Chance Oil and Gas, Eagle Plains Project: Linear Feature Study

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EXECUTIVE SUMMARY

The Eagle Plains Exploration Project (the Project) is an oil and gas exploration project located in north Yukon. Chance Oil and Gas Ltd. (Chance) intends to conduct exploratory activities to confirm the quality, quantity, and extent of hydrocarbons over ten years. Work will include seismic exploration and exploratory wells supported by an expanded winter road network. Oil and gas exploration activities create long, narrow clearings through natural vegetation, such as seismic lines and roads, collectively known as 'linear features.' Linear features can be a management challenge because they can affect how people and animals move and plants disperse within a landscape. For example, in southern parts of the boreal forest, linear features appear to affect predator-prey dynamics that can result in increased caribou mortality by wolves. The North Yukon and Peel Watershed Regional Land Use Plans identify mitigations to minimize the potential effects of linear features, including cautionary (0.75 km/km²) and critical (1.0 km/km²) indicator levels of linear disturbance.

Intermittent exploration activities in the Eagle Plains area from the 1950s to 2014 have created a network of winter roads, 2D seismic lines, and, most recently, 3D seismic lines in parts of the Regional Study Area (RSA). However, the extent of liner features that currently occur in the RSA, the structural, vegetation, and functional characteristics of different linear feature types, and their degree of regeneration are unknown. EDI Environmental Dynamics Inc. conducted a linear features study to characterize the structural, vegetation, and functional aspects of linear features in the RSA to address these information gaps. The study addressed three objectives: (1) comprehensive mapping and classification of existing linear feature footprints within the RSA; (2) quantification of structural aspects (e.g., widths) and functional aspects (ease of travel and sightlines) of linear features; and (3) quantification of regeneration pathways and structural stages of linear features. This combined information supports assessing potential effects of linear features in the Project application and refinement of mitigation measures for linear features to minimize possible effects.

The linear features inventory was compiled from multiple spatial datasets and was verified and supplemented using satellite imagery in a Geographic Information System. Linear feature densities were estimated for each linear feature type. Estimates were adjusted to account for (i) overlap with open habitats, such as recent burns, where vegetation heights were similar on and off the line, and (ii) for average rates of regeneration determined from field studies.

Site selection used a stratified random design to obtain a representative sample of different feature types across the RSA. Ground and aerial surveys measured specific structural, vegetation, and functional characteristics across the different line types. Measures included width, successional class, structural stage, vegetation composition and height, and sightline distances. A 'walk test' was used to index ease of movement for large mammals. A driving survey documented the visibility of seismic lines from the Dempster Highway (i.e., as an index of potential human access onto the seismic lines). An aerial winter track survey was conducted in March 2020 to assess ungulates' relative use of different linear feature types.

Four primary types of linear features occur in the RSA, totalling 4,269 km: 2D seismic (34%), 3D seismic (51%), winter roads (14%), and the Dempster Highway (1%). The unadjusted linear feature density for the RSA totalled 1.79 km/km². After accounting for burns, natural openings and regeneration, the adjusted linear

feature density for the RSA totalled 0.52 km/km², below the cautionary and critical indicator levels in the North Yukon and Peel Watershed Regional Land Use Plans.

Structural, vegetation, and functional characteristics differed substantially among linear feature types. 3D seismic accounts for the largest extent of linear features in the RSA and had the narrowest widths and limited functional effects (e.g., the proportion of features used by ungulates in the winter was less than a third of the rates of use on 2D and winter roads). Winter roads had the widest average widths and the greatest functional effects except for the Dempster Highway. However, a substantial portion (39%) had also regenerated into or past the Tall Shrub stage (which this study suggests may be the best criterion for functional recovery). Most 2D lines had substantial vegetation regeneration, resulting in the shortest average sightlines and slowest movement speeds. However, ungulates still appeared to select them to travel on during winter.

Except for the Dempster Highway, where walking speeds were near twice the rate of other linear feature types, there was relatively little difference in movement rates among linear feature types and control areas. The density of shrubs and trees primarily limited movement rates. 2D lines, which had the highest density of shrubby regeneration, had the slowest average movement rates. For other linear feature types, the combination of vegetation regeneration on linear features and the naturally open nature of most adjacent undisturbed areas did not convey a substantial increase in movement rates on linear features compared to undisturbed areas.

Sightline distances on 2D lines and winter roads were also affected mainly by the degree of vegetation regeneration. Where regeneration was limited, sightlines on 2D lines and winter roads regularly exceeded 150 m. On 3D lines, which have not had enough time since their creation for vegetation to regenerate to the height that restricts vision, sightlines were limited by meanders purposely constructed to reduce sightlines. The meanders employed on 3D lines were also effective in reducing the detectability of the lines from the Dempster Highway. In the blind test, where observers did not know the location of the 3D lines, only 5% (4 out of 74) crossings were spotted. With a map showing the crossing locations, only two additional 3D lines were detected.

These results provide information to assess the potential effects of linear features in the Project application and refine mitigation measures.

ACKNOWLEDGEMENTS

EDI Environmental Dynamics Inc. (EDI) completed the work within the traditional territories of the Vuntut Gwitchin First Nation (VGFN), First Nation of the Na-Cho Nyäk Dun, and the Tetlit Gwich'in Council (Secondary Use Area). Tyrel Kassi, a VGFN citizen, played an active role in the field components of the project. We thank him for his diligence and shared perspectives during the project.

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ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Definition
2D	Two Dimensional
3D	Three Dimensional
AIC	Akaike's Information Criterion
asl	above sea level
BC	British Columbia
°C	degrees Celsius
ELC	Ecosystem and Landscape Classification
GIS	Geographic Information System
GPS	Global Positioning System
ha	hectares
IMA	Integrated Management Area
km	kilometers
km^2	square kilometers
km/hr	kilometer per hour
LIS	Low Impact Seismic
LMU	Landscape Management Unit
m	meter
mm	millimeter
NND	Na-cho Nyäk Dun
NWT	Northwest Territories
NYRLUP	North Yukon Regional Land Use Plan
PCH	Porcupine Caribou Herd
OHV	Off-Highway Vehicle
PWRLUP	Peel Watershed Regional Land Use Plan
RSA	Regional Study Area
the Project	the Eagle Plains Project (proposed by Chance Oil and Gas Ltd.)
YLUPC	Yukon Land Use Planning Council

1 INTRODUCTION

1.1 PROJECT OVERVIEW

The Eagle Plains Project (the Project) encompasses a 2,386 km² area in north-central Yukon, approximately 605 km north of Whitehorse and 40 km south and west of Eagle Plains hotel, along the Dempster Highway (Map 1-1). The Project occurs within the Eagle Plains petroleum basin, north of the Ogilvie River and west of the Richardson Mountains. The basin contains proven natural gas and oil reserves (Peel Watershed Planning Commission 2019), including 4.6 billion m³ of gas and 3.2 million m³ of oil (Hannigan 2014).

The Regional Study Area (RSA) has had intermittent periods of oil and gas exploration since the 1950s. That activity has developed winter roads, seismic lines, and exploratory wells across parts of the current RSA. Approximately 40 exploration wells have been drilled at Eagle Plains. Eight wells are maintained in suspended status, and the remaining wells have been plugged and abandoned. Seismic exploration has included approximately 10,000 km of two-dimensional (2D) lines (mainly before 1985), and about 325 km² of three-dimensional (3D) seismic was conducted in 2013–2014 (Northern Cross (Yukon) Ltd. 2014).

The current exploration program will build on past exploration to better define the extent, amount and quality of oil and gas deposits. Under the current program, Chance Oil and Gas Ltd. proposes conducting additional 3D seismic over large extents of the RSA and drilling up to 30 exploratory wells. Depending on the drilling program results, extended flow testing over several months may be conducted at a subset of the wells to determine the quantity and quality of the oil and gas deposit. The existing winter road network will be expanded to support the seismic and drilling programs. Most work is expected to be conducted in the winter (e.g., seismic line clearing and drilling); however, seismic recordings and extended flow testing may also occur during summer.

Oil and gas exploration activities create long, narrow clearings through natural vegetation, such as seismic lines and roads, collectively known as 'linear features.' Linear features can be a management challenge because they can affect how people and animals move and plants disperse within a landscape. For example, in southern parts of the boreal forest, linear features appear to affect predator-prey dynamics that can result in increased caribou mortality by wolves. The North Yukon and Peel Watershed Regional Land Use Plans identify mitigations to minimize the potential effects of linear features. The Plans also include cautionary (0.75 km/km²) and critical (1.0 km/km²) linear density indicator levels.

1.2 PURPOSE AND OBJECTIVES

Intermittent exploration activities in the Eagle Plains area from the 1950s to 2014 have created a network of winter roads, 2D seismic lines, and, most recently, 3D seismic lines in parts of the RSA. However, the extent of liner features that currently occur in the RSA, the physical and functional characteristics of different linear feature types, and their degree of regeneration are unknown.

EDI Environmental Dynamics Inc. (EDI) conducted a linear features study to characterize the physical and functional aspects of linear features in the RSA to address these information gaps. The three objectives of this study were to: (1) conduct comprehensive mapping and classification of existing linear feature footprints within the RSA; (2) determine physical aspects (e.g., widths) and functional aspects (ease of travel and sightlines) of linear features; and, (3) quantify regeneration pathways and stages of linear features. The combined information forms the basis for assessing the potential effects of linear features in the RSA and refining mitigation measures for linear features.

1.3 STUDY AREA

The RSA for the Eagle Plains Project is approximately 2,386 km² (238,566 ha), centred in the Eagle Plains Ecoregion in north Yukon (Map 1-1). The area consists of subdued topography of rolling hills and sloping plains. The RSA is centred on a major watershed divide (denoted by the location of the Dempster Highway), with the northwestern two-thirds of the RSA draining into the Porcupine River watershed to the north, via Chance Creek, and west, via McParlon Creek and the Whitestone River. The southeastern third of the RSA drains into the Peel River watershed via Dalglish Creek.

Development in the RSA and the surrounding Eagle Plains is low. The Dempster Highway is the primary vehicle access corridor, running from approximately Dawson City, Yukon in the south to Inuvik, Northwest Territories in the north, and transiting the RSA. The Eagle Plains settlement is on the Dempster Highway, approximately 40 km northeast of the RSA and includes the Eagle Plains Hotel and the Government of Yukon's Highway Maintenance camp. The Eagle Plains area has had intermittent periods of oil and gas exploration since the 1950s. That activity has created winter roads, seismic lines, and exploratory wells across parts of the RSA. Approximately 40 exploration wells have been drilled at Eagle Plains. Eight wells are maintained in suspended status, and the remaining wells have been plugged and abandoned. Approximately 10,000 km of 2D lines have been developed across the Eagle Plains Ecoregion, mostly between 1961 and 1984 (Access Consulting Group and EBA Engineering Consultants Ltd. 2001, GEOTIR 2014). More recently, approximately 2,200 km of 3D LIS exploration was conducted in a 325 km² area between November 2013 and April 2014 (GEOTIR 2014). This 3D exploration grid is near the centre of the RSA, spanning north and south of the Dempster Highway.

1.3.1 REGIONAL ECOLOGICAL SETTING

The Eagle Plains Ecoregion is a 20,400 km² portion of the Taiga Cordillera Ecozone in north Yukon between the Richardson and Ogilvie Mountains. Unlike much of the mountainous Taiga Cordillera, most of the Eagle Plains Ecoregion occurs as low altitude rolling topography between 300 m and 600 m above sea level (masl), with few scattered peaks above and around 1,000 masl (Ecological Stratification Working Group 1995). Most of the ecoregion is unglaciated terrain, with surficial features formed due to permafrost and frozen ground-related processes, including thermokarst subsidence, soil creeps, cryoturbation, solifluction, and active layer detachment slides on shale (Yukon Ecoregions Working Group 2004).

The Eagle Plains Ecoregion experiences moderate precipitation, with annual amounts around 400 mm. Most precipitation falls as rain throughout the summer, averaging 50 to 80 mm per month, June through August. Precipitation is lighter through September to April and falls as snow, with average winter snowpacks of 80 cm peaking in April. The climate is strongly affected by latitude, with extended winter conditions from October to early May. There is a substantial variation in seasonal temperatures in the Eagle Plains, with cool short summers and long cold winters. Average winter temperatures are between −30°C and −25°C, with extremes as low as −60°C. Average summer temperatures are around 13°C, with extremes as high as 30°C. Due to the northern latitude, this region experiences continuous sun above and below the horizon, in summer and winter, respectively.

Most of the Ecoregion, including the northeast portion of the RSA, drains north into the Yukon River via the Whitestone, Porcupine and Eagle rivers. That part of the RSA includes the headwaters of the Eagle River and several other tributaries of the Porcupine River, along with the Chance and McParlon Creek subdrainages of the Whitestone River. The southeast corner of the Ecoregion drains east to the Mackenzie River via the Peel, Wind and Ogilvie Rivers. Dalglish and Enterprise creeks flow directly into the Peel River. The few lakes in the Ecoregion are generally oxbow or thermokarst lakes (Yukon Ecoregions Working Group 2004). Several wetland complexes are associated with larger creeks in the RSA.

The Eagle Plains Ecoregion is within the continuous permafrost zone where permafrost can be found up to 200 m thick. The Eagle Plains Ecoregion is dominated by the Cryosolic soils that occupy much of the northern third of Canada, characterized by near-surface permafrost. Turbic Cryosols predominate, exhibiting patterned ground formations and hummocks, and are often associated with open stands of black spruce (*Picea mariana*), tamarack (*Larix laricina*) and birch (*Betula* spp.). The active permafrost layer in these ecosystems generally ranges between 20 cm and 90 cm below the surface. The active layer depth is generally deeper directly under hummocks and shallower under inter-hummock areas (Yukon Ecoregions Working Group 2004).

The RSA is entirely within the Subarctic Bioclimate Zone (Environment Yukon 2014). Vegetation in the RSA is characterized by open-canopy, spruce-dominated habitats where permafrost and short cool growing seasons limit tree growth and often result in stunted, disclimax vegetation communities (Environment Yukon 2016). Hummocky, black and white spruce (*Picea glauca*) woodlands with well-developed shrub communities are common in upland areas. White spruce and ground lichens increase in abundance in well-drained sites. Areas with low slope gradients and fine-textured soils often have ground cover dominated by cottongrass tussocks beneath a shrub layer of birch, black spruce, Labrador tea (*Rhododendron groenlandicum*), and occasionally tamarack (*Larix laricina*) (Yukon Ecoregions Working Group 2004).

Forest fires are a common disturbance agent in the region, and burns of various ages occur throughout the RSA. Fires increase the depth of the active permafrost layer and changes in soil moisture and productivity, affecting vegetation regeneration and resulting in terrain disturbances, such as slope failures and erosion. Regenerating burns are dominated by shrubs, such as scrub birch (*Betula glandulosa*), willows (*Salix spp.*) and alder (*Alnus spp.*), with Alaskan paper-birch (*Betula neoalaskana*) often the first tree species to colonize burn areas. As burns regenerate into young and mature forest, black and white spruce typically become the dominant forest species. Residual Alaskan birch in spruce-dominated stands often defines the extent of old burns (Yukon Ecoregions Working Group 2004).

Mammal diversity is relatively low in the Eagle Plains Ecoregion due to its northern location and low productivity. Voles (*Microtus* spp., *Myodes* spp., *Phenacomys* spp.), American marten (*Martes americana*), ermine (*Mustela erminea*), and red fox (*Vulpes vulpes*) are common smaller mammals. Wolves (*Canis lupus*), wolverines (*Gulo gulo*), and both black and grizzly bears (*Ursus americanus* and *U. arctos*.) are present at low densities. Moose (*Alces alces*) inhabit the region year-round. The RSA overlaps a small portion of the winter range of the Porcupine caribou herd (PCH), a subpopulation of the barren-ground caribou (*Rangifer tarandus granti*). The PCH is an iconic species in north Yukon, with high cultural, social, economic, and ecological values. The PCH's population has been increasing over the last several decades and is currently estimated to consist of 202,106 to 234,808 caribou (Caikoski 2017, Porcupine Caribou Technical Committee 2018). The PCH is known to occupy portions of the Eagle Plains Ecoregion in fall and winter when they tend to occur in smaller groups over a larger area than during other seasons.

1.3.2 REGIONAL LAND USE PLANNING

The RSA overlaps four First Nation Traditional Territories. Most of the RSA is within the Traditional Territory of the Vuntut Gwitchin First Nation. The southeastern portion is in an area of overlapping Traditional Territories of Vuntut Gwitchin First Nation, the Tetlit Gwich'in Council, the First Nation of Na-cho Nyäk Dun, and Tr'ondëk Hwëchin. Although the RSA is located outside of any First Nation Settlement Lands, it does abut Vuntut Gwitchin First Nations Settlement Lands on parts of its east and southwest borders. Each First Nations government has provided input to, and approved of, the Regional Land Use Plan(s) on their Traditional Territory under the respective First Nation Final Agreements.

1.3.2.1 North Yukon Regional Land Use Plan

The RSA lies mainly within the North Yukon Planning Region and is subject to the North Yukon Regional Land Use Plan (NYRLUP) (Map 1-1). The NYRLUP was created to protect the natural and cultural resources of the region while allowing sustainable economic development opportunities (Vuntut Gwitchin Government and Yukon Government 2009). It provides management direction for using public and settlement lands based on four principles: sustainable development, precautionary principle, conservation, and adaptive management. The NYRLUP divides the Planning Region into 23 land management units classified into three categories: protected area, integrated management area (IMA), and community area. IMAs are further classified into four zones: Zone 1 (lowest development), Zone II (low development), Zone III (moderate development), and Zone IV (highest development). IMA zones are classified based on the area's sensitivity to landscape disturbance, ecological and cultural values, risk of significant impacts, and level of acceptable change. The RSA is a Zone IV IMA with lower ecological and cultural values in a moderately sensitive biophysical setting. Subsequently, Zone IV IMAs allows for the highest development level to occur.

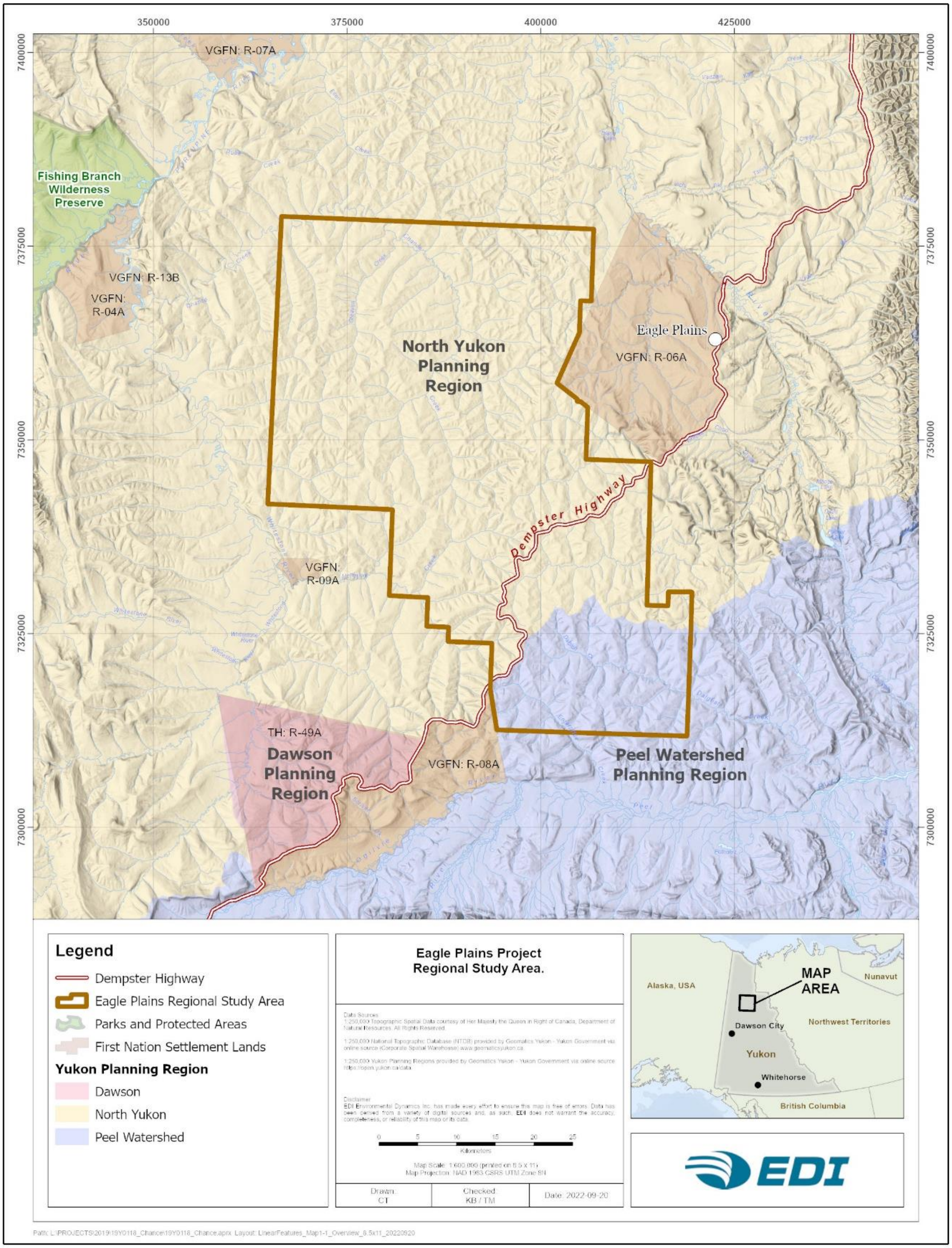
The NYRLUP encourages results-based management and uses cumulative effects indicators to determine if goals and objectives are met. Results-based management allows for innovation and creativity in land-use strategies and approaches. The two cumulative effects indicators included in the NYRLUP are direct surface disturbance and linear density. The NYRLUP guidelines for Zone IV IMAs are 0.75–1.0% surface disturbance and 0.75–1.0 km/km² linear density (Vuntut Gwitchin Government and Yukon Government 2009).

However, as surface disturbances and linear features reach a level of functional recovery and become part of the continuous landscape, they can be subtracted from the total amount of disturbed area (Vuntut Gwitchin Government and Yukon Government 2009). The NYRLUP suggests using a height of 1.5 m for woody vegetation in forested areas, as vegetation above this height would likely no longer allow for travel or access by humans or wildlife and is, therefore, considered functionally recovered. Activities considered exempt from functional disturbance restrictions are (1) new linear features less than 1.5 m wide; (2) land-use activities that occur on frozen water bodies; (3) winter work with no required clearing of trees; and (4) winter work that uses existing disturbances and linear features.

1.3.2.2 Peel Watershed Regional Land Use Plan

The southeastern corner of the RSA lies within the Peel Watershed Planning Region (PWPR) and is subject to the Peel Watershed Regional Land Use Plan (PWRLUP) (Peel Watershed Planning Commission 2019) (Map 1-1). Like the NYRLUP, the PWRLUP was established to provide management direction and ensure long-term sustainable development in the Planning Region. The PWRLUP was founded on three main themes: environmental protection, social considerations, and economic development. It follows a similar framework as the NYRLUP. The PWPR is divided into 16 Landscape Management Units (LMU), which each share similar ecological characteristics, planning issues, and management intent. Each LMU is categorized by a land-use designation system. Conservation Areas are managed to protect ecological and cultural resources, while IMAs are 'working' landscapes where new development and surface disturbance may be allowed. IMAs are further classified into Zones, which correspond to the level of allowable development with comparable justification as the NYRLUP. The RSA is part of LMU 7 (Dalglish Creek), classified as an IMA Zone IV, allowing for the highest level of development.

Like the NYRLUP, the PWRLUP encourages results-based management and uses the same cumulative effects indicators, surface disturbance and linear density to inform decisions. The PWRLUP cautionary and critical indicators are identical to those of the NYRLUP: 0.75–1.0% surface disturbance and 0.75–1.0 km/km² linear density. As surface disturbances reach a level of functional recovery and no longer enable travel or access by wildlife and people, they can be subtracted from the total amount of disturbed area. The PWRLUP suggests using a 1.5 m woody vegetation height as a threshold for functional recovery in forested or shrubland areas. In areas dominated by low-growing vegetation, a feature could be considered functionally recovered when covered by native species roughly the same height and composition as the surrounding vegetation. To be considered as "functionally recovered," features must have similar sediment and run-off compared to background levels, roughly match original contours, and have no human-brought materials on the site. Exceptions to the linear density calculation are identical to those outlined in the NYRLUP.



Map 1-1. Eagle Plains Project Regional Study Area.

2 BACKGROUND

The term "linear feature" refers to any narrow, linear clearings of vegetation on the landscape. They include roads, seismic lines, power lines, and pipelines. Seismic lines are the dominant linear feature class in northern Canada, accounting for approximately 46% of all linear features in the Canadian boreal region (Pasher et al. 2013). Seismic exploration detects underground oil and natural gas reservoirs by analyzing sound waves reflected from the underlying geology (Yukon Energy Mines and Resources 2006). Sound waves are emitted by detonating small charges in a series of drilled shot holes (up to 20 m deep) or by vibrating a heavy metal plate on the ground's surface using a truck-mounted vibrator (Yukon Energy Mines and Resources 2006). Both methods require cleared travel corridors for equipment transportation, which results in a network of seismic lines across the landscape where seismic exploration has occurred.

Until the late 1990s, conventional 2D was the primary form of seismic exploration used in North America. 2D seismic lines were created using bulldozers to clear all vegetation in straight swaths, approximately 5–10 m wide in their earliest form. These wide, straight lines were necessary to enable large, heavy equipment movement. This process resulted in significant physical disturbance, often removing most surface vegetation and roots and the top layer of soil (Bliss and Wein 1972). Progressive improvements in 2D seismic exploration methods reduced the environmental impact, such as clearing in winter instead of summer and raising and adding mushroom shoes to the bulldozer blade to reduce soil disturbance. Despite these improvements, many of the 2D seismic lines created in the 1960s and 1970s in northern Canada remain disturbed, with little evidence of ecological recovery (Lee and Boutin 2006, van Rensen et al. 2015).

3D seismic exploration provides more accurate subsurface geological structure data than 2D technology. 3D seismic exploration techniques were developed in the mid-1990s, and their use became widespread in the early 2000s (Dabros et al. 2018). At the same time as the transition to 3D, the seismic industry was transitioning to smaller and more specialized equipment that reduces cost, improves efficiency and reduces environmental impacts. Modern seismic equipment and methods typically use what is referred to as Low Impact Seismic (LIS) methods that minimize line widths and site disturbance and compaction. Typical 3D seismic lines are 2–3 m wide, constructed in 100–500 m spaced grids, and follow meandering rather than straight routes. There have been substantial improvements in the equipment used for 3D seismic line creation: low ground pressure mulchers, lighter equipment, ATV-mounted equipment, mushroom shoes and smear blades, and 'envirodrills' greatly reduce physical and vegetation disturbance (Dabros et al. 2018). These methods often leave the ground vegetation intact and only remove trees and tall shrubs, reducing overall disturbance and facilitating faster regeneration. The location of the seismic line can be adjusted on the fly in the field to minimize impacts, such as avoiding the cutting of large trees.

Continuous advancements in seismic exploration technology have improved geophysical accuracy while simultaneously reducing environmental impact. Numerous studies have examined the effects of linear disturbances on soil, hydrology, vegetation, regeneration, and wildlife responses (see Dabros et al. 2018 for a comprehensive review). Although the bulk of literature focuses on 2D seismic lines, as they have been part of the landscape for over 60 years, there have been several recent studies investigating the effects of LIS and 3D seismic lines (e.g., Kemper and Macdonald 2009a, Kansas et al. 2015, Golder Associates 2016).

Linear features have been associated with various environmental effects, including permafrost thaw, soil compaction and rutting, increased soil moisture and pooling, altered snow cover, temperature and wind patterns, and varied vegetation and wildlife responses (Dabros et al. 2018). In addition to the immediate loss of vegetation, linear features can create extensive edge effects, facilitate non-native or disturbance-induced species establishment, alter species composition, and positively and negatively affect wildlife (Dabros et al. 2018).

One of the most extensively studied effects of linear features in the southern boreal forest is the indirect effects that linear features can have on mortality risk to woodland caribou (*R. tarandus caribou*). Linear features can result in complex effects on populations dynamics that include (i) increases in secondary prey (moose and deer), which elevate wolf populations (apparent competition) and (ii) more efficient hunting by predators along linear features (facilitated predation) (Wittmer et al. 2007, Latham et al. 2011, Dickie et al. 2017a, Keim et al. 2019b, 2021). Research has also documented the responses of birds to linear features (Bayne et al. 2005, Machtans 2006, Lankau et al. 2013), bears (Tigner et al. 2014, Finnegan et al. 2018), and furbearers (Tigner et al. 2015).

Most studies investigating impacts and recovery of seismic lines and other linear features were conducted in southern boreal forest ecosystems (i.e., Boreal Plains Ecozone; e.g., Lee and Boutin 2006, Kansas et al. 2015, van Rensen et al. 2015, Dickie et al. 2017a). There are fundamental differences in the climate, vegetation communities, wildlife communities, and ecological processes in taiga ecosystems that may result in different patterns and responses to linear features. For example, regeneration patterns of linear features in taiga ecosystems over permafrost can follow different successional trajectories than those of southern boreal regions (Simpson 2008). The few studies that have examined linear features in taiga regions have found similarities and differences to southern studies revegetation (Kemper and Macdonald 2009, Dabros et al. 2018). One of the key objectives of this study was to collect local information from Eagle Plains that can be used to better contextualize or adapt the findings from other studies to the Eagle Plains Project.

3 METHODS

A GIS analyses and field surveys were conducted to characterize linear features within the RSA. The inventory of linear features in the RSA was developed in a GIS by compiling available spatial data and then verifying and updating that against satellite imagery. Field studies quantified the width, vegetation characteristics, ecological function (line-of-sight, large mammal ease of movement assessment), and visibility of lines from the Dempster Highway.

3.1 LINEAR FEATURES INVENTORY

The inventory of existing linear features in the RSA was developed in a GIS by compiling available spatial data and then verifying and updating that against satellite imagery. A preliminary linear feature database was first developed that was used to support field surveys (described below in this section). A second step linked the field data to the linear feature database and conducted a more thorough review and verification process using satellite imagery to produce a final linear feature dataset for the RSA (see details in section 3.5.1).

Linear feature spatial data were obtained from the following sources:

- Yukon Government Energy, Mines and Resources "Oil and Gas Seismic Lines" dataset (a combination of less detailed National Energy Board data pre-1999 and the more detailed company-submitted data post-1999) (Yukon Government 2019)
- Natural Resources Canada CanVec "Roads," "Trails," and "Cut Lines" 1:50,000 scale datasets (Natural Resources Canada 2019)

The two datasets were merged into one dataset of all linear features documented in Yukon and clipped to the RSA. Key attribute data included (if available) the linear feature type (i.e., 2D and 3D seismic lines, winter roads, trails, Dempster Highway), width, year of establishment, and data source. This preliminary linear feature dataset was compared against satellite imagery at a (minimum) 1:10,000 scale to verify its accuracy. Any linear features that did not correspond with features visible in satellite imagery were either corrected or deleted based on satellite imagery interpretation. In the case of duplicate features across datasets, the 'best' data were attributed to a single feature by considering the spatial accuracy and the amount and accuracy of attribute data, as assessed against satellite imagery. Where duplicate widths occurred in the two source datasets, the wider width was retained.

3.2 LINEAR FEATURE CHARACTERISTICS SURVEY

Field studies quantified the width, vegetation characteristics, line-of-sight, and large mammal ease of travel assessment across the linear feature types identified from the GIS inventory. One aspect of the field study was to compare vegetation, line-of-sight, and ease of movement on the linear features to undisturbed areas adjacent to the cleared lines. Three types of surveys collected data for the linear feature study: ground surveys (finest level of detail), air surveys (medium level of detail), and air calls (coarsest level of detail). EDI crews collected field data between July 28 and August 8, 2019.

3.2.1 SITE SELECTION

All ground surveys and aerial surveys occurred at predetermined, random sites. Sample sites were selected using a clustered, random sampling approach. This approach balanced obtaining a random, representative sample across linear feature types with survey efficiency (i.e., without clustering sites, the travel time between points would have been substantially greater and resulted in smaller sample size). Survey sites were drawn from 5,000 points distributed randomly across the set of mapped linear features (minimum spacing of 200 m between points). Each point was randomly assigned a unique number.

Each survey cluster included options for both ground and air surveys. For ground surveys, the cluster used a 2 km radius designed to accommodate approximately four ground survey sites, intended to be surveyed within a half-day of work (and close enough so crews could walk between sites). The objective was that two ground clusters could be surveyed by a crew each day. For air surveys, a 4 km radius was used that generally provided at least ten random survey site options. The objective for air survey clusters was that they could be surveyed while transiting between ground survey clusters.

Survey sites were selected via a two-stage process. The first stage was randomly drawing 100 points from the 5,000-point dataset. These points defined the survey clusters and served as actual survey sites. In this first stage, site selection was stratified to obtain an approximately equal sample across 2D, 3D and winter roads. This overweighted sampling of 2D and winter roads, relative to their extents in the RSA, but those features had the highest uncertainty in terms of their widths, vegetation characteristics, and functional characteristics. Stratification was necessary to obtain sufficient sample sizes across these less-common features. The second site-selection stage selected additional random points from the 5,000-point dataset in proximity to the first point, using the 2 km radius for ground surveys and the 4 km radius for aerial surveys.

The RSA was divided into 10 work areas to implement the sample design, each corresponding to a day of surveys. Each day the survey crew selected clusters to survey using the ascending order of the random identification number of the first point used to define each cluster. Similarly, points within each cluster were prioritized in ascending order of the random identification number. Normally, at least two ground clusters and two air clusters were sampled each day. However, that varied somewhat depending on the number of sample sites available in each cluster and the availability of the helicopter.

3.2.2 LINEAR FEATURE CHARACTERISTICS AND SURVEY METHODS

3.2.2.1 Linear Feature Characteristics

A range of structural, vegetation, human use, and functional characteristics was assessed in the field. A list of the various characteristics examined, with a description of each, is provided in Table 3-1. Successional classes and structural stages of vegetation are defined in Table 3-2 and Table 3-3, respectively.

Table 3-1. Description of physical, ecological and function characteristics assessed in the Eagle Plains linear feature study.

Parameter	Description	Survey Measured [1]
Plot location	Latitude and longitude using WGS 1984, measured by Garmin GPS units to ~4 m accuracy.	G, AS, AC
Linear feature type	Dempster Highway, winter road, 2D, 3Dc (conductor lines), 3Dr (receiver lines), and 3D5 (3D lines used both for seismic and local equipment/vehicle travel.	G, AS, AC
Linear feature width	During ground surveys, measured to the nearest 0.05 m and replicated four times. During aerial surveys, they were visually estimated to the nearest 1 m.	G, AS
Percent mulch	Percent cover of mulch (wood chips) on the seismic line, estimated to the nearest 1% using visual estimates. In areas with dense trees or large shrubs, the thick mulch layer produced during line clearing can hinder vegetation regeneration.	G, AS
Successional class	Refers to the successional trajectory of vegetation regeneration on the linear feature. Includes normal, magnified, stagnated, retrogressive, no succession, or recent disturbance class following Simpson (2008)[1].	G, AS, AC
Burn status	Burnt or not burnt; based on visual assessment (i.e., burned trees, charred ground vegetation).	G, AS, AC
Structural stage	Categorical descriptor of the dominant vegetation life form in the plot following the *Field Manual for Describing Yukon Ecosystems* criteria (Environment Yukon 2017). Structural stage categories are defined in Table 3-3.	G, AS
Height and species of tallest vegetation	Measured to the nearest 0.1 m for the tallest vegetation layer, approximated by the 90th percentile height to exclude extreme heights of individual plants.	G
Cover and species of dominant trees	Percent cover was recorded to the nearest 1% if less than 10%, and to the nearest 5% if over 10%. One or two dominant tree species were recorded.	G, AS
Cover and species of dominant shrubs	Percent cover was recorded to the nearest 1% if less than 10%, and to the nearest 5% if over 10%. Up to five co-dominant shrub species were recorded. Ground shrubs were excluded.	G, AS
Ecosite	Ecosite was recorded using Predictive Ecosystem Mapping (PEM) Units, available at the time of the survey. However, separate vegetation surveys indicated that the accuracy of the PEM mapping was poor, and ecosites were not used in subsequent analyses.	G
Permafrost activity/degradation	Present or absent. Additional comments (i.e., type of activity, percent cover) were recorded if applicable.	G
Wildlife trails	Present or absent. If present, rated as poorly, moderately, or well defined.	G
Potential for Off-Highway Vehicle (OHV) passage	Present or absent. Based on professional judgment, a 4x4 side-by-side is summer, considering obstructing vegetation, ground conditions (e.g., wetlands, peatlands), and graminoid tussocks.	G, AS
Signs of human activity	Present or absent. If present, applicable comments were recorded.	G
Ground disturbance	Percent cover of visibly disturbed ground. If present, type and additional descriptive comments were recorded.	G

[1] G=Ground Survey, AS=Aerial Survey, AC=Air Call.

[2] Between 2006 and 2008, Yukon Government, Department of Energy, Mines, and Resources investigated the recovery status of linear features in the Eagle Plains, British Mountains, and Peel River Plateau Ecoregions (Simpson 2008). They found that linear features typically regenerated into one of six categories: normal succession, magnified succession, retrogressive succession, successional stagnation, no succession, and recent disturbance (Table 3-2).

Table 3-2. Descriptions of successional classes on linear features in the Eagle Plains area (following Simpson 2008).

Successional Class	Description
Normal succession	Vegetation is similar to the adjacent undisturbed area but often in an earlier seral stage. E.g., often young trees surrounded by early successional shrubs and forbs. The disturbance was likely limited to removing trees and shrubs, with little to no disturbance to soil or permafrost.
Magnified succession	Vegetation on the feature is taller than the adjacent undisturbed area. Deciduous species often dominate tree and shrub layers, but a similar pattern was also observed for coniferous trees on some sites. The response is likely due to increased site productivity (including increased soil moisture, nutrients, and temperature) due to soil disturbance or increased depth to permafrost. Most frequently, but not exclusively, observed in burns.
Retrogressive succession	Sites are typically moss or sedge-dominated (rarely forb or low shrub), with high moisture content, often including standing water (i.e., micro wetlands), that contrast to upland conditions in adjacent undisturbed areas. The condition appears to result from permafrost melting and water pooling associated with vegetation removal and removal/compaction of the peat layer and mostly associated with winter roads.
Successional stagnation	Vegetation is typically dominated by graminoids or shrubs and not progressing to more advanced successional stages. Disturbance to soil or permafrost is likely. The ground may have been compacted. Almost exclusively associated with winter roads.
No succession	No ecological differences between the linear feature and adjacent undisturbed areas except that there is no or very little tree or shrub regeneration on the line, other than what was left after creation of the feature. Disturbance appears to be limited to the removal of trees and shrubs, with little to no disturbance to ground vegetation, soil, or permafrost.
Recent disturbance	Newer seismic line where successional patterns could not be determined. Features in this class were most likely trending to 'normal succession' or 'no succession', but the degree of regeneration was too limited to classify confidently.

Table 3-3. Structural stage categories used in ground and air surveys for the Eagle Plains linear feature study.

Structural Stage Code	Structural Stage Name	Description
1	Non-vegetated	Very recent disturbance (e.g., fire or flood) and no vegetation or less than 5% vegetation.
2	Sparse/Cryptogram	Either the initial stages of primary succession or a cryptogram community maintained by environmental conditions (e.g., bedrock, talus). Sparse tree, shrub and herb cover. Either sparsely vegetated overall (low cover of vascular plants and cryptograms, if present) or dominated by cryptograms.
2a	Sparse	5–10% vegetation cover.
2b	Bryoid	Bryophyte-dominated.
2c	Lichen	Lichen-dominated.
3	Herb	Early successional stage (e.g., post-fire forest succession) or a herb community maintained by environmental conditions or disturbance. Vegetation is dominated by herbs, although if the site overall is sparsely vegetated, herb cover can be low as long as herbs characterize the vegetation. Trees and shrubs are usually sparse or absent; however, shrub cover and stature (compared to herb cover and stature) determine whether the site is considered herbaceous.
3a	Forb-dominated	Includes non-graminoid herbs and ferns.

Structural Stage Code	Structural Stage Name	Description
3b	Graminoid-dominated	Includes grasses, sedges, reeds, and rushes.
3c	Aquatic	Floating or submerged plants dominate.
3d	Ground shrub-dominated	Dominated by dwarf woody species such as kinnikinnick (*Arctostaphylos uva-ursi*) or dwarf willows.
4	Shrub	Early successional stage of a forest or a shrub community maintained by environmental conditions or disturbance. Dominated either by shrubby vegetation, including tree seedlings or saplings; or, if sparsely vegetated overall, dominated by shrubs, which characterize the community as a shrubland.
4a	Tall Shrub	Dominated by woody plants >2 m tall with diameter at breast height (dbh) ≤7 cm.
4b	Low Shrub	Dominated by woody plants <2 m tall.
5	Treed: Pole/Sapling	Trees >2 m tall and with dbh >7 cm, typically densely stocked. Self-thinning and vertical structure are not yet evident in the canopy. Younger stands are vigorous (usually >15 to 20 years old); older stagnated stands (up to 100 years old) are also included; time since disturbance usually <40 years; up to 100+ years for dense (5,000–15,000+ stems per ha) stagnant stands.
6	Treed: Young Forest	Self-thinning has become evident and the forest canopy has begun to differentiate into distinct layers. A more open stand than at the pole/sapling stage.
7	Treed: Mature Forest	Trees established after the last stand-replacing disturbance have matured; a second cycle of shade-tolerant trees may have become established; shrub and herb understoreys become well developed as the canopy opens up.
8	Treed: Old Forest	Stands of old age with complex structure; patchy shrub and herb understoreys are typical; regeneration is usually of shade-tolerant species with a composition similar to the overstorey. Fire-maintained stands may have a single-storey appearance.
9	Treed: Very Old Forest	Very old stands with complex structures, abundant large trees, snags and coarse woody debris (CWD); snags and CWD occurring in all stages of decomposition; stands are comprised entirely of shade-tolerant overstorey species, with well-established canopy gaps.

3.2.2.2 Survey Methods

Three types of surveys assessed linear feature characteristics: ground surveys (finest level of detail), air surveys (medium level of detail), and air calls (coarsest level of detail). The reason for using different survey types was to maximize the sample size obtained, recognizing that the ability to collect certain types of data, or the level of measurement precision, decreased from ground surveys to aerial surveys to air calls. The characteristics that were measured during each survey type are noted in Table 3-1. Surveys were conducted between July 28 and August 8, 2019.

Ground surveys collected the most information and had the highest measurement precision of the three survey methods. All parameters listed in Table 3-1 were recorded. Field measurements generally followed methods in *Field Manual for Describing Terrestrial Ecosystems* (BC MFLNRORD and BC MOE 2010) with parameter specific details noted in Table 3-1. Photographs were taken of representative on-line and off-line plots.

Air surveys collected moderate resolution data on linear features. Air surveys efficiently collected a larger quantity of more generalized data than ground surveys. The subset of parameters recorded for aerial surveys is noted in Table 3-1. The survey methods generally followed procedures outlined for helicopter-based 'visual checks' in *Standard for Terrestrial Ecosystem Mapping in British Columbia* (Resources Inventory Committee 1998). Data were collected by hovering in a helicopter approximately 30 m over the sample sites for approximately three minutes while field crews recorded data for the reduced set of variables. Like ground surveys, relevant data were collected for both on-line and off-line plots. Photographs were taken at representative air survey plots (Attachment A).

Air calls collected data at the coarsest resolution of the three survey types, and no off-line data were collected. The data collected during air calls were limited to linear feature type, successional class, and burn status. Air calls were opportunistically conducted when EDI crews were flying through the RSA and linear features were encountered.

A fundamental aspect of the field study was to compare linear feature characteristics to adjacent undisturbed areas. Hence, field surveys included paired on-line and off-line plots at each sample site (excluding sites assessed via air calls). Off-line plots were located 50 m off the linear feature, with the direction off the feature selected randomly at each site using a coin toss. Data collected for each sample site were recorded on tailored survey forms (Attachment B).

3.2.2.3 Line-of-Sight and Ease of Travel

In addition to the structural and vegetation measures noted above, line-of-site and ease-of-movement were assessed as functional characteristics of the linear features at each ground plot. The sightline, measured to the nearest metre, was calculated as the farthest line that could be sighted using a range finder at the height of 1.5 m off the ground. Two measurements were recorded, one in each direction along the linear feature. Sightline measurements were repeated using the same bearings in the off-line plot.

Ease of travel was assessed using a 'walk test,' as Keim et al. (2019a) described in a study assessing the functional recovery of linear features. They found that ease of travel, as measured by a walk test conducted by human researchers, positively correlated with the intensity of use by several wildlife species. One EDI crew member timed themselves to the nearest second for the walk test while walking an approximately 75 m transect, measured to the nearest metre using a hip chain. This walk test was repeated in both the on-line and off-line plots, the paired transects spaced in parallel, approximately 50 m apart. The same observer conducted both walk tests to minimize observer bias at each site.

3.3 VISIBILITY OF LINEAR FEATURES FROM THE DEMPSTER HIGHWAY

One of the management concerns associated with seismic exploration is that seismic lines create travel routes that humans use. The probability of human use of seismic lines to access the surrounding landscape likely increases if the seismic line is visible and accessible from roads. The intersections of seismic lines and winter roads with the Dempster Highway are the primary locations where this could originate. Driving surveys were conducted along the 47 km section of the Dempster Highway within the RSA to determine the number and type of linear features that could be located and accessed by the public from the Dempster Highway. Two types of surveys were conducted: a blind search where the location of the linear features was unknown and a 'map search,' where the observers had a map of the linear features that showed where they occurred. Both surveys were conducted on August 8, 2019.

The blind search approximated the proportion and type of linear features that the public could locate and access without prior knowledge of their locations. An EDI field crew drove along Dempster Highway at 35 km/h and attempted to identify linear features by visual inspection alone, unaware of where they intersected the highway. When a linear feature was identified, the crew stopped to record the following parameters:

- linear feature type;
- sight line distance;
- evidence of human use;
- evidence of wildlife use; and
- potential for OHV passage.

Photographs were taken, and relevant comments were recorded for each linear feature intersection where applicable.

The map search was a targeted search designed to approximate the proportion and type of linear features the public could spot from the Dempster Highway with prior knowledge of their locations. Using a map of linear features present in the RSA, an EDI field crew drove along the Dempster Highway, slowing to 10 km/h and attempting to identify the linear features when passing a point where the map showed they intersected the highway. When a linear feature intersection was reached, the crew recorded whether the line was visible or not and the parameters listed above for the blind search where a line was detected.

3.4 WINTER TRACK SURVEY

An aerial survey was conducted to assess the relative frequency of use of different liner feature types by ungulates and humans in late winter (March 2020). The survey consisted of 11 transects spanning the width of the RSA. Three of the transects were established parallel to the Dempster Highway at 50 m, 1 km and 5 km off the highway. The remaining transects were spaced approximately 5 km apart across the remainder of the RSA.

Before the field survey, each transect was established in a GIS. Each intersection with a linear feature was given a unique identification point and used to generate a field form (i.e., with a row for each linear feature intersection). The field survey involved flying along each transect and recording the presence of ungulate tracks or human tracks (e.g., snowmobile tracks) at each linear feature that was traversed. Surveys were conducted via helicopter at approximately 70 km/h, 50 m above the ground, with one navigator/data recorder and one primary observer. The surveyors classified tracks to species and counted the number of unique tracks. However, overlapping tracks and dustings of new snow made track identification and counts uncertain in over half the detections. Therefore, analyses defaulted to the simple presence/absence of ungulate tracks. The primary metric examined was the proportion of linear features with ungulate tracks.

The original survey plan was also to count tracks in undisturbed areas between linear features. However, tracks were so numerous that surveying the entire area between linear features would have required substantially reducing the aircraft speed. This would have reduced the number of transects that could have been surveyed. As a compromise, field crews subsampled the area between lines by surveying an approximate 200 m band of an undisturbed area adjacent to each linear feature.

In conjunction with winter fish habitat assessments, the transects were surveyed over six days (March 7–13, 2020). Each day, one or two transects were surveyed while transiting to/from the study area. No track-erasing snowfalls occurred during the survey period. Snow depths ranged from 65 to 80 cm.

3.5 DATA PREPARATION AND ANALYSIS

3.5.1 SPATIAL DATA

The project generated two primary spatial datasets — a point database corresponding to all field survey sites and the linear feature database. The Linear Feature Survey Point Database (ArcGIS point feature class) contains all location-specific (point coordinate) field data collected at sample sites in summer 2019. Several fields were added to this database based on calculations and spatial joins (e.g., year of linear feature establishment and most recent fire). Paired on-line and off-line plot data were recorded as part of the same sample site coordinate.

The Linear Feature Inventory (ArcGIS polyline feature class) is a compilation of all documented linear features within the RSA, verified by comparing the preliminary linear feature inventory to aerial and satellite imagery and ground-truthing results.

Several modifications were made to improve the accuracy and detail of the Linear Feature Inventory:

- Linear features were classified into the following categories:
    - 2D (historical seismic lines, typically >3m wide),
    - 3D5 (including 4–5 m wide 3D lines that were used for both seismic and local vehicle/equipment travel);
    - 3Dc (3 m wide 3D seismic conductor lines);
    - 3Dr (2 m wide 3D seismic receiver lines);
    - winter roads (any trails or limited use roads used by vehicle or equipment, generally wider than 5 m and often with an obviously curving path); and,
    - Dempster Highway.
- Overlapping features (within a 3 m tolerance) were addressed according to the following rules:

- If two linear features of the same or unknown age overlapped, the wider feature was saved and the narrower feature deleted.
- If two linear features of the same or unknown width overlapped, the more recent feature was saved and the older feature deleted.
- If a 3D line overlapped with a 2D line, both lines were saved. This is because the older 2D lines were often still evident on the landscape in some state of regeneration, as were the 3D lines. However, both were saved since it was unknown at what state each line was in (i.e., if the 2D line was still evident, or only the 3D line, or both in varying states of regeneration). This occurred for 33 km of linear features within the RSA.

The preliminary linear feature inventory within the RSA was compared against a recent high-resolution satellite or aerial imagery (generally, 0.5–1 m resolution) at a 1:10,000 (or finer) scale to verify the accuracy of the source data. Any features that were visibly offset from georeferenced imagery were corrected to match the imagery.

Some older (1960s and 1970s) 2D seismic lines included in the source databases did not appear in satellite imagery. These 2D lines were compared against the imagery along the length of the feature to search for any sign of linear disturbance and then cross-referenced with field surveys conducted along the line, if present. These unverified linear features were classified as 'not applicable' and excluded from analysis if there was no evidence of linear disturbance along the feature's length in the imagery, which could often be verified with associated surveys noting that the feature was 'not present,' 'not visible,' or 'completely regenerated.' Unverified linear features were retained if there was evidence of linear disturbance along any feature's length in the imagery or if associated surveys had noted that the feature was present and in some state of regeneration, even if the feature was not visible in the imagery. A total of 199,473 m of erroneous or regenerated linear features were deleted from the linear feature inventory within the RSA.

Some linear features were visible on the imagery that had not been included in any of the source databases. In these cases, the linear features were manually digitized and classified into linear feature types based on visual assessment and attributes of adjacent connecting features, if present. Digitized linear features were assigned a year if they were obviously a continuation of a documented feature or if they were surrounded by features of the same type and year. Otherwise, the year was not included. High-resolution imagery was not available for the southernmost portion of the RSA (approximately 25 km by 15 km). This area was compared against lower quality Google Earth imagery, but this was not detailed enough to detect undocumented linear features if any existed (Google Earth 2019). However, existing linear features were verified using this method. A total of 202,945 m of linear features were digitized within the RSA.

After the Linear Feature Inventory was verified and corrected to be consistent with imagery and field observations, it was spatially joined to the Linear Feature Survey Point Database. In cases where the survey point did not correspond with any nearby linear feature, or if a linear feature was deleted (following the methods described above), the data were retained in the survey point database, but the linear feature type was updated to 'not applicable' and excluded from data analysis. Ten survey plots were identified as 'not applicable' and excluded from analyses; thus, the corrected sample size for survey plots is n = 210.

3.5.2 FIELD DATA

After completing field sampling, data forms and field notes were reviewed for completeness and accuracy during an internal data quality-assurance process. All associated digital photographs and GPS coordinates were reviewed to correspond to the appropriate field plots. A summary of field plots by linear feature type and survey type is provided in Table 3-4. All recorded data were entered into MS Excel databases (Microsoft 2019). Spatial data were uploaded to the ArcGIS platform (ESRI 2019).

Field-collected data were summarized primarily using Excel spreadsheets (Microsoft 2019). More detailed statistical analyses were performed on select data using R Statistical Software (R Development Core Team 2020). For example, the variation in ease of travel and vegetation cover as a function of linear feature types, burn history, successional stage, or ecosite were explored. During formal analyses, standard assumptions of normality and homogeneity of variance were assessed, and variance-covariance structures were applied to model heterogeneity (of residuals) if required. For instance, the sightline distance (m) was fourth-root transformed to meet normality. In certain models, random effects were included to account for variance among different subjects. For example, observers were included as a random variable to account for observer bias (i.e., a random intercept model; package "nlme", Pinheiro et al. 2016). Corrected Akaike's Information Criteria (AICc) scores were used to compare sets of candidate models. Models with the lowest AICc score were selected because they yielded the best balance (parsimony) between explained variance and level of complexity.

Table 3-4. The number of sites surveyed using ground surveys, air surveys, and air calls for each linear feature type in the Eagle Plains RSA.

Linear Feature Type	Survey Type			
	Ground Survey	Air Survey	Air Call	Total
2D	31	32	44	107
3D-5m wide	5	0	0	5
3D-Conductor	26	3	0	29
3D-Receiver	23	1	0	24
Winter Road	18	17	8	43
Dempster Highway	2	0	0	2
Not Applicable	3	2	5	10
Total	108	55	57	220

3.5.3 LINEAR FEATURE DENSITY CALCULATION

Linear feature densities were calculated in two ways: (1) using the total linear feature extents, and (2) adjusting the extents to account for (a) lines through 'open' habitats, such as wetlands and recent burns, where the vegetation on the line did not differ from vegetation off the line, and (b) functionally recovered linear features such as 2D lines from the 1960s and 1970s that had advanced regenerated at least to the Tall Shrub structural stage. Adjustments were determined by intersecting the Linear Feature Inventory with a recently developed

Ecological Landscape Classification (ELC) map of the RSA (a companion Eagle Plains Project baseline report). The ELC map documented the type and structural stage of vegetation communities across the RSA. The extent of linear features in open habitats was determined by the lengths of linear features overlapping Low Shrub, Herb and Bryoid structural stages in the ELC maps. This includes seral habitats regenerating from burns and ecosystems that are maintained in those stages over time, such as wetlands and shrub-carrs. The extent of regenerated linear features was determined by integrating the proportion of regenerated lines observed from the field surveys (e.g., 61% for 2D lines) with the length of lines through non-open vegetation types in the ELC map. Adjustments were applied to generate functional linear feature densities for each linear feature type individually (i.e., to compare the relative extents of different feature types) and combined to provide an overall density for all linear feature types. For example, the linear feature density for 2D lines was calculated by starting with the total length of 2D lines in the RSA, reducing that by the length of lines through open vegetation types, then reducing the remaining extent by the average proportion of 2D lines that were observed to be regenerated, and then dividing the remaining total length of lines by the extent of the RSA.

4 RESULTS

4.1 LINEAR FEATURE INVENTORY AND DENSITIES

A total of 4,269 km of linear features were mapped and verified in the RSA (Map 4-1, Table 4-1). Winter roads and 2D seismic occur in varying densities across much of the RSA. The extent of 3D seismic is limited to the one area straddling the Dempster Highway in the centre of the RSA.

The total linear feature density in the RSA was 1.79 km/km², based on a total length of 4,269 km and the RSA area of 2,386 km². 3D seismic lines accounted for approximately half of the total length of linear features in the RSA, 2D seismic lines accounted for about one-third, followed by winter roads and the Dempster Highway (Table 4-1). Adjusting for open habitats (i.e., areas in structural stages Low Shrub, Herb, and Bryoid) and vegetation regeneration[1] resulted in substantially lower densities of 0.52 km/km² (Table 4-2). Relatively large extents of recent wildfires were the greatest factor reducing linear feature densities. The relative proportions of the different linear feature types were similar after adjustments, though the proportion of 3D increased and 2D decreased. This was mainly due to the greater degree of vegetation regeneration on 2D lines, consistent with their age since disturbance.

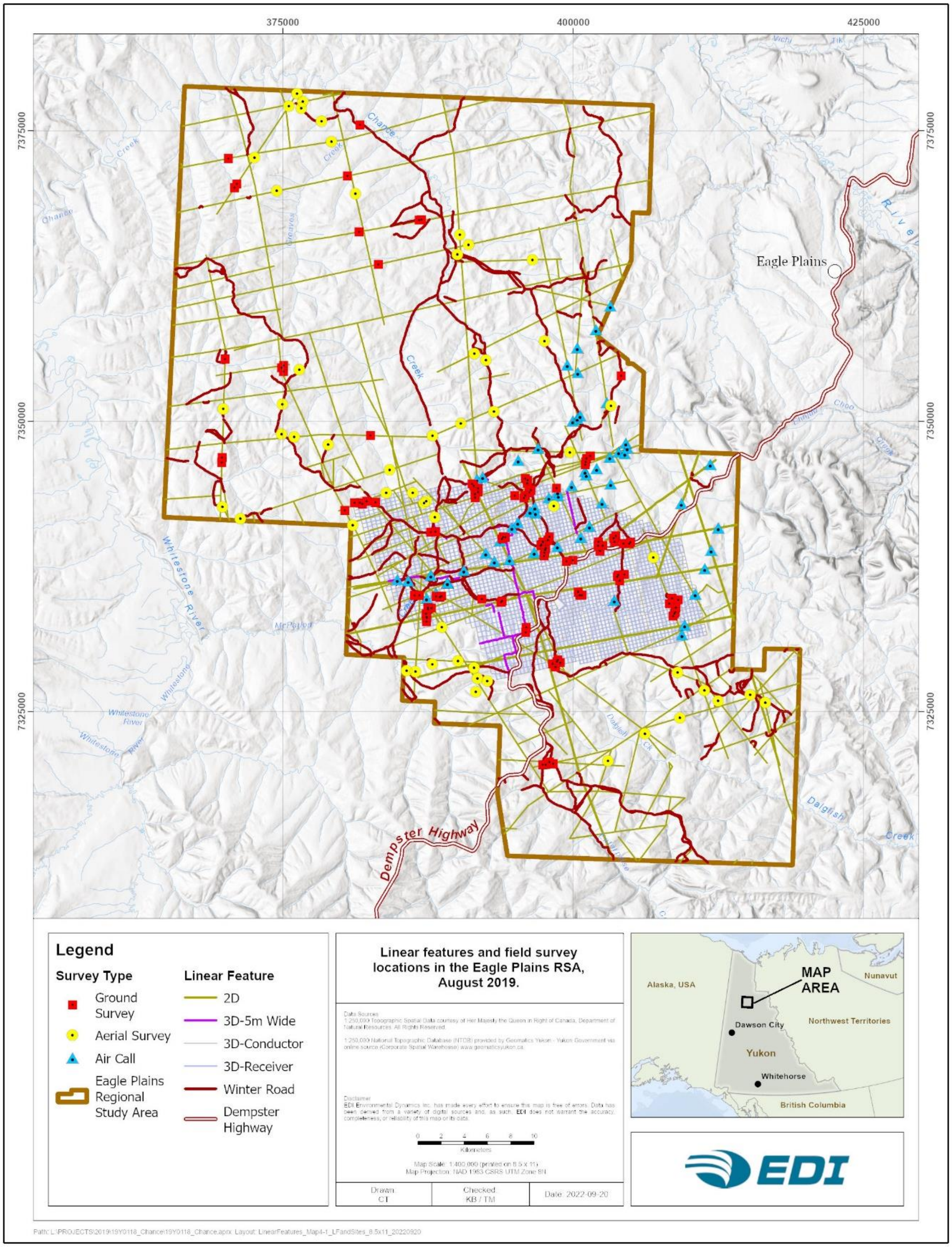
Table 4-1. Summary of total length and density of linear features documented in the Eagle Plains RSA.

Linear Feature Type	Total Length (km)	The Proportion of Total Length	Linear Feature Density (km/km²)
2D	1,452	34%	0.608
3D (combined)	2,165	51%	0.907
3D-5m wide	48	1%	0.020
3D-Conductor	1,189	28%	0.498
3D-Receiver	928	22%	0.389
Winter Road	596	14%	0.250
Dempster Highway	47	1%	0.020
Unknown	8	<1%	0.003
Total	**4,269**	**100%**	**1.788**

[1] See Section 5.5 Functional Recovery of Linear Features for details about vegetation regeneration criteria.

Table 4-2. Summary of total effective length and density of linear features in the Eagle Plains RSA adjusted for open habitat and vegetation regeneration.

Linear Feature Type	Total Length (km)	Proportion of Total Length	Linear Feature Density (km/km²)
2D	289	23%	0.121
3D (combined)	750	60%	0.314
3D-5m wide	21	<1%	0.009
3D-Conductor	401	32%	0.168
3D-Receiver	328	26%	0.138
Winter Road	171	14%	0.072
Dempster Highway	26	<1%	0.011
Unknown	8	<1%	0.003
Total	1,243	100%	0.521



Map 4-1. Linear features and field survey locations in the Eagle Plains RSA, August 2019.

4.2 LINEAR FEATURE CHARACTERISTICS

4.2.1 LINE WIDTHS

Line width varied by linear feature type. Mean line widths ranged from 1.96 m for the narrowest line type (3D receiver lines) to 33.75 m for the Dempster Highway (Table 4-3). Standard error around mean estimates were smallest for 3D seismic lines, which were cleared in the same season using the same equipment and methods, and greatest (by a large margin) for winter roads. The average difference in widths between 3D conductor (wider) and 3D receiver lines was 1.2 m.

Table 4-3. Widths of different linear feature types in the Eagle Plains RSA.

Linear Feature Type	n	Minimum mean width (m)	Maximum mean width (m)	Overall mean width (m)	Standard Error (m)
2D	107	3.97	8.5	5.42	0.11
3D-5m wide	5	5.30	6.40	5.68	0.22
3D-Conductor	29	2.50	4.80	3.17	0.13
3D-Receiver	24	1.63	2.53	1.96	0.04
Winter Road	43	2.53	17.97	7.42	0.66
Dempster Highway	2	33.00	34.50	33.75	0.75

4.2.2 MULCH COVER

Mulching of woody vegetation is common during seismic line clearing activities and was used in the 2013/14 3D program. In areas with thick tree or shrub cover, mulching can create a thick blanket of wood chips that inhibits vegetation regeneration (Golder Associates 2016). There was no evidence that this was an issue with any of the seismic lines within the RSA. On average, the percent cover of mulch was <1% on all line types.

4.2.3 HUMAN USE

No sign of human use was detected along linear features during the summer ground surveys (e.g., OHV tracks, ruts, water crossings, vegetation trampling/scarring, tree blazes, trap sets, garbage, and campsites), except for the two sites on the Dempster Highway.

On average, 42% of on-line sites were deemed passable to an OHV (a 4x4 side-by-side) during summer, considering obstructing vegetation, ground conditions (e.g., wetlands or peatlands), and the presence of graminoid tussocks (Table 4-4).

Table 4-4. Proportion of survey sites deemed passable to OHV in summer across different linear feature types in the Eagle Plains RSA.

Linear Feature Type	No. Survey Sites	% Passable
2D	55	9%
3D-5m wide	5	80%
3D-Conductor	29	59%
3D-Receiver	24	75%
Winter Road	29	55%
Dempster Highway	2	100%
Total	144	42%

4.2.4 SUCCESSIONAL CLASSES

Linear features surveys in the Eagle Plains RSA observed five of the six of the successional classes documented by Simpson (2008): normal succession, magnified succession, stagnated succession, no succession, and recent disturbance (Figure 4-1) (Attachment A). No retrogressive succession sites were observed at official survey sites. However, a small number of retrogressive sites were incidentally observed on winter roads while travelling through the RSA.

Most sites surveyed (79%) were undergoing normal succession. The next most common successional class was magnified succession, occurring in 11% of sites, followed by stagnated succession, occurring in 5% of sites. All 3D seismic lines surveyed followed a normal successional trajectory, except for one site that was classed as recently disturbed. Magnified succession was most common in 2D seismic lines (21%), while stagnated succession was most common in winter roads (19%). Successional classes were defined as 'not present' if the linear feature was not present in the field or had regenerated to a stage that was not discernable from the adjacent areas. The Dempster Highway was classified as recently disturbed due to the regular maintenance of the road.

Fire history appeared to influence some successional classes. Magnified succession was more common at burnt sites (19 burnt versus 5 unburnt). In contrast, stagnated succession was more common at unburnt sites (3 burnt versus 7 unburnt). Sites on a normal successional trajectory did not appear to have any relationship to burnt status. The remaining successional classes were too uncommon to draw any conclusions.

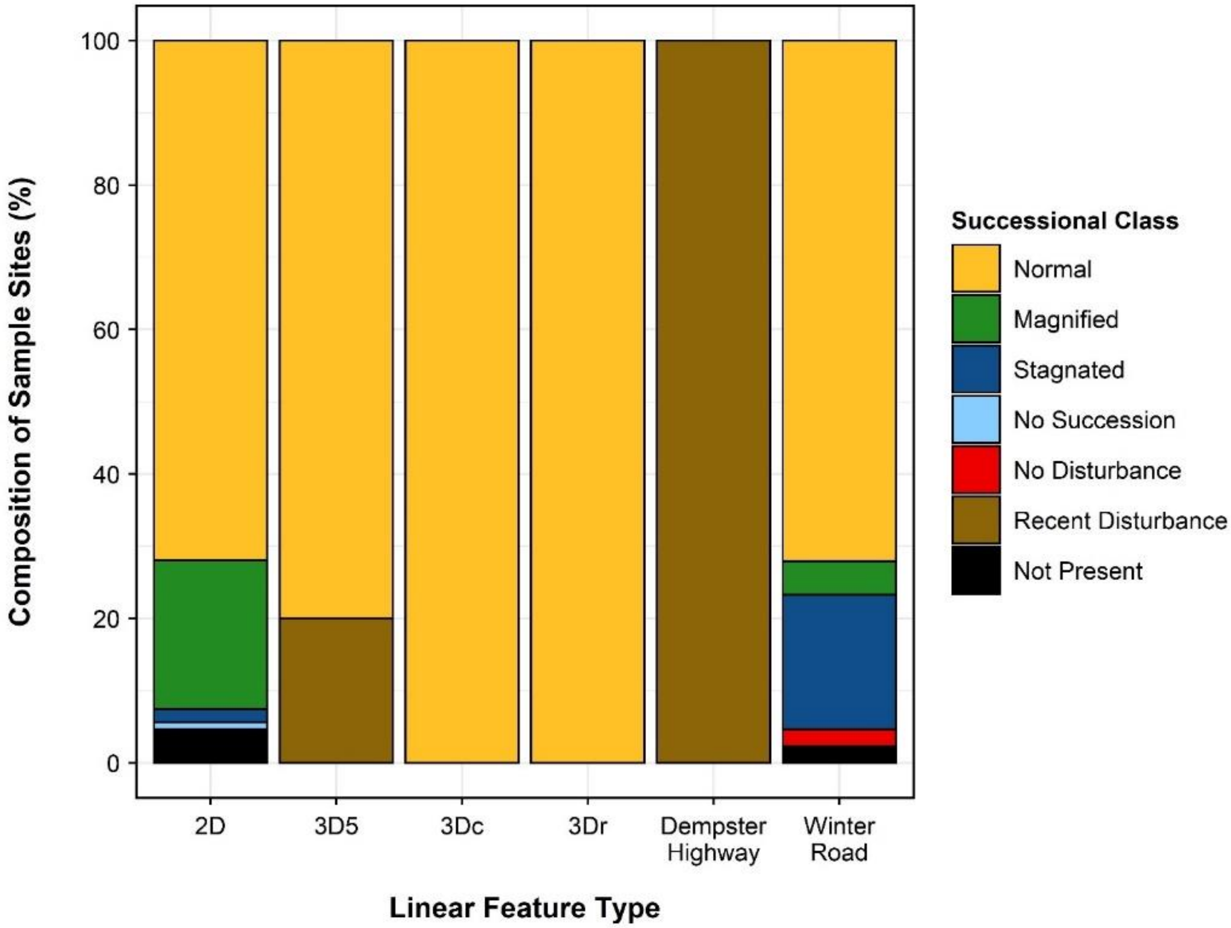


Figure 4-1. Summary of successional classes observed across different linear feature types in the Eagle Plains RSA.

4.2.5 STRUCTURAL STAGE

Most linear features were in a Low Shrub (56.1%) or Tall Shrub (29.0%) structural stage. However, the distribution of structural stages varied substantially across linear feature types (Table 4-5). Although herbaceous and forested stages occurred at some on-line plots, they were not common (less than 5%each). Nearly all forested structural stages were observed on 2D seismic lines and winter roads, reflecting the long time since they were created. Tall Shrub stages were almost twice as frequent in 2D seismic lines than any other linear feature type. Conversely, 83% of 3D linear features were in the Low Shrub structural stage, with most of the remaining in the Tall Shrub stage. The differences in structural stages between 2D and 3D lines appear to be primarily due to the time since disturbance. Winter roads were less consistent in their structural stages; herbaceous, shrubland and forested stages were all observed with moderate frequency. The two Dempster Highway plots were the only non-vegetated stages recorded.

Off-line plots were also mostly in Low Shrub and Tall Shrub stage, but they also included a higher proportion of Young Forest and Mature Forest compared to on-line plots (Table 4-5; Photos A-15 to A-20 in

Attachment A). For off-line plots, the Low Shrub sites were mostly burned areas, and the Tall Shrub sites were mostly stunted, open-canopy, black spruce forest 2–8 m tall.

Fire had a strong effect when comparing structural stages between paired on-line and off-line plots (Figure 4-2). The top two charts in Figure 4-2 show that the pattern of structural stages for burnt areas was very similar between on-line and offline plots. The bottom two charts show that the pattern of structural stages differs substantially between on-line and offline plots in unburnt areas. In unburnt areas, off-line plots had much lower numbers of sites in Low Shrub and much higher numbers of sites in Young Forest and Mature Forest than on-line plots. For burnt areas, the on-line and off-line plots at the same site were the same structural stage in 72% of cases, and within one structural stage of each other 91% of the time (e.g., Tall Shrub vs Pole Sapling). For areas that were not burnt, the on-line and off-line plots at the same site were the same structural stage in only 29% of cases. These results demonstrate that in the absence of fire, pronounced differences between linear disturbances and the surrounding community are evident in both recent (3D) and legacy (2D and winter road) linear feature types. But following a fire, the vegetation structure on-line and off-line are likely to be similar (Photos A-22 to A-24 in Attachment A).

Table 4-5. Vegetation structural stages observed on different linear feature types as a proportion of all plots sampled (n = 156) in the Eagle Plains RSA.

Linear Feature Type	No. Sites	Structural Stage[1]								
		Non-vegetated	Bryoid	Herb	Low Shrub	Tall Shrub	Pole-Sapling	Young forest	Mature forest	Old Forest
2D	62	0%	0%	2%	37%	47%	2%	8%	3%	2%
3D-5m wide	5	0%	0%	20%	80%	0%	0%	0%	0%	0%
3D-Conductor	29	0%	0%	0%	83%	14%	0%	3%	0%	0%
3D-Reciever	24	0%	4%	0%	83%	13%	0%	0%	0%	0%
Dempster Highway	2	100%	0%	0%	0%	0%	0%	0%	0%	0%
Winter Road	33	0%	0%	12%	48%	27%	3%	3%	6%	0%
Off-line	155	0%	1%	1%	33%	29%	1%	18%	17%	1%

[1] See Table 3-3 for structural stage codes and descriptions.

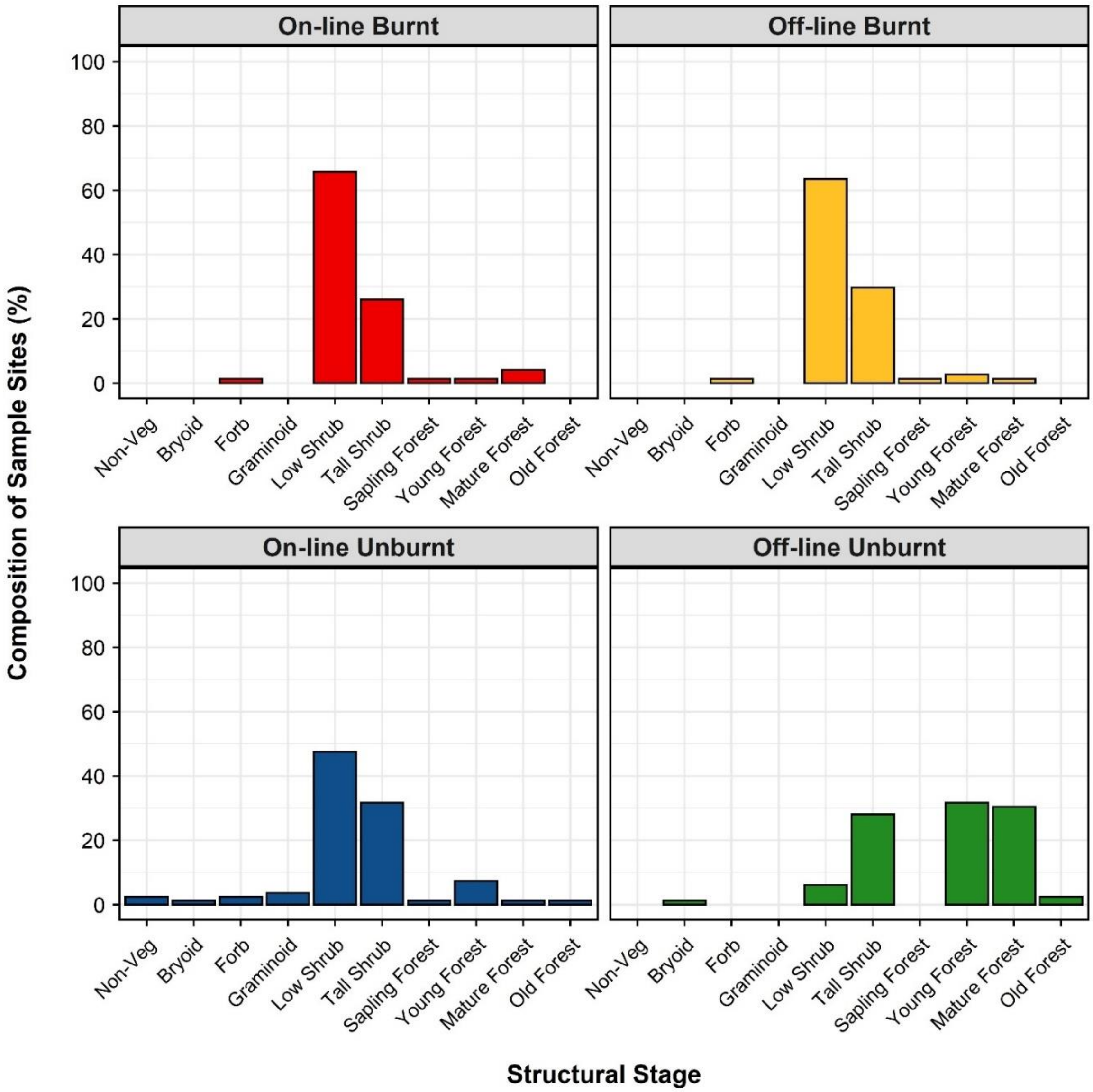


Figure 4-2. Comparison of structural stages on linear features to off-line plots in burnt and unburnt areas, in the Eagle Plains RSA.

4.2.6 VEGETATION HEIGHT

Based on the similarity of patterns in vegetation composition and structure, linear feature types were combined into two groups for assessment of patterns in height: (i) 2D and winter roads and (ii) 3D. A wide range of vegetation heights was recorded at both on-line and off-line plots in the RSA, from 0.3 m to 16 m. Collectively, off-line plots had a normal distribution of vegetation heights between 0 m and 4 m, and then a scattered distribution across heights up to 16 m (Figure 4-3). Plots with ≥4 m tall vegetation accounted for approximately 40% of all off-line reference plots.

In comparison, recovering 2D seismic lines and winter roads shared a relatively uniform distribution between 0 m and 4 m but with a peak occurring at vegetation heights measuring 1.5–2 m tall (Figure 4-4). Only 21% of 2D and winter roads contained dominant vegetation ≥4 m, and only 5% were ≥8 m tall. 3D seismic lines were rarely composed of vegetation ≥2 m, and most of the vegetation (67%) recovering on 3D lines was less than 1 m (Figure 4-5). This is very different from the off-line undisturbed height distribution. However, 3D lines were all only five years old at sampling, and shorter vegetation was expected.

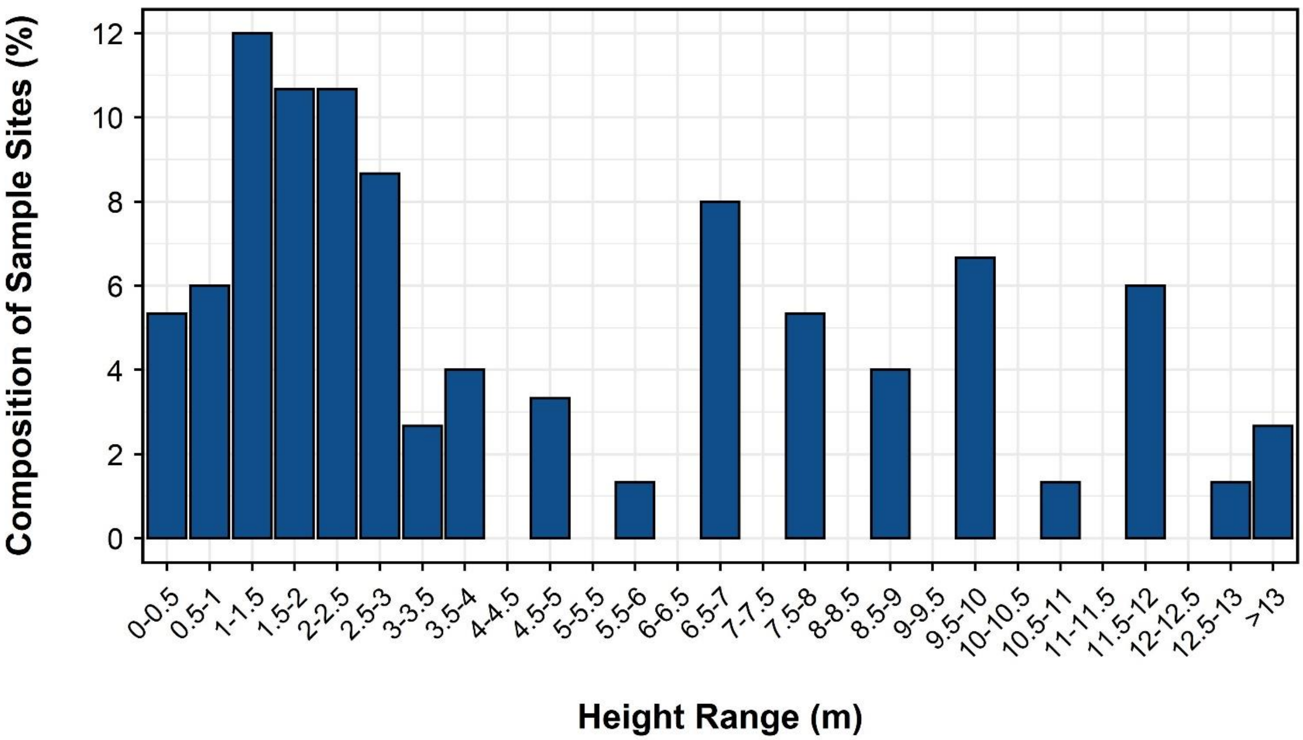


Figure 4-3. Vegetation height distribution of off-line reference plots in the Eagle Plains RSA.

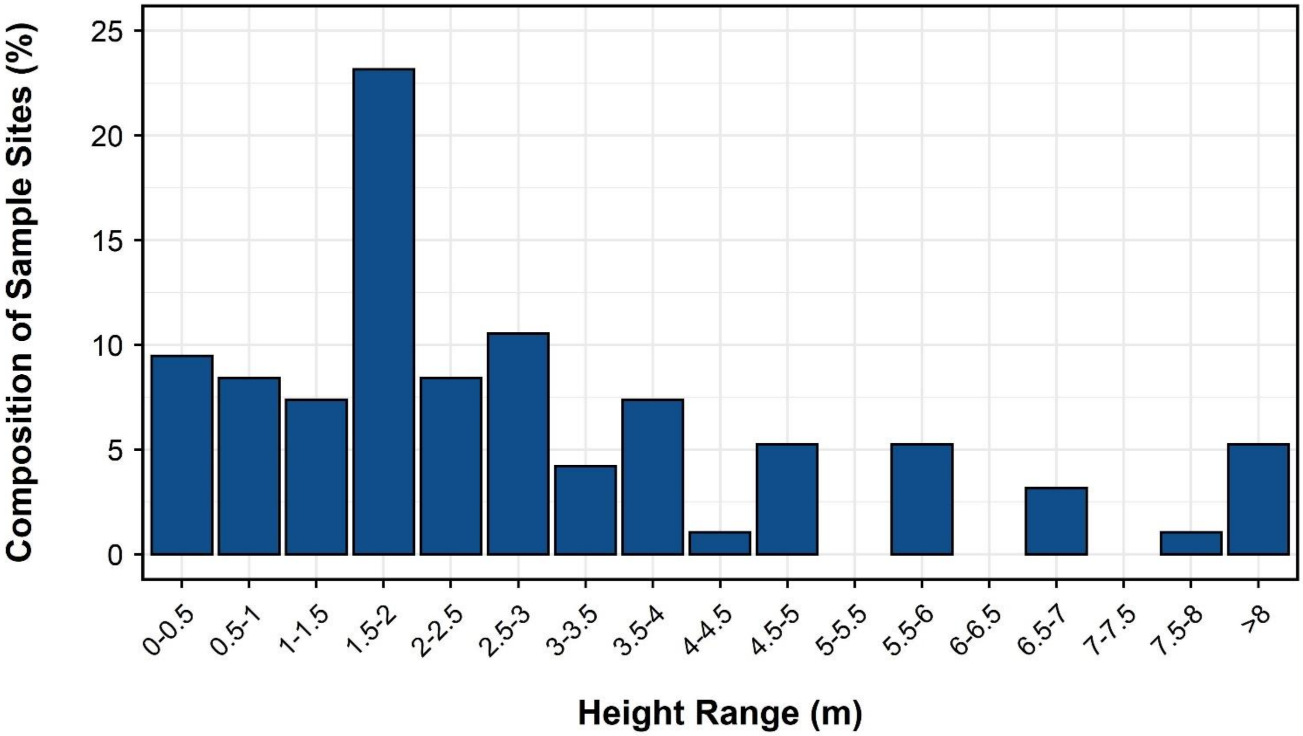


Figure 4-4. Vegetation height distribution of on-line 2D and winter road plots in the Eagle Plains RSA.

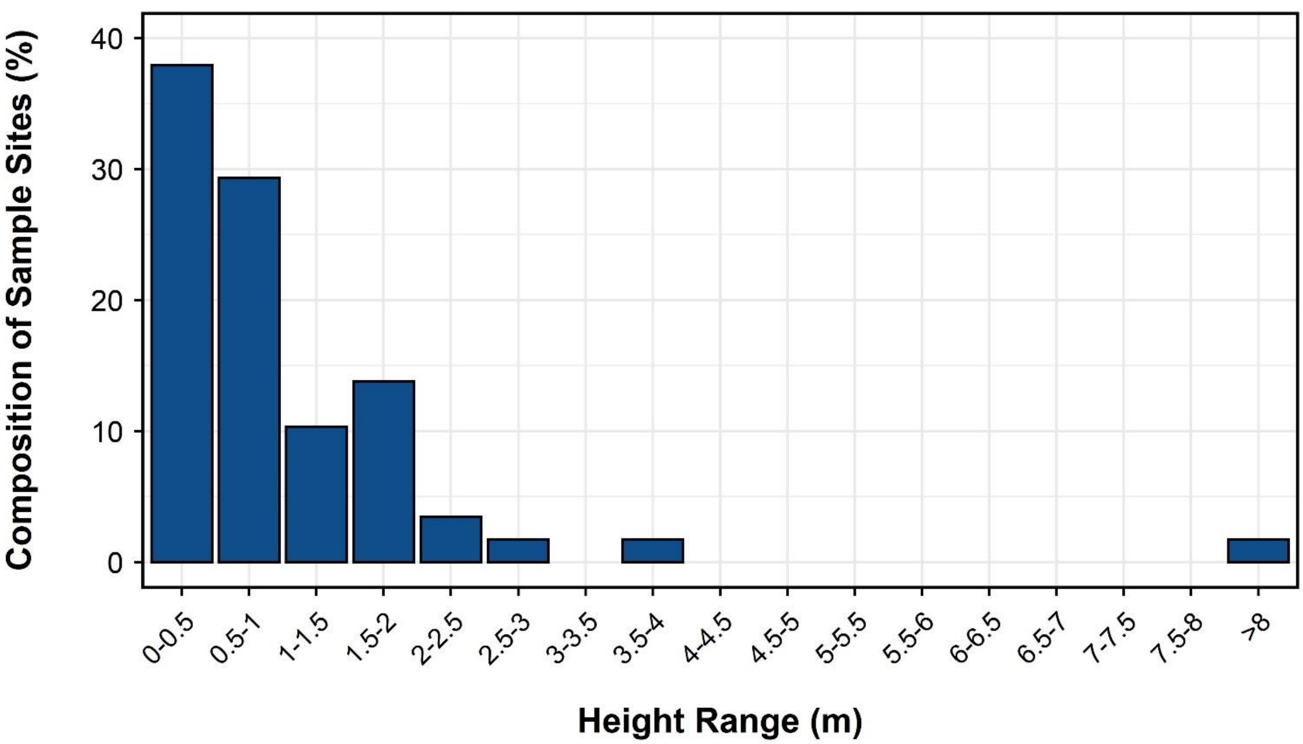


Figure 4-5. Vegetation height distribution of on-line 3D plots in the Eagle Plains RSA.

4.2.7 VEGETATION COVER

Tree and shrub cover varied between linear feature types and burn status (Table 4-6). Generally, tree cover was low on undisturbed reference plots (mean tree cover of 8% on unburnt and 2% on burnt sites). This is typical of the taiga cordillera landscape — forests are generally stunted and sparse due to poor nutrient regime and continuous permafrost conditions (Smith et al. 2004). Of the on-line plots, tree cover was greatest on 2D seismic lines and burnt winter roads (5% to 8%) and lowest on 3D seismic lines and the Dempster Highway (0%), regardless of burn status. This is likely due to the recently disturbed 3D seismic lines that are too young for trees to have re-established. Burnt 2D seismic lines and winter roads had greater tree cover than unburnt lines.

Shrub cover was much greater than tree cover overall. Shrub cover was typically 30–40% on unburnt off-line plots and 40–50% on burnt off-line plots. Shrub cover was highest on 2D seismic lines (~54%), regardless of burn status. Shrub cover was moderate on winter roads (38–45%) and lowest on unburnt 3D seismic lines (8–22%). Burnt 3D seismic lines had approximately twice as much shrub cover as unburnt 3D lines.

Table 4-6. Summary of the mean tree and shrub cover (%) between on-line and off-line, and burnt and unburnt plots surveyed in the Eagle Plains RSA.

Linear Feature Type	Burn Status	Mean Tree Cover (%)		Mean Shrub Cover (%)	
		On-line	Off-line	On-line	Off-line
2D	Burnt	7.0	3.5	54.0	36.0
	Unburnt	5.5	13.4	53.2	32.8
3D5	Burnt	0.0	0.3	41.7	60.0
	Unburnt	0.0	0.5	7.5	42.5
3Dc	Burnt	0.0	0.2	40.4	46.1
	Unburnt	0.4	6.0	21.5	34.3
3Dr	Burnt	0.0	0.7	35.0	51.9
	Unburnt	0.0	5.5	20.6	32.5
Winter Road	Burnt	7.7	1.0	45.0	43.8
	Unburnt	1.3	4.0	37.5	32.3
Dempster Highway	Unburnt	0.0	1.0	0.0	37.5

4.2.8 LINE-OF-SIGHT AND EASE OF TRAVEL

Line-of-sight (sightline) distance was examined primarily as a function of line type; however, vegetation height (the primary factor affecting sightlines) was also examined for on-line and off-line plots for each linear feature type using multiple linear regression. Mean sightlines varied significantly by linear feature type (Table 4-7, $F_{4,187} = 3.3$, $P = 0.01$). For reference, the average sightline distance for offline controls was 46.7 m. This relatively far distance reflects the open stand structure on most sites in the region. Burn status had little influence on sightlines (e.g., burnt off-line=50.2 m, unburnt offline=43.6 m). 2D lines had the shortest average sightline distances at 41.2 m. This was mainly due to the advanced stage of regenerating vegetation on the lines. Where regenerating vegetation was limited, sightline distances on 2D lines frequently exceeded 150 m.

On 3D lines, the time since clearing was too recent for regenerating vegetation to obscure sightlines. Instead, sightline distances on 3D lines were generally controlled by bends in the lines, which were specifically designed as mitigation measures to reduce sightlines. For 3D lines, sightline distances decreased from 3D5 to 3Dc to 3Dr lines. The reduction in sightline distances resulted from differences in line width and the average distance between bends across the feature types.

The regression analysis also found a significant interaction between on-line versus off-line occurrence and vegetation height ($F_{1,187}$ = 13.0, P = 0.0004), whereby on-line plots had, on average, more negative slopes than off-line plots. In other words, sightlines at on-line plots decreased more drastically than off-line plots with each incremental increase in vegetation height. This is consistent with the qualitative observations of field crews that the regenerating vegetation on lines was thicker than the vegetation off lines.

Similar to sightline distances, determining differences in ease of travel among line type the primary factor of interest for the walking speed tests. However, burn status, and the percent cover of trees and shrubs were expected to be the most important explanatory variables related to walk speeds, so they were included as secondary variables using a mixed-effects linear regression. Walking speeds across linear feature types and the differences between on- and off-line plots within linear feature types varied significantly (Table 4-8, $F_{5,170}$ = 3.4, P = 0.006). However, the magnitude of the difference between on-line and off-line plots was modest. Even the Dempster Highway only conveyed a 35% increase in walking speed over off-line plots. Other researchers, in other areas, often observed walk speeds on linear features were often at least twice as fast as off-line transects (Keim et al. 2019a).

Notwithstanding the modest magnitude of faster walking speeds on-lines, there were clear patterns in walking speed differences across linear feature types. 2D lines were the one feature type where walking speeds were slower on lines than off lines. This reflected the thick, shrub stage vegetation that had regenerated on most 2D lines, which impeded travel (similar to the effect that regenerating vegetation had on sightline distances in the previous section). Walk speeds decreased across the other feature types in relation to line width and the degree to which ground cover was levelled or compacted.

Statistical analyses indicated that both burn status ($F_{1,170}$ = 17.85, P < 0.0001) and percent cover of shrubs and trees (hereafter woody vegetation; $F_{5,170}$ = 5.29, P = 0.0002) affected walking speeds, both on and off lines. On average, walk speeds in burns were approximately 10% slower than in unburnt areas. This is partly related to thicker woody cover in most burns, which hinders walking speed because of the time it takes to push through or walk around it. Walking speeds significantly decreased, on average, by 0.04 (CI = 0.02–0.06) km/h and with every 10% increase in the percent of woody cover off-line and 0. 11 (0.07–0. 15) km/h on 2D lines.

Table 4-7. Average sightline distances along different linear feature types in the Eagle Plains RSA.

Linear Feature Type	n	Average Sightline Distance (m)	Comments
2D	30	41.2	Sightlines are frequently reduced by regenerating vegetation >1.5m tall
3D-5m	5	105.6	Has fewer bends than 3Dc and 3Dr
3D-Conductor	26	75.9	Sightlines limited by bends in lines; too recent for regenerating vegetation to impede sightlines
3D-Receiver	23	60.2	Sightlines limited by bends in lines; too recent for regenerating vegetation to impede sightlines
Dempster Highway	2	814.8	
Winter Road	17	106.2	
Off-Line Controls	103	46.7	

Table 4-8. Differences in walking speeds among linear feature types in the Eagle Plains RSA.

Linear Feature Type	n	Average Walk Speeds (km/h)		Difference (%)
		On-line	Off-line	
2D	28	2.5	2.8	-10%
3D5	5	3.8	3.0	30%
3Dc	23	3.5	3.1	13%
3Dr	23	3.2	2.9	10%
Dempster Highway	2	5.6	4.1	35%
Winter Road	16	3.6	3.1	17%
Off-Line Controls	97	n/a	2.9	

4.3 VISIBILITY OF LINEAR FEATURES FROM THE DEMPSTER HIGHWAY

Overall, the blind search identified 11 of 100 possible linear feature intersections with the Dempster Highway (Table 4-9). Five of the features were roads that were classified as winter roads in the GIS inventory, but most (four) were actually short, all-season roads leading to gravel pits or well sites. Two of the observed features were human truck/OHV trails that led to camp sites 100–200 m off the Dempster Highway, and four were 3D seismic lines. The map search detected two more 3D lines, one 2D line, and one old winter road. The 2D line and the old winter road had regenerated into Young Forest structural stages. Excluding the four short secondary roads into gravel pits and well sites, and the two human trails, only 8% of linear features that intersected the Dempster Highway were visible during the two driving surveys.

Only 6 of the 74 3D lines that crossed the Dempster were detected. The combination of construction design (i.e., creating a bend in the 3D line adjacent to the highway) and regenerating vegetation in the right-of-way made it difficult to detect the 3D lines. Evidence of human use (e.g., packed vegetation, tire tracks, rutting, garbage, campfire remnants, tree stumps, or tree blazes) was observed on four of the short, all-season roads and the two trails. No evidence of human use was noted on any of the 2D or 3D seismic lines, or the three winter roads (including the Chance and Blackie winter roads). However, some types of human use do not leave sign during the snow-free season (e.g., snowmobile use in the winter).

Table 4-9. Summary of linear features identified and intersecting the Dempster Highway during a blind search test.

Linear Feature Type	No. Features Intersecting the Dempster	No. (%) Observed Blind Search	No. (%) Observed Map Search	Total No. (%) Observed	OHV Accessible	Sign of Human Use
2D	18	0 (0%)	1 (6%)	1 (6%)	0	0
3D	74	4 (5%)	2 (5%)	6 (8%)	4	0
Secondary Roads	8	5 (63%)	1 (13%)	6 (75%)	5	4
Trail	n/a	2 (n/a)		2	2	2
Total	100	11 (11%)	4 (4%)	15 (15%)	11	6

4.4 WINTER TRACKS

In total, 462 linear features were surveyed for winter tracks over 358 km along the 11 transects. No human sign was observed on any linear features, except the Dempster Highway. Ungulate tracks were frequently observed travelling along linear features. The proportion of linear features with tracks decreased with decreasing linear feature widths, from 29% on winter roads, 24% on 2D lines, 8% on 3D conductor lines, and 6% on 3D receiver lines (Figure 4-6).

The frequency of use in adjacent undisturbed areas, corrected to account for different survey extents between the linear features and the undisturbed areas, was 1%. As discussed in the methods, it was difficult to compare the frequency of use along linear features to use in undisturbed areas. The issue is that for the comparison to be relevant, the survey design needs to account for the size of the sample units (i.e., the extent of the undisturbed area needs to be comparable to the width of the linear features), and the two samples should be independent. These conditions were not achieved under the current survey design (i.e., the extent of the survey area in the undisturbed area was much larger than the width of the linear feature, and the location of the undisturbed area was spatially correlated to the linear feature). The estimated relative use rate of 1% in undisturbed areas adjusts the total counts within the 200 m survey area to 5 m (i.e., the average linear feature width); however, the adjustment fails to account for spatial correlation between the two samples. Therefore, the estimate of use in undisturbed areas could be biased. Notwithstanding this limitation in the estimate of travel rates in undisturbed areas, it is supported by qualitative observations of the survey crew that travel rates on even the least used linear features (i.e., 3D lines) are higher than undisturbed areas.

The relative use of linear features by ungulates also appeared to vary with distance from the Dempster Highway, with features within 1 km of the highway receiving lower use than features equal to or greater than 5 km from the highway (Figure 4-7). It is worth noting that the Highway and 1 km transects were completed on the first and second day of surveys, respectively, and the other transects were surveyed one to six days later, providing more time for tracks to accumulate. Snowfall data prior to the crew's arrival on site was not available; however, road crews at Eagle Plains reported that there had not been a major snowfall in the area for at least a week. Based on this information, the issue of time since last snow has less potential to bias results than if a track-erasing snow event had recently occurred.

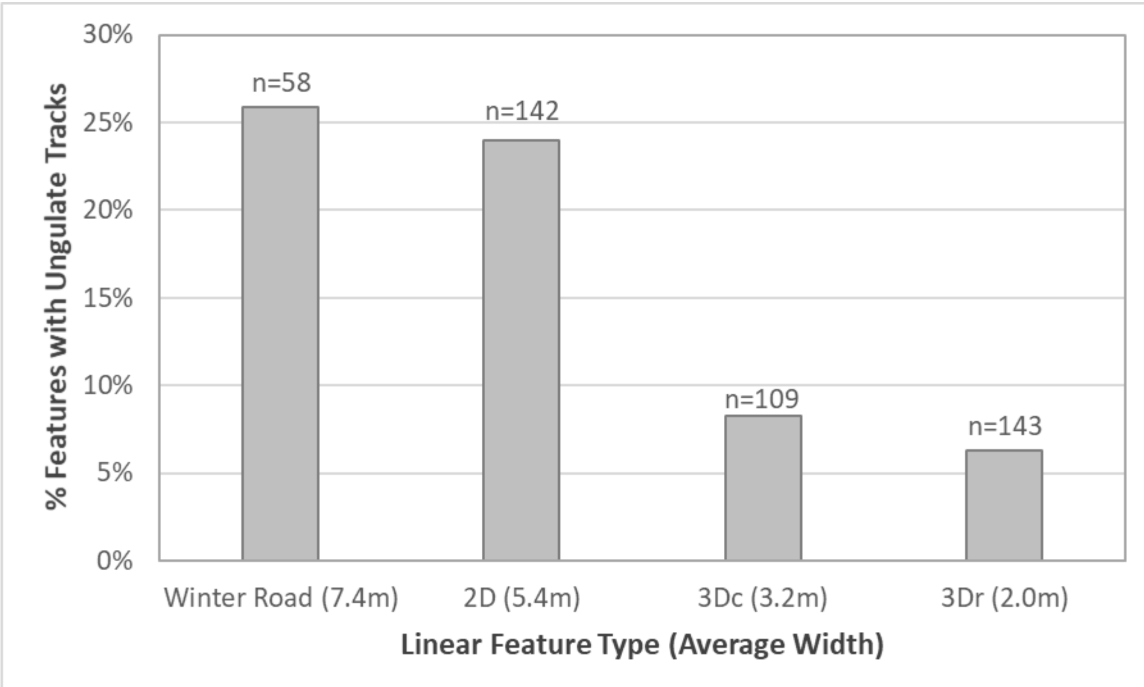


Figure 4-6. Relative use of different linear feature types by ungulates in the Eagle Plains RSA, March 2020.
The numbers above bars indicate the number of features surveyed.

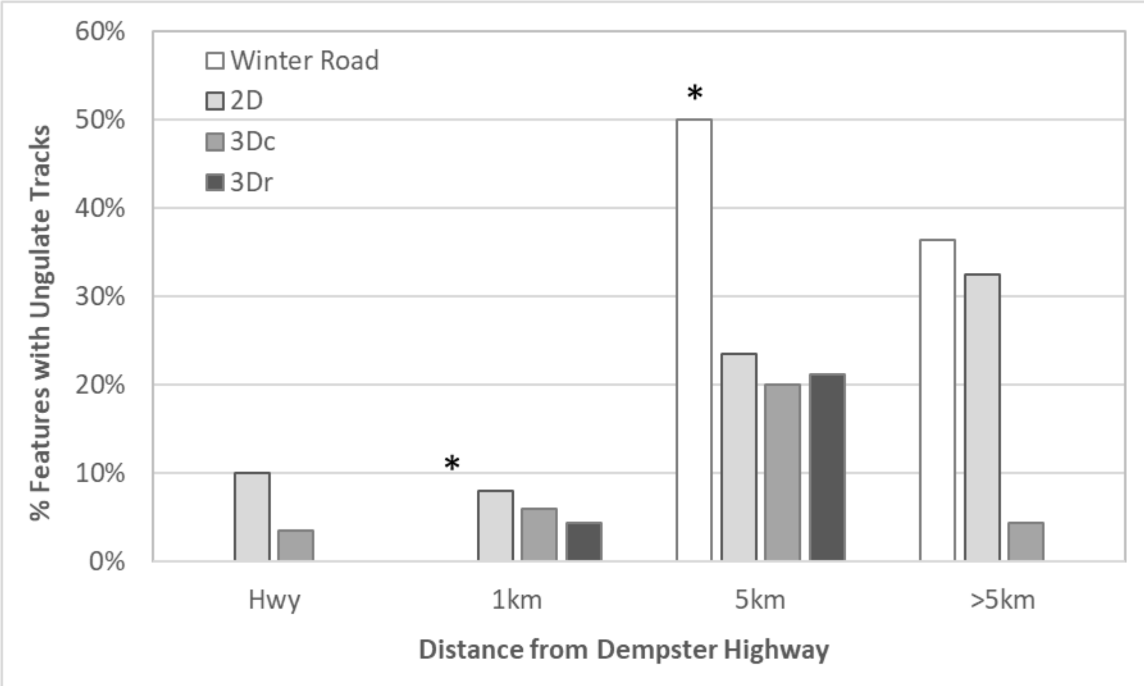


Figure 4-7. Relative use of different linear feature types by ungulates in relation to distance from the Dempster Highway in the Eagle Plains RSA, March 2020.

*The * indicates bars with small samples sizes (n=5-10); all other instances have at least 10 data points per feature type within each distance class*

5 DISCUSSION

5.1 SUMMARY OF LINEAR FEATURES IN THE EAGLE PLAINS RSA

Table 5-1 summarizes key characteristics across linear feature types in the Eagle Plains RSA.

Table 5-1. Summary of structural, ecological and functional characteristics of linear feature types in the Eagle Plains RSA.

Linear Feature Type	Mean Width (m)	Mean Sightlines (m)	Mean Movement Speed (km/h)	% Regenerated[1]	% Inhibited Regeneration[2]	Linear Feature Density (km/km^2)	Adjusted Linear Feature Density (km/km^2)[3]	% Ungulate Use[4]
3D seismic	2.6	71.98	3.36	14	0	0.91	0.31	7
2D seismic	5.4	41.17	2.53	61	4	0.61	0.12	24
Winter Roads	7.4	106.18	3.58	39	19	0.25	0.07	26
Dempster Highway	33.8	814.75	5.60	0	100	0.02	0.01	N/S
Off-line Controls	N/A	46.67	2.95	N/A	N/A	N/A	N/A	N/S

[1] as characterized by reaching a tall shrub stage, or greater.
[2] including stagnated and disturbed successional patterns.
[3] accounting for burns, natural openings, and regeneration.
[4] percent of lines with ungulate tracks during March 2020.

2D Seismic — 2D lines are, on average, the oldest features in the area and have had the longest time to regenerate. Most features were cleared before 1985, but some were developed in the early 2000s. Historical 2D lines were generally long and straight, with moderate widths of 4–8 m. Lines were typically constructed with bulldozers that cut into the moss layer and often included some patches of soil disturbance. The combination of site disturbance and wider widths generally resulted in a successional reset to pioneering vegetation (including early seral graminoids, forbs, and shrubs). Most sites were following a normal successional pathway (73%). However, 27% of sites exhibited atypical pathways, dominated by magnified succession (21%, mostly in burns), stagnated succession (3%) or no succession (1%). Sixty-one percent of the 2D sites had regenerated to a Tall Shrub or more advanced structural stage. 2D lines had the shortest sightlines and slowest walk test speeds of all feature types (including off-line controls), reflecting the regenerating vegetation's effect on these functional metrics. During winter, ungulates regularly used 2D lines to travel along.

3D Seismic — All 3D lines were created during the last exploration period, during the winter of 2013/14. 3D lines constitute the most extensive combined lengths of the different linear feature types, but their areal extent is limited to a relatively small portion of the RSA along the Dempster Highway. Due to their basic design, as well as specific mitigations, 3D lines minimize environmental effects compared to other linear feature types. They are narrow (averaging 3.2 m and 2.0 m for conductor and receiver, respectively), often narrower than average tree spacing in the region. They were constructed during winter, over snow, using low-ground pressure equipment, which avoids ground disturbance and maintains vegetation in the moss, herb and low shrub layers. The lines were constructed with a meandering path, and strategically placed sharp angle dogleg bends to reduce the visibility of the lines from roads, reduce sightlines along them, and hamper travel by OHVs. All 3D lines that were surveyed were undergoing a normal successional pathway and were dominated by the same vegetation as in adjacent undisturbed areas. Regenerating vegetation was mostly in a Low Shrub structural stage, consistent with the relatively short six-year period since they were cleared. Sightlines and movement speeds were intermediate compared to other linear feature types, with sightlines primarily controlled by dogleg bends purposely designed to reduce sightline distances. Ungulates occasionally used 3D lines to travel on in winter, but at less than a third of the rate as 2D lines and winter roads.

Winter Roads — A network of winter roads across much of the RSA results from the historical exploration programs that have occurred. Although many of the winter roads were initially developed during the earliest exploration programs, vegetation has not had the same opportunity to regenerate as on 2D lines because the vegetation was re-cleared on several roads during subsequent exploration programs. The average width of winter roads was 7.4 m, but major roads, like the Chance road, were often 10–12 m wide. Historical winter roads were typically cleared with a bulldozer, and then snow was packed and graded to create a road surface. Similar to historical 2D seismic, the combination of site disturbance and wider widths (i.e., that increases solar exposure) generally resulted in a successional reset to pioneering vegetation (including early seral graminoids, forbs, and shrubs). Most sites were following a normal successional pathway (72%), but 26% of sites exhibited atypical pathways, dominated by stagnated succession (19%), magnified succession (6%) and no succession (1%); 2% of the sites were classified as no disturbance (indistinguishable from vegetation community off the road). Thirty-nine percent of the winter road sites had regenerated to a Tall Shrub or older structural stages. Winter roads had the longest sightlines and fastest walk test speeds of all feature types, other than the Dempster Highway, reflecting the variable levels of regenerating vegetation that occurred on winter roads. During winter, ungulates regularly used 2D lines for travel.

Dempster Highway — The Dempster Highway is the only all-season road in the RSA (except for short spurs off the Dempster to well sites and gravel pits). It is fundamentally different from all other linear features in the area in terms of wide width, surface material and maintenance, long sightlines, regular traffic, and base of access for human land use activities such as hunting, camping, and trapping.

5.2 LINEAR FEATURE CHARACTERISTICS

5.2.1 FIRE

The presence or absence of recent forest fires affected several linear feature characteristics, including linear feature width, successional class, structural stage, and vegetation height and cover. Mean measured linear features widths were 0.2–0.6 m wider at burnt sites than at unburnt sites. This may be due to the already shorter vegetation at burnt sites, which would reduce overgrowth occurring from forest edges and decrease the measured width between driplines (branches extending into the linear feature from either side of the line).

Magnified succession was nearly four times more common in burnt plots than unburnt plots, and stagnated succession was half as common. Fire likely facilitates magnified succession by increasing soil temperatures, accelerating decomposition, and releasing stored water and nutrients to promote vegetation growth (Seccombe-Hett and Walker-Larsen 2004, Simpson 2008). Stagnated succession is likely less common at burnt sites because the associated nutrient and water increase allows woody plant species to colonize more easily and advance through successional stages.

Overall structural stage distribution was very similar between burnt on-line and off-line plots, but was markedly different between unburnt on-line and off-line plots. Furthermore, when the structural stages were compared between paired on-line and off-line plots, they matched two to four times more frequently at burnt sites than at unburnt sites and were mismatched two to six more frequently at unburnt sites than at burnt sites. Nearly all burnt plots were in a low shrub, or tall shrub structural stage, which is expected as fires tend to remove overstory trees, and shrubs generally colonize rapidly post-fire (Seccombe-Hett and Walker-Larsen 2004).

Vegetation height was 4.4 m shorter in burnt than unburnt reference plots, and tree cover was approximately 6% less. These modest differences reflect the stunted and open nature of the taiga forest. There was little change in vegetation height between burnt and unburnt linear features, likely because there were very few linear disturbances in a forested structural stage; most of them, even in unburnt conditions, were already in a shrub-dominated stage due to the clearing of trees. For shrub cover, except for 2D seismic lines, the mean was approximately 10% to 20% greater at burnt plots than at unburnt plots. The increase in shrub cover at burnt sites was most prominent in 3D seismic lines due to their comparatively lower pre-fire shrub cover.

Post-burn vegetation was, on average, shorter and shrubbier than unburnt off-line plots, but taller and shrubbier than unburnt on-line plots. Furthermore, burnt paired plots were more similar in vegetation characteristics than unburnt paired plots. This evidence supports the theory that forest fires in taiga ecosystems resets the landscape to some extent and effectively erase signs of anthropogenic disturbance (Seccombe-Hett and Walker-Larsen 2004, Simpson 2008). Forest fire in the taiga returns ecosystems to an early successional stage (i.e., low shrub) and synchronizes baseline biophysical conditions on a landscape scale, allowing previously disturbed and undisturbed areas to recover at equal rates, as has been documented by Seccombe-Hett and Walker-Larsen (2004). Thus, most linear features that have experienced forest fires no longer create different ecological conditions or functional disturbances than the surrounding landscape.

5.2.2 SUCCESSIONAL CLASS

The idea that vegetation regeneration on linear features could follow different successional trajectories came out of work by the Yukon Government in the early 2000s (Simpson 2008). That work described six successional trajectory classes observed in the Eagle Plains area. However, that study did not quantify the relative extents of linear features that followed the different trajectories. This study used the classes that the Yukon Government work developed and quantified the proportion of linear features in each successional class across a random sample of linear features.

Successional classes in the Eagle Plains RSA varied according to linear feature type and burn status. However, one of the key findings was that normal succession was the dominant trajectory observed for all linear features except the Dempster Highway. All 3D seismic lines followed a normal successional trajectory, except for one recently disturbed site. This was likely attributable to the low impact methods used in 3D line creation that minimize ground and vegetation disturbance, creating conditions more likely to result in a normal successional trajectory (Yukon Energy Mines and Resources 2006, Golder Associates 2016). Magnified and stagnated succession were only observed in 2D seismic lines and winter roads. These linear features were generally wider and were created using methods that cause greater disturbance to soils, hydrology, and vegetation, leading to these alternative successional trajectories (Simpson 2008, Jorgenson et al. 2010, Dabros et al. 2018). Magnified succession is unique among the classes in that it results in accelerated vegetation regeneration. Magnified succession was most common on burned 2D seismic lines where the combination of site disturbance associated with the 2D lines and fire is suspected of causing accelerated soil warming, moisture availability, and nutrient flush, which increase on-line vegetation growth (Simpson 2008). Successional stagnation was most common on unburnt winter roads. Stagnation tends to occur on features that have experienced ground disturbance or have been seeded to agronomic species, which may have happened on winter roads in the RSA (Simpson 2008). Repeated disturbance associated with multiple exploration programs over time may also limit successional advancement and contribute to successional stagnation (Lee and Boutin 2006, Jorgenson et al. 2010).

Although some alternative successional pathways were observed in this study, most linear features in the Eagle Plains RSA are following a normal successional trajectory. This implies that most of these disturbances will recover to an ecological condition like that of the surrounding community with adequate time.

5.2.3 STRUCTURAL STAGE

The taiga forest in Eagle Plains presents a unique situation where the Tall Shrub stage is applied to two very different stand conditions. One condition, the more traditional, is of regenerating stands following a natural or anthropogenic disturbance. In this setting, the vegetation consists of deciduous shrubs and 2–8 m tall, 10–30 years old trees. The stage is transitional, with the vegetation expected to advance to the Pole-Sapling stage over time. The second condition where the Tall Shrub stage is applied is to stunted, old, black spruce stands in a disclimax state. In this setting, the vegetation consists of open, stunted, black spruce stands that are typically ≥50 years old and 2–8 m tall. Stands in this condition are expected to remain in the same condition over time(i.e., a disclimax state). Structurally, the stunted black spruce trees function more like shrubs than trees. Both Tall Shrub conditions (referred to as disturbance and disclimax forms hereafter) are widespread across the RSA in off-line sites. Only the disturbance form was observed on linear features.

The structural stage on linear features was predominantly Low Shrub or Tall Shrub, determined mainly by the time since line clearing and burn status. Less than 4% of surveyed features were in forested stages (Pole-Sapling or greater). Off-line plots had a higher proportion of forested structural stages (37%). However, they were still predominantly Low Shrub and Tall Shrub, resulting from extensive burns across the RSA and large extents in the disclimax form for Tall Shrub in un-burned areas.

The structural stage of on-line plots was also influenced by successional class. The small number of forested structural stages observed on features only occurred on sites undergoing normal succession. Stagnated succession was associated with only the Herb structural stage, which was expected as stagnation is defined by its high herbaceous species cover (among other factors) that limits the establishment of other structural groups. Magnified succession was the one atypical successional class with accelerated vegetation growth. Most structural stages on sites with magnified succession were in Tall Shrub and, occasionally, Pole/Sapling. Often the structural stage on magnified succession sites was one stage greater than the off-line plot.

5.2.4 VEGETATION HEIGHT

This study observed a range of vegetation heights across different feature types. Except for the 3D lines, the linear features' age was unknown, so it was impossible to estimate growth rates. Although some regenerating vegetation on 2D seismic lines and winter roads reached 8 m high, most were between 1.5 m and 2 m. Though the ages of specific features were mostly unknown, the minimum age for most was at least 35 years. Having most vegetation heights at only 1.5–2.0 m after this long period suggests regeneration growth rates on linear features may be quite slow. This pattern of slow vegetation growth on linear features may partly reflect the generally poor growing conditions in the taiga region. Still, it is also a pattern that has been observed on linear features in other studies in the southern boreal forest.

Interestingly, the vegetation heights on linear features in Eagle Plains are greater than reported in several other studies. For example, approximately 65% of sites on linear features in northeast Alberta had not advanced beyond a cover low forbs after 35 years (Lee and Boutin 2006). Key factors that have been linked to slow vegetation regeneration on linear features were continued human disturbance (e.g., OHV travel), ecosystem type (bogs and fens regenerated much slower than upland sites), competition from early seral and invasive graminoids and forbs, and soil or site degradation associated with feature construction (Lee and Boutin 2006, van Rensen et al. 2015, Finnegan et al. 2018).

There is limited data on vegetation regeneration in the taiga. A study from NWT found that vegetation regeneration on conventional seismic lines was affected by both a time lag for seedling establishment (as long as 17 years for black spruce) and slow growth rates (83 years to reach 5 m) (Seccombe-Hett and Walker-Larsen 2004). In burned areas, the seedling establishment delay was reduced to five years.

Although the 3D lines in Eagle Plains were only six years old when they were surveyed, a combination of field survey results and information from other studies suggests that vegetation recovery on 3D lines could be much faster than the previous examples for conventional 2D lines. This is because the undisturbed ground conditions and maintenance of the vegetation community in the moss, forb and low shrub layer provide both plants and growing conditions that support faster shrub and tree growth compared to sites beginning primary succession. In northeast British Columbia, Golder Associates (2016) found that in the first year following 3D seismic line creation, there were already black spruce seedlings exceeding 0.5 m in height. These seedlings were plants that were initially present on the site and that had survived line clearing. This is consistent with the results of this study, where nearly all of the 3D plots contained black spruce seedlings. Despite their relatively young age, most 3D seismic lines in Eagle Plains included shrubs and trees between 0.5 m and 1 m tall. Although growth rates in Eagle Plains are not known, similar species that occur in Eagle Plains were observed to grow 5–10 cm per year on 3D lines in the boreal forest in northeastern British Columbia (Golder Associates 2016). If similar growth rates occur in Eagle Plains, regeneration on the 3D lines can be 2 m over the next 5–20 years.

5.3 HUMAN USE AND ACCESS ALONG LINEAR FEATURES

The NYRLUP and the PWRLUP indicate that one of the primary concerns about linear features is that they can increase human access into remote areas. This has been demonstrated in southern regions, and that access can have secondary effects of inhibiting vegetation regeneration (Lee and Boutin 2006) and, in winter, packing snow that can affect predator-prey dynamics (Latham et al. 2011, McKenzie et al. 2012, Keim et al. 2019a). In the boreal forest in northern Alberta, OHV travel was common on most conventional 2D seismic lines. After 35 years, approximately 20% of the lines were considered to have been converted to tracked access routes (Lee and Boutin 2006). In the same study, about 65% of the lines remained cleared after 35 years, and OHV use along the lines was identified as one factor contributing to the lack of vegetation regeneration. In contrast, there is little evidence of human use along linear features in the Eagle Plains RSA. No sign of human use was detected along linear features during the summer ground surveys (e.g., OHV tracks, ruts, water crossings, vegetation trampling/scarring, tree blazes, trap sets, garbage, campsites, etc.) or the winter track survey (e.g., snowmobile tracks). Although these surveys provided limited snapshots in time, and that some types of human activity leave little sign (e.g., evidence of snowmobile tracks have limited persistence during winter and leave no sign behind after snow melt), the results suggest that human use of the area is very limited outside of the Dempster Highway corridor. This is consistent with general comments from highway workers, staff at the Eagle Plains Hotel, pilots, and some First Nation residents that most areas beyond the Dempster Highway corridor receive very little human use. Specific instances of use of the area outside the Dempster Highway corridor include intermittent activity on the community trapline that occurs in Eagle Plains and occasional forays by hunters (First Nation and non-First Nation), mostly in winter.

People's limited use of the Eagle Plains area is likely due to its far distance from any human settlements and the difficulty of travel off the Dempster Highway. The network of winter roads in the area does provide access via specific types of OHVs in summer and snowmobiles in winter. However, there was no evidence observed that this occurs regularly. Travel along seismic lines, though possible in specific locations, would be hampered over any substantial distance by vegetation regeneration along the historical 2D lines, the narrow widths of and frequent dogleg bends in 3D lines and, during summer, difficult terrain (extensive peatlands and graminoid tussocks).

5.3.1 EFFECTIVENESS OF MITIGATION MEASURES FOR 3D SEISMIC LINES

In addition to the narrow widths of 3D lines, which hampers OHV travel, the 3D lines included regular bends in the lines, which were designed to limit the visibility of the lines at intersections with roads and other seismic lines, and to hamper OHV along the lines further. The driving survey along the Dempster found that this mitigation was very effective in reducing the visibility of the 3D lines from the road (i.e., only 6 of the 74 3D lines intersecting the Dempster Highway were visible). Incidental observations during ground surveys observed similarly reduced visibility of 3D lines crossing winter roads. Regular bends in the 3D lines away from roads were also designed to limit human access by reducing sightlines and making travel more difficult along the line (i.e., needing to reduce speed to navigate the tight turns of a dogleg bend approximately every 70 m).

5.4 FUNCTIONAL CHARACTERISTICS OF LINEAR FEATURES

In addition to human travel, linear features can also affect how wildlife move within a landscape. Several studies in western Canada have documented the effects of linear features on the movements and population dynamics of large mammals, such as caribou, moose, deer, wolves and bears (Latham et al. 2011, McKenzie et al. 2012, Dickie et al. 2017b, Keim et al. 2019a). EDI focused on two established indicators of human and wildlife access and travel on linear features: sightline distance and ease of travel. These measurements act as a proxy for the functional recovery of disturbed areas. They are mainly dependent on vegetation height, cover, and terrain.

5.4.1 LINE-OF-SIGHT

Line-of-sight or sightline distance is how far one can see under normal conditions and was compared between linear features and paired reference plots. It has been proposed that humans and predators select linear disturbances because it is easier to travel and detect prey using those features (Finnegan et al. 2018). As vegetation grows taller and denser, sightlines diminish, and the use of linear features decreases (e.g., for wolves, Dickie et al. 2017a). This study found that average sightlines were farther on-line versus off-line for most linear feature types, but that sightlines varied substantially across line types. Sightlines were shorter on seismic lines than on roads, especially 2D lines which had more advanced vegetation regeneration than other feature types. On 3D lines, sightlines averaged approximately 30 m farther on lines than off lines. However, this difference probably provides little advantage to predators or human hunters because the increase is still within the olfactory and auditory detection zone for most large prey species. Average sightlines were 60 m farther on winter roads than surrounding forest, which may begin to confer more advantage to predators and hunters.

The range of sightlines observed on most linear features probably do not provide an advantage to detect prey species visually. For 2D lines and winter roads, sightline distances were primarily driven by the height and density of regenerating vegetation. The recovery period for 2D seismic lines appears to be sufficient to support vegetation that reduces visibility to a similar level as the surrounding habitats. The reason for longer sightlines on winter roads is that they are subject to intermittent re-activation, where the vegetation is cleared once again, which resets vegetation recovery and maintains longer sightlines. In contrast to 2D lines and winter roads, where sightlines were largely determined by vegetation regeneration, the sightlines on 3D lines were presently limited by the bends purposely constructed into the lines. Sightlines along all feature types will continue to diminish over time as vegetation regeneration continues.

5.4.2 EASE OF TRAVEL

Ease of travel is a fundamental indicator of functional recovery of linear features. Wolves, bears, and humans have been documented to select linear features with greater ease of travel, which is generally associated with lower and more sparse vegetation and stable, even terrain (Dickie et al. 2017b, Keim et al. 2019a). Access and travel resistance are the main determinants of predator and human use of linear features and the key concern of linear disturbances in the RSA (Vuntut Gwitchin Government and Yukon Government 2009, Peel Watershed Planning Commission 2019).

The walk test used in this study, as an index of ease of travel, found differences among linear feature types and between linear features and controls. However, the magnitude of the differences for both comparisons was modest. Even the Dempster Highway only conveyed a 35% increase in walking speed over off-line plots. Other researchers, in other areas, often observed walk speeds on linear features were often at least twice as fast as off-line transects (Keim et al. 2019a). Two conditions associated with the Eagle Plains area appear to limit the advantage of travelling on linear features. One is that the vegetation in most ecosites and structural stages is relatively open and has a limited effect on impeding movement. The second factor is that ground conditions limiting movement, including soft, thick peat and graminoid tussocks, were similar on both on-line and off-line plots for most linear feature types.

Notwithstanding the modest magnitude of faster walking speeds on-lines, there were clear patterns in walking speed differences across linear feature types. 2D lines were the one feature type where walking speeds were slower on lines than off lines. This reflected the thick, shrub stage vegetation that had regenerated on most 2D lines, which impeded travel (similar to the effect that regenerating vegetation had on sightline distances in the previous section). Walk speeds decreased across the other feature types in relation to line width and the degree to which ground cover was levelled or compacted. 3D seismic lines allowed slightly easier travel than paired off-line plots. They usually had lower vegetation cover and clearer route selection. As linear feature width decreased in 3D lines, walking speed also decreased. This implies that width may be related to functional recovery, with narrower lines having smaller impacts than wider lines, even within an already narrow linear feature type. Although ease of travel was greater in 3D seismic lines than surrounding community, it is expected that this will decrease in future years as vegetation increases in height and density.

5.5 FUNCTIONAL RECOVERY OF LINEAR FEATURES

Functional disturbance is defined in the NYRLUP and PWRLUP as "*physical land use disturbance that results in disruption of soil or hydrology, or that requires the cutting of trees*." One of the main concerns with linear disturbances under these land use plans is that such features can technically allow increased access to previously remote areas, potentially leading to a greater harvest of wildlife and fish, higher predation rates, and a change in how people and wildlife use the land (Vuntut Gwitchin Government and Yukon Government 2009). A disturbance can be considered functionally recovered and subtracted from the overall linear density when it no longer facilitates access or travel by humans or wildlife (Vuntut Gwitchin Government and Yukon Government 2009), or otherwise no longer functions as a surface disturbance (Peel Watershed Planning Commission 2019). Both plans use 1.5 m vegetation height as a threshold for functional recovery in forested communities. The

PWRLUP includes the following additional criterion for recovery "*in non-forested areas (dominated by vegetation under 1.5 m), when the disturbed area is covered by native species roughly the same height and composition as the surrounding dominant vegetation*" (Peel Watershed Planning Commission 2019):

One limitation of using height alone as a functional recovery criterion is that it does not consider vegetation density. Although regeneration may meet the recommended height criteria, if it is very sparse (as is often the case in the Eagle Plains Ecoregion), it may still facilitate access and travel by humans and wildlife. Attachment Photo A-25 provides an example in the Eagle Plains RSA where tall but sparse regeneration meets the 1.5 m criteria but does not inhibit access or travel.

The combined results of this study indicate that using regeneration to the Tall Shrub structural stage may be a more appropriate criterion for functional recovery. Attachment Photo A-3 and Attachment Photo A-10 provide examples of linear features that have regenerated to a tall shrub structural stage. Using the Tall Shrub criterion, 38% of all linear features in the RSA would be considered functionally recovered compared to 53% using the 1.5 m height criterion. For this study, the more conservative criterion of reaching the Tall Shrub structural stage was used to adjust (reduce) linear feature densities.

5.6 LINEAR FEATURE INVENTORY AND DENSITY

This study was successful in mapping all linear features within the RSA. The combined results of the mapping exercise and the field studies found that the extent of open habitats (burns and naturally open habitats like wetlands and shrublands), and the degree of vegetation regeneration, played a significant role in the effective density of linear features across the RSA. Before accounting for open areas and regeneration, the total linear feature density was 1.79 km/km². After accounting for open areas and vegetation regeneration (to the Tall Shrub structural stage), the effective linear feature density was 0.52 km/km². The NYRLUP and PWRLUP suggest cautionary levels for linear density of 0.75 km/km² and critical levels of 1.0 km/km² (Vuntut Gwitchin Government and Yukon Government 2009, Peel Watershed Planning Commission 2019).

The Yukon Land Use Planning Council (YLUPC) was conducting a pilot study of surface disturbance across the broader Eagle Plains Ecoregion (Skinner 2021) at the same time as this study. The methods they used consisted of mapping and attributing human-caused disturbances solely using high-resolution satellite imagery. The YLUPC classified vegetation into eight broad classes based on whether the surrounding area was forested or non-forested, the similarity of vegetation on-line to off-line, and the presence or absence of woody cover (i.e., shrubs or trees). The features were then classified as recovered or not-recovered based on the presence of woody cover (recovered) or, if woody cover was not present, the similarity to surrounding vegetation (i.e., if similar then recovered, if not similar, then not-recovered). Historical field data and photographs from the area (Simpson 2008) were used to verify interpretations.

The spatial data from the YLUPC work was not available to compare in detail to the linear feature inventory compiled in this study. However, the mapping linework is expected to be very similar because satellite imagery was used to verify and supplement the linear feature geospatial data compiled in this study (presumably the same satellite imagery that YLUPC used because the imagery was obtained from Yukon Geomatics). One difference between the two products is that the YLUPC completed the inventory for the entire Eagle Plains Ecoregion, while this study was restricted to the RSA. Another difference is that the attribute data in this study is expected to be more detailed and more precise than the YLUPC data because (i) the original geospatial data includes some information, like date of creation, that would be impossible to estimate from imagery, and (ii) because this study linked field surveys to the mapping exercise to determine line widths and other characteristics more precisely.

Although it is impossible to directly compare the linear feature density estimates between the two studies, due to the different study extents, the general pattern of results is similar. The YLUPC estimated the linear density (accounting for recovery) to be 0.38 km/km^2 across the entire Eagle Plains Ecoregion. This is consistent with the estimate from this study for the RSA of 0.52 km/km^2 because the portion of the Ecoregion outside the RSA has lower linear feature density than the RSA.

6 CONCLUSION

This study successfully mapped all linear features within the RSA and measured a suite of structural, vegetation, and functional characteristics across different feature types. Generally, the effects associated with linear features (i.e., differences between conditions on-line and adjacent off-line areas) correlated to feature width and the degree of ground disturbance. In terms of combined effects across the range of feature types that occur in the Eagle Plains RSA, the ranks were:

Dempster Highway >>> Winter Roads > 2D Seismic > 3D-5m >> 3D Conductor > 3D Receiver[2]

The effects of 3D lines (both conductor and receiver lines) appear to be substantially lower than other feature types. This reduced magnitude of effects is important because 3D lines have the longest combined length of exiting linear features. They are also the predominant feature planned for the next exploration program. Important findings for 3D lines include:

- Relatively narrow line widths of 2–3 m are often smaller than natural tree spacing and minimize the potential for changes to microsite conditions (e.g., solar radiation, air and ground moisture) reported in other studies.
- Minimal ground disturbance and maintenance of the moss, herb, and low shrub layers, which retains the natural vegetation community and accelerates vegetation regeneration.
- Successful application of mitigations, notably dogleg bends that minimize sightlines, ease of human travel, and visibility of lines from roads.
- Ungulate use of 3D lines in winter was less than a third of the rate observed on 2D lines and winter roads.

The adverse effects of linear features in other areas are often caused or exacerbated by human use after the lines are initially constructed, including effects on vegetation regeneration and predator-prey dynamics. Human use does not appear to be a significant factor in Eagle Plains. No sign of human use was observed outside the Dempster Highway corridor.

Substantial vegetation regeneration has occurred on existing features in the Eagle Plains RSA. Previous work by the Yukon Government identified the potential for atypical successional trajectories to occur on linear features in the region. Although atypical succession occurred to a limited extent, this study determined that 81% of the sites exhibited a normal succession (100% on 3D lines). Only 5% exhibited inhibited regeneration trajectories (mostly stagnated succession on winter roads). Regarding functional recovery, 53% of sites met the NYRLUP and PWRLUP criterion of vegetation reaching 1.5 m, and 38% of sites met the criterion of attaining a Tall Shrub structural stage. Using the Tall Shrub structural stage as a criterion of functional recovery may be a more ecologically appropriate criterion to meet LUP objectives.

The extent of open habitats (e.g., burns, wetlands and shrublands) and the degree of regeneration on existing linear features (mostly the older 2D lines and winter roads) play an important role in calculating effective linear

[2] Relative magnitudes of effects: >>> large effect, >> moderate effect, > small effect.

feature density in the RSA. Before accounting for open areas and regeneration, the total linear feature density was 1.79 km/km². After accounting for open areas and vegetation regeneration (to the Tall Shrub structural stage), the effective linear feature density was 0.52 km/km².

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ATTACHMENTS

ATTACHMENT A EAGLE PLAINS PROJECT LINEAR FEATURES SURVEY PHOTOGRAPHS

Attachment Photo A-1. Air survey plot SL237, an unburnt 2D seismic line undergoing normal succession at a young forest structural stage when surveyed.

Attachment Photo A-2. Air survey plot SL269, an unburnt 2D seismic line undergoing normal succession at a low shrub structural stage when surveyed.

Attachment Photo A-3. **Ground survey plot SL310, an unburnt 2D seismic line undergoing normal succession at a tall shrub structural stage when surveyed.**

Attachment Photo A-4. **Aerial view of 3D seismic lines undergoing normal succession – meandering routes were used to mitigate some functional disturbance impacts.**

Attachment Photo A-5. Ground survey plot SL357, a burnt 3D5 seismic line undergoing normal succession at a low shrub structural stage when surveyed.

Attachment Photo A-6. Ground survey plot SL277, an unburnt 3Dc seismic line undergoing normal succession at a low shrub structural stage when surveyed.

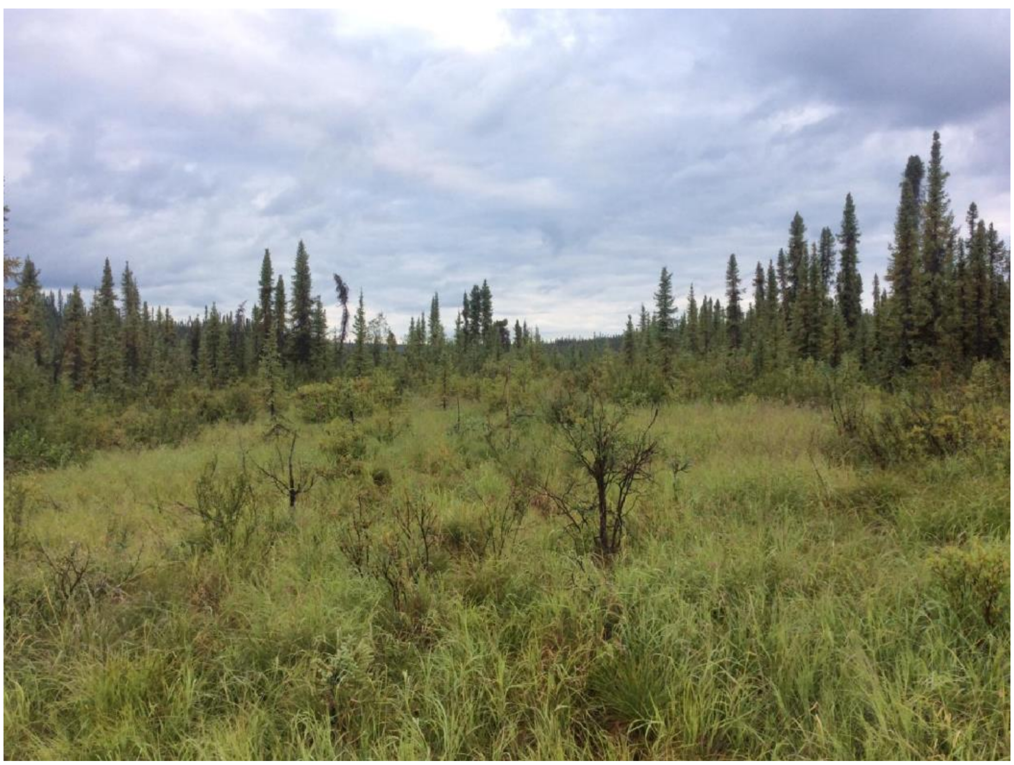
Attachment Photo A-7. Ground survey plot SL255, an unburnt 3Dr seismic line undergoing normal succession at a low shrub structural stage when surveyed.

Attachment Photo A-8. Aerial view of a burnt 2D seismic line undergoing magnified succession at a tall shrub structural stage when observed.

Attachment Photo A-9. Air survey plot SL234, an unburnt winter road undergoing magnified succession at a sapling forest structural stage when surveyed.

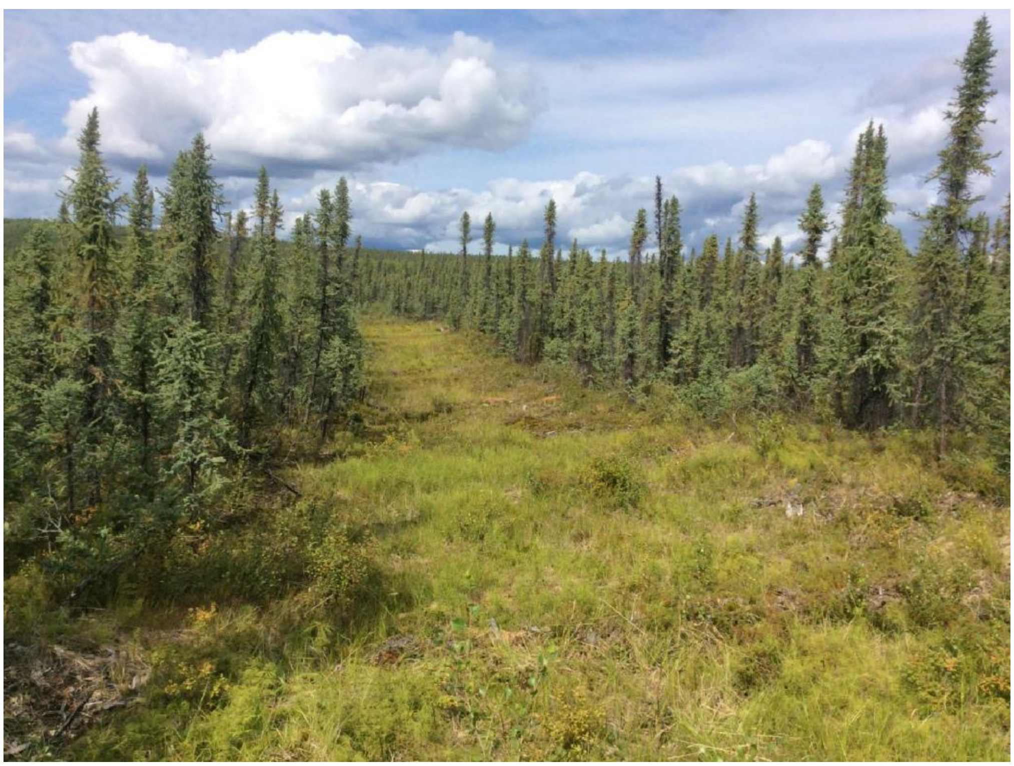
Attachment Photo A-10. Ground survey plot SL317, a burnt 2D seismic line undergoing magnified succession at a tall shrub structural stage when surveyed.

Attachment Photo A-11. Air survey plot SL238, an unburnt winter road undergoing stagnated succession at a forb-dominated herb structural stage when surveyed.



Attachment Photo A-12. Ground survey plot SL264, an unburnt winter road undergoing stagnated succession at a graminoid-dominated herb structural stage when surveyed.

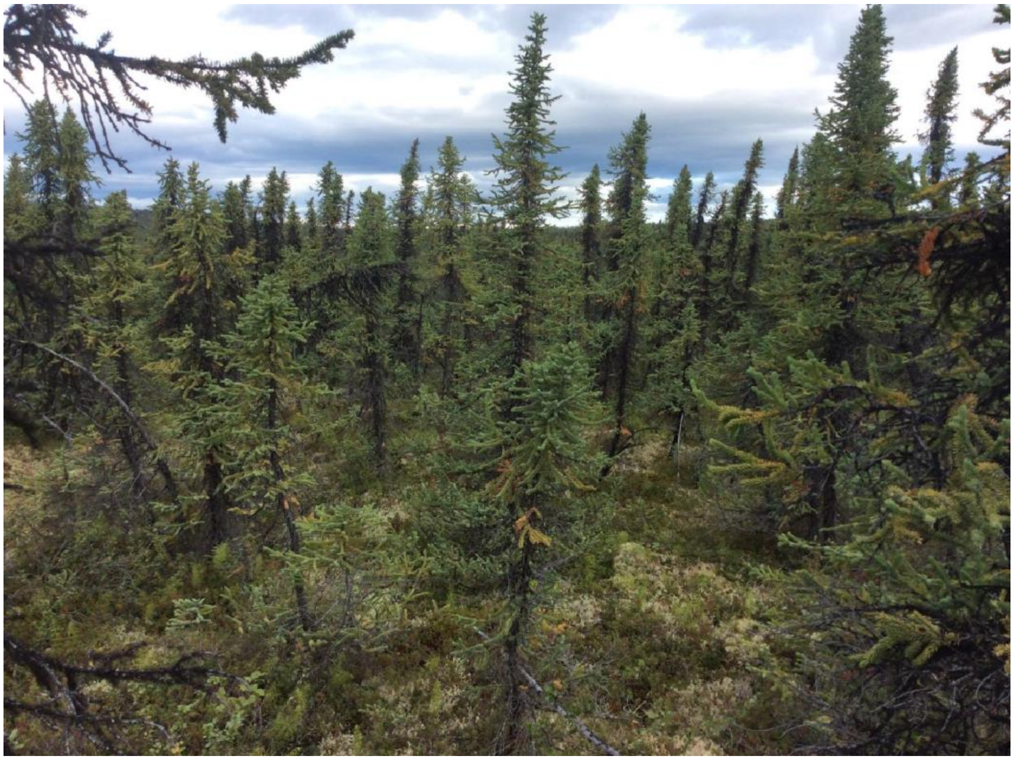
Attachment Photo A-13. Ground survey plot SL226, a burnt 2D seismic line undergoing normal succession at a forb-dominated herb structural stage when surveyed.



Attachment Photo A-14. Ground survey plot SL329, an unburnt 3D5 seismic line classified as recent disturbance at a forb-dominated herb structural stage when surveyed.

Attachment Photo A-15. Ground survey plot SL338, an unburnt, undisturbed reference plot at a low shrub structural stage when surveyed.

Attachment Photo A-16. Ground survey plot SL350, a burnt undisturbed reference plot at a low shrub structural stage when surveyed.



Attachment Photo A-17. Ground survey plot SL304, an unburnt undisturbed reference plot at a tall shrub structural stage when surveyed.

Attachment Photo A-18. Ground survey plot SL346, a burnt undisturbed reference plot at a tall shrub structural stage when surveyed.

Attachment Photo A-19. Ground survey plot SL3260, an unburnt undisturbed reference plot at a mature forest structural stage when surveyed.

Attachment Photo A-20. Ground survey plot SL264, an unburnt undisturbed reference plot at an old forest structural stage when surveyed.

Attachment Photo A-21. Ground survey plot SL243, a burnt winter road with melt pockets present, indicating permafrost degradation.

Attachment Photo A-22. Air survey plot SL228, a burnt 2D seismic line recovering at the same rate and stage as the surrounding community.

Attachment Photo A-23. Air survey plot SL326, a burnt winter road recovering at the same rate and stage as the surrounding community.

Attachment Photo A-24. Ground survey plot SL287, a burnt 3Dr seismic line recovering at the same rate and stage as the surrounding community.

Attachment Photo A-25. Ground survey plot SL216, a feature with regenerating trees over 1.5 m tall but very sparse, illustrating one of the limitations of the NYLUP and PWRLUP functional recovery threshold.

ATTACHMENT B DATA FORMS

Eagle Plains Linear Features Study

Surveyors: ___________ **Date**: _______________ **Type**: Air / Ground

Waypoint: ________________ **Map Info**: _______________________

Line Widths: _____/_____/_____/______ **% Mulch**:__________

Succ. Class: Normal / No Succ / Magn / Stagn / Regress / Rcnt Dist

	On Line	Off Line
Struct. Stage		
Veg Ht / Spp	/	/
% Tree		
Tree Spp		
% Shrub		
Shrub Spp		
Ecosite		
Photos		
Sight Line (m)	/	/
Walk Test*	Dist: Time: Surveyor:	Dist: Time: Surveyor:

*Use same Surveyor for both walk tests.

Comments: ____

Eagle Plains Linear Features Study

Surveyors: ___________ **Date**: _______________ **Type**: Air / Ground

Waypoint: ________________ **Map Info**: _______________________

Line Widths: _____/_____/_____/______ **% Mulch**:__________

Succ. Class: Normal / No Succ / Magn / Stagn / Regress / Rcnt Dist

	On Line	Off Line
Struct. Stage		
Veg Ht / Spp	/	/
% Tree		
Tree Spp		
% Shrub		
Shrub Spp		
Ecosite		
Photos		
Sight Line (m)	/	/
Walk Test*	Dist: Time: Surveyor:	Dist: Time: Surveyor:

*Use same Surveyor for both walk tests.

Comments: ____