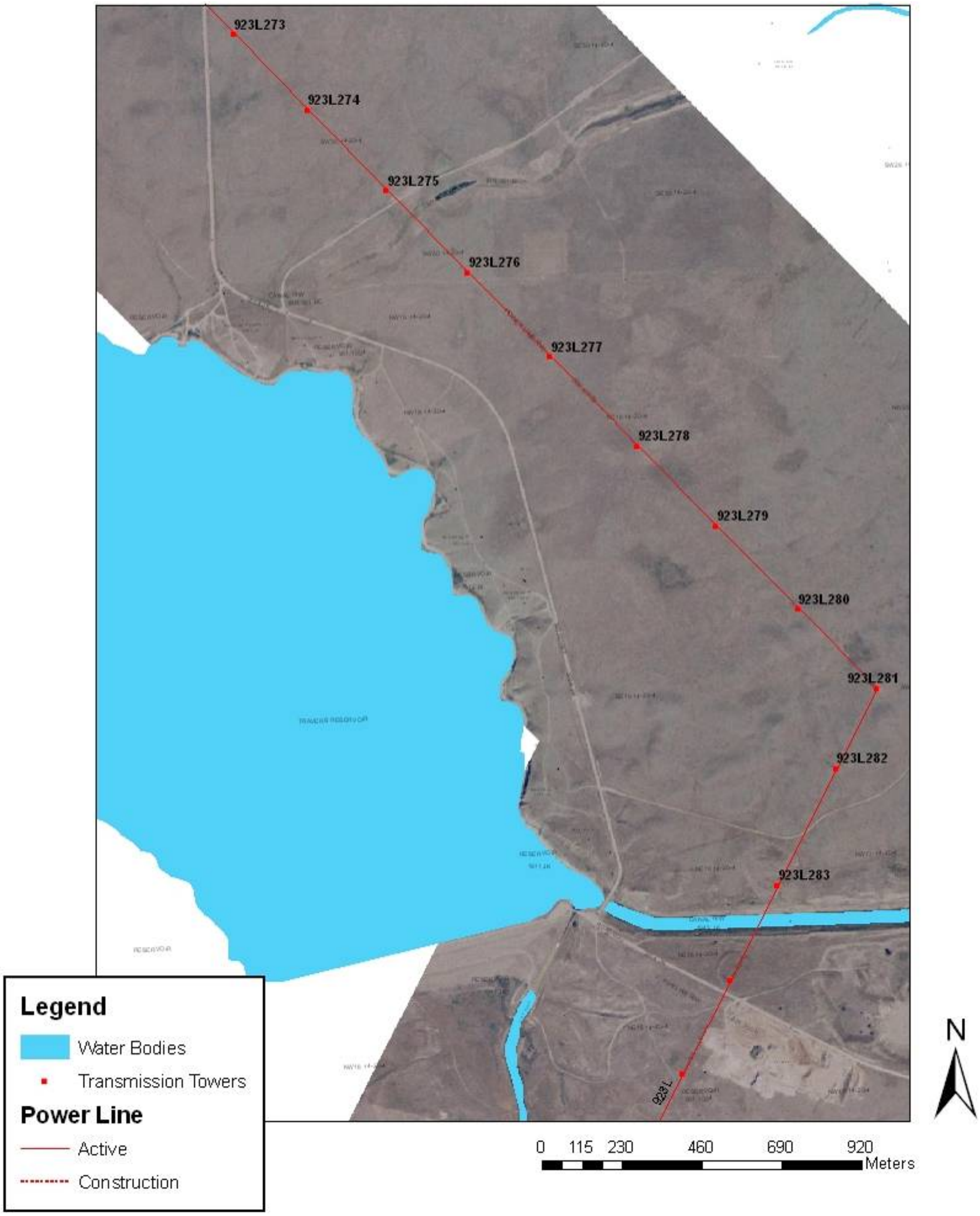
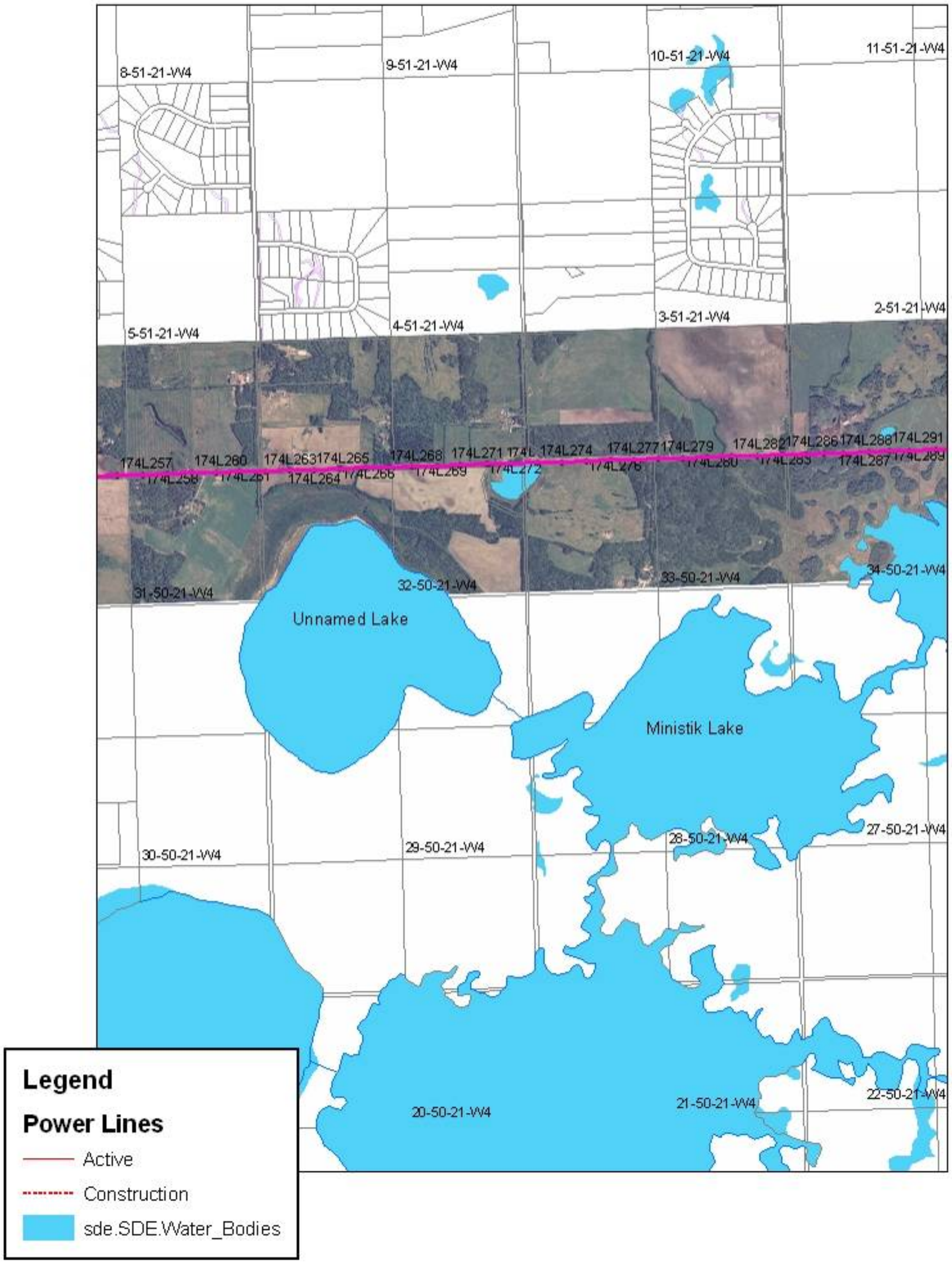
0 235 470 940 1,410 1,880
Meters

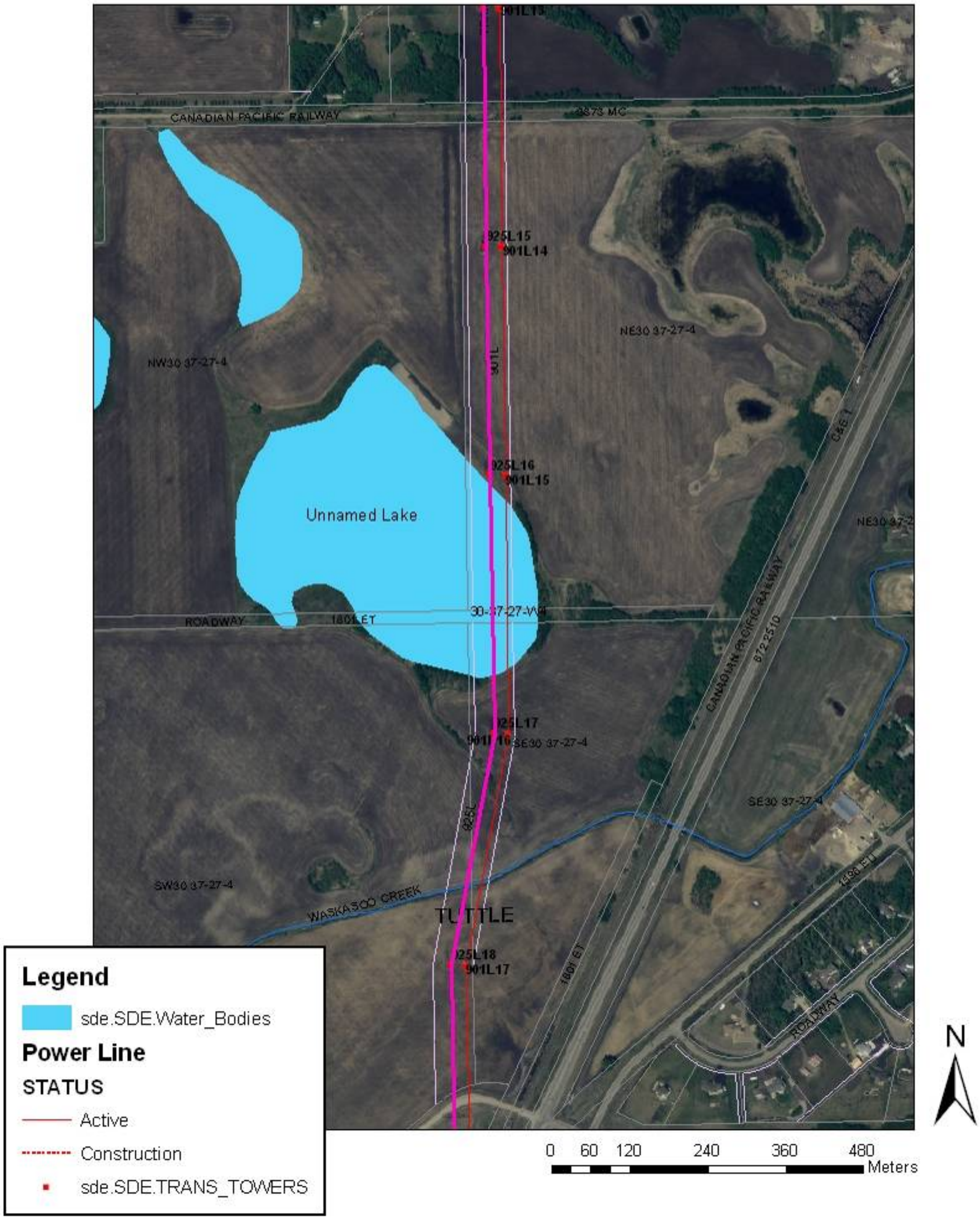
Traverse Reservoir



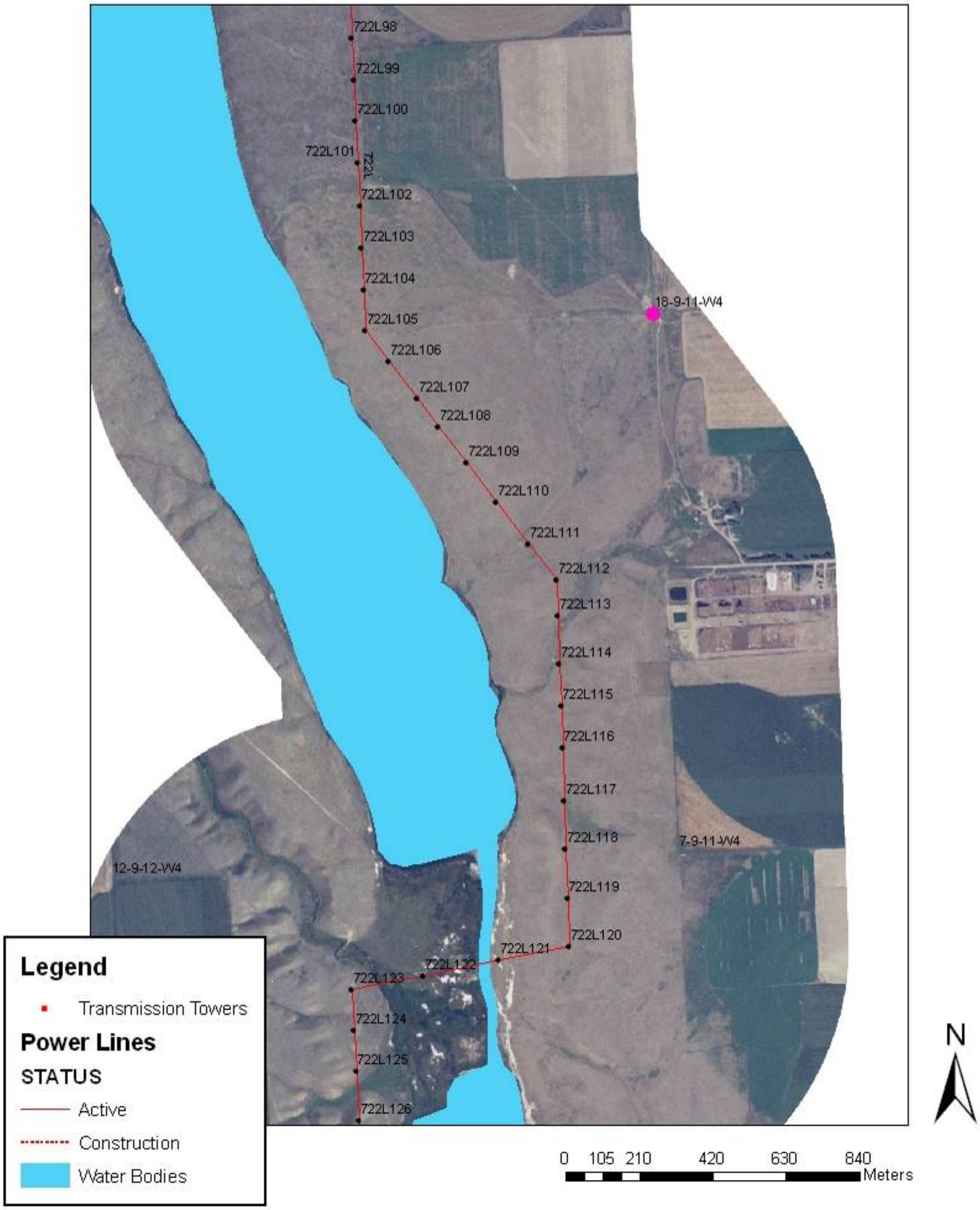
Unnamed Lake near Ministik Lake



Unnamed Lake near Red Deer



Yellow Lake



722L98
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18-9-11-W4
7-9-11-W4
12-9-12-W4
Legend
Transmission Towers
Power Lines
STATUS
Active
Construction
Water Bodies
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