December 2015

9 TO 13 YEAR FOLLOW-UP MONITORING IN THE LITTLE SMOKY CARIBOU RANGE

15-ERPC-07

Caribou Range Restoration Project Treatment Sites

Submitted to:
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REPORT

Report Number: 1529431

Golder Associates

Executive Summary

To meet habitat targets within boreal caribou ranges, the federal Recovery Strategy for the Woodland Caribou, Boreal Population in Canada (Environment Canada 2012) identifies coordinated actions to reclaim woodland caribou habitat as a mitigation step to meeting current and future caribou population objectives. Actions include restoring industrial landscape features such as roads, seismic lines, pipelines, cut-lines, and cleared areas in an effort to reduce landscape fragmentation and the changes in caribou population dynamics associated with changing predator-prey dynamics in highly fragmented landscapes. Based on the federal recovery strategy habitat targets and current range conditions, it is expected that boreal caribou range plans in Alberta will have a requirement to restore significant amounts of habitat along linear disturbance features. Habitat restoration (i.e., mechanical site preparation, planting and/or seeding of tree species) as well as implementing access control measures are considered the primary mechanisms to enhance the rate of recovery of linear disturbance features to naturally occurring vegetation.

As caribou habitat restoration initiatives have become more widespread across Alberta in the last decade, key uncertainties have been recognized regarding what treatment types are appropriate for habitat restoration, how to measure success, and timelines to reach functional habitat. To that end, a collaborative research initiative was initiated by Golder Associates with support from the Foothills Landscape Management Forum (FLMF), the Petroleum Technology Alliance of Canada (PTAC) and the Government of Alberta to monitor the vegetation attributes on restoration treatment sites implemented from 2001 to 2007, as part of the Caribou Range Restoration Project in the Little Smoky caribou range.

The study approach for this project attempted to understand how planted and naturally ingressing tree seedling species (black spruce and lodgepole pine) responded to site treatments in order to answer the following questions: 1) Are planted seedlings significantly taller compared to naturally ingressing seedlings on treated sites?; 2) Is the average current year's leader growth significantly greater for planted seedlings compared to naturally ingressing seedlings on treated sites?; and 3) Are planted seedlings or naturally ingressing seedlings on treated sites significantly taller than seedlings on untreated naturally recovering lines? Growth patterns (i.e., individual tree height-age trajectories) were also modelled for both planted and naturally ingressing tree species on treated sites using mean leader growth, mean height and age to determine their respective trajectories within both lowland and upland sites.

A field program was conducted during the summer of 2015 to collect regeneration data on treated seismic lines (68 plots) and naturally revegetating seismic lines (3 plots). Data collected in 2015 was supplemented by 2008 data collected on naturally regenerating seismic lines (13 plots). Survey locations were selected from seismic lines treated under the Caribou Range Restoration Project. Various ecological and tree regeneration data were collected at each site, as well as cursory soil information, and documentation of any wildlife or human usage. Treatment site details from the Caribou Range Restoration Project files including the time since treatment, type of treatment and a photographic inventory of all visited sites were captured together with the field data. Wooden fences installed through the Caribou Range Restoration Project for access control purposes were documented photographically as encountered during travel between survey sites.

For the purpose of analysis, treatment types were not separated out as the majority of sites were mounded and planted. The primary response variables were mean black spruce height and mean black spruce leader growth (current year) of planted and naturally ingressing seedlings. Mean lodgepole pine height and leader growth (current year) were also analyzed, though only for naturally ingressing seedlings, as lodgepole pine was generally not included in the original planting regime. Mean maximum age and height of lodgepole pine and black spruce were calculated to provide a relative comparison that could be plotted on respective height – age growth trajectories. Height – age trajectory models were developed for planted and natural ingress black spruce seedlings, on upland and lowland site types, as well as natural ingress of lodgepole pine seedlings on upland sites.

Overall, treated lines had little to no recent signs of ATV/UTV use and more than half of the wooden fences installed for access control in this area were found to be in relatively good condition. Mounding was the primary site treatment applied (69% of upland sites and 85% of lowland sites) and black spruce was the primary species planted on the mounds. Mounds degraded over time and were more obvious in upland sites compared to lowland sites. Mounding provided suitable microsites for natural ingress and both planted and natural ingress species were present on mounds.

Planted black spruces on treated sites were significantly taller and had significantly greater leader growth compared to natural ingress black spruce. Additionally, black spruce on treated lowland sites were found to be significantly taller and had significantly greater leader growth than upland sites. Overall, lowland sites on average had taller seedlings, with planted individuals being taller than naturally ingressing individuals. Treatment age, shrub cover and depth to water did not have a significant effect on the height of all black spruce seedlings (planted and natural ingress) measured on seismic lines.

The results from the height-age trajectory models showed that the predicted height of black spruce and lodgepole pine on upland or lowland sites, respectively, tended to be at the lower end of the provincial site index curves for the Upper Foothills Subregion, indicating a conservative model. Treating seismic lines on wetter sites through mounding and planting of black spruce indicated an acceleration of recovery times by a minimum of 4 to 5 years compared to natural ingress on treated lines and 10 years compared to naturally recovery on untreated lines. Planted black spruce on treated lowland sites reached 1.4 m by age 14 and 2.7 m by age 22, compared to natural ingress black spruce which reached 1.4 m by age 18 and 2.7 m by age 29.

In contrast, treating upland sites with mounding and planting of black spruce did not appear to accelerate the rate of recovery over natural vegetation recovery for either lodgepole pine (natural ingress) or black spruce. Although growth rates were similar or inconclusive for upland planted or natural ingress black spruce seedlings, it should be noted that the CRRP used mounding with the planting of black spruce on the top of the mounds within these treatment sites. These results suggest that treatment needs to be more targeted to natural regenerative systems and applied based on an understanding of site limiting factors (moisture, nutrients, shade) and conditions to achieve the most optimal results.

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Acknowledgements

This project was sponsored and funded by the Foothills Landscape Management Forum (FLMF), the Alberta Upstream Petroleum Research Fund, and the Government of Alberta (GOA). Project facilitation was provided by the Petroleum Technical Advisory Council (PTAC). Suncor Energy, ConocoPhillips Canada, and the Canadian Association of Petroleum Producers (CAPP) provided access to previous monitoring reports and data to support the project. Technical review and advice was provided by Dr. Scott Nielsen, Associate Professor in the Faculty of Agricultural, Life & Environmental Sciences, Department of Renewable Resources, University of Alberta, and Tim Vinge, Landscape Restoration Ecologist with Alberta Environment and Parks. Field work was completed by Golder and Aseniwuche Environmental Corporation with support from Highland Helicopters. This report was prepared by Golder Associates Ltd. with contributions from Louise Versteeg, Valerie Coenen, Murdoch Taylor, Christopher Shapka, Brian Coupal, and Paula Bentham.

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

1.1 Background

Woodland caribou (*Rangifer tarandus caribou*) is listed as ‘Threatened’ on Schedule 1 of the *Species at Risk Act* (SARA) (SARA 2015) and by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (COSEWIC 2015). In Alberta, all populations of woodland caribou are listed as threatened under the *Alberta Wildlife Act* (Alberta Sustainable Resource Development [ASRD] 2010) and are designated as “At Risk” (ASRD 2010). Given the current status and continued decline of woodland caribou populations, a number of federal and provincial recovery plans and strategies have been initiated to facilitate the maintenance or recovery of woodland caribou populations in Canada (Government of Alberta [GOA] 2011; British Columbia Ministry of Environment [BC MoE] 2011; Environment Canada [EC] 2012).

At the national level, the federal Recovery Strategy for the Woodland Caribou, Boreal Population in Canada (EC 2012) outlines that all boreal caribou populations are to be self-sustaining and have a minimum of 65% undisturbed habitat in their range (EC 2012). To meet the undisturbed habitat target within boreal caribou ranges, the federal strategy (EC 2012) identifies caribou range planning, specifically coordinated actions to reclaim woodland caribou habitat, as a mitigation step to meeting current and future caribou population objectives. Actions include restoring industrial landscape features such as roads, seismic lines, pipelines, cut-lines, and cleared areas in an effort to reduce landscape fragmentation and the changes in caribou population dynamics associated with changing predator-prey dynamics in highly fragmented landscapes.

Currently, specific range plans for the West Central Alberta caribou ranges, including the Little Smoky caribou range, have not yet been finalized. However, based on the federal recovery strategy, it is expected that the West Central Alberta caribou range plan, as well as subsequent range plans in Alberta, will have a requirement to restore significant amounts of linear disturbances. Habitat restoration (i.e., mechanical site preparation, planting and/or seeding of tree species) as well as implementing access control measures are considered the primary mechanisms to enhance the rate of recovery of linear disturbance features to naturally occurring vegetation (ACCGB 2008; GOA 2013). It is hypothesized that implementation of these types of treatments will benefit woodland caribou by reducing the lag time for vegetation (specifically trees and shrubs) to reach a height where human and predator use is reduced and the linear disturbance can be considered on a trajectory to becoming restored functional caribou habitat. Functional habitat, in regard to habitat restoration of historical linear disturbances, has been defined by the Canadian Association of Petroleum Producers (CAPP 2015) as: "The application of techniques on anthropogenic disturbances that deter the interaction between caribou and their predators in the near term, and supports habitat recovery in the long-term”.

Although caribou habitat restoration activities have been implemented on a variety of linear disturbances in Alberta since 2002, (e.g., Diversified Environmental Services [DES] 2004; CRRP 2007a; Golder 2010, 2012a, 2012b; Oil Sands Leadership Initiative [OSLI] 2012a) very little information has been gathered on the effectiveness of these treatments in accelerating the recovery of vegetation on these linear disturbances to functional caribou habitat. Several organizations, including the Foothills Landscape Management Forum (FLMF), the Petroleum Technology Advisory Council (PTAC) / Canadian Association of Petroleum Producers (CAPP), Foothills Research Institute (fRI), Canada's Oil Sands Innovation Alliance (COSIA), Regional Industry Caribou Collaboration (RICC), University of Alberta, Alberta Environment and Parks (AEP) and associated members, have been engaged in efforts to implement, examine and potentially test the efficacy of habitat restoration as a key management lever for woodland caribou conservation. One area of focus has been to assess the effectiveness of past treatment initiatives, including natural revegetation recovery, as a means to help inform the design and cost of restoring historic linear disturbances. These types of assessments are designed to look at the relative successes and failures of habitat restoration treatments relative to site conditions (i.e., ecosite) and treatment type, including seedling survival, seedling growth rates, unintended consequences, human use, animal use, line of sight, density, crown closure, and primary prey browse species presence.

1.2 Caribou Range Restoration Project

A Caribou Range Restoration Project (CRRP) was first established within Alberta in 2001 (Szkorupa 2002) in an effort to address growing concerns with the relationship between industrial development and declining local caribou populations. At that time, research from James (James 1999) suggested wolves were gaining a predation advantage using linear features created by industry, and that indirect habitat loss for boreal caribou was occurring through the avoidance of habitat adjacent to human disturbance (Dyer 1999; Neufeld 2006; Oberg 2001). In addition, seismic lines were reported to have very slow reforestation rates (Revel et al. 1984; Osko and MacFarlane 2000), with slow tree regeneration attributed to root damage from the original disturbance, compaction of the soil in tire ruts, insufficient light reaching the forest floor, introduction of competitive seed mixes (i.e., plant seed mixes), drainage of sites, and repeated disturbances (e.g., all-terrain vehicles) on seismic lines (MacFarlane 1999 and 2003; Sherrington 2003). Rehabilitation of existing anthropogenic disturbances within caribou range was expected to reduce the degradation of functional habitat over the long-term, with caribou no longer exhibiting avoidance of the disturbance feature (e.g., Oberg 2001). The CRRP piloted techniques with the objectives of promoting revegetation of these linear features, while discouraging access for predator, primary prey, and human use.

The CRRP was a multi-stakeholder group initiated and steered by the provincial government agency Alberta Sustainable Resource Development (ASRD), and the Boreal Caribou Committee (BCC) (Dzus 2001). Although the CRRP was not extended beyond 2007, the project did incorporate silviculture methods based on knowledge of silviculture treatments from the forest industry, focusing on access control treatments and enhancing the vegetation recovery rate of historical seismic lines, pipelines, and lease roads. Treatments included tree/shrub seedling planting, seeding of tree species, tree/shrub transplanting, mounding, spreading of woody debris, and soil de-compaction. Based on the outcome of treatments and learnings on linear restoration, the CRRP prepared a Guidance Document (CRRP 2007a) which included recommended practices for implementing a habitat restoration program, from the planning through to the treatment stages. A monitoring protocol document for revegetation (unpublished) (CRRP 2007b) was also prepared, but no long-term monitoring of treated sites was implemented. It was recognized at the beginning of the program that restoring linear development features is not equivalent to replanting a typical monoculture or mixed stand forestry cutblock'. Linear development features vary with respect to the width and type of initial disturbance, compaction levels, soil types, moisture regimes, and light levels. In addition, restoration objectives often differ, including discouraging predator and human access, and the establishment of vegetation which is not preferred browse for moose or deer.

A number of initiatives and trials established since the CRRP have focused on establishing vegetation and access control treatments on linear development features located within caribou ranges. Restoration programs have been developed under requirements to meet project approval conditions (provincially through Alberta Environmental Protection and Enhancement Act approval conditions for in-situ projects and federal pipeline approvals through the National Energy Board) as well as voluntary programs. Habitat restoration programs have included implementing treatments to encourage native vegetation establishment such as creating microsites using an excavator, seedling planting (tree and shrub species, frozen seedlings) (e.g., Golder 2005; DES 2004; Enbridge 2010; Golder 2010; Golder 2011; Golder 2012a; OSLI 2012a), spreading coarse woody debris (Vinge and Pyper 2012; Pyper and Vinge, 2012) and tree-felling (Cody 2013; OSLI 2012a).

2.0 OBJECTIVES

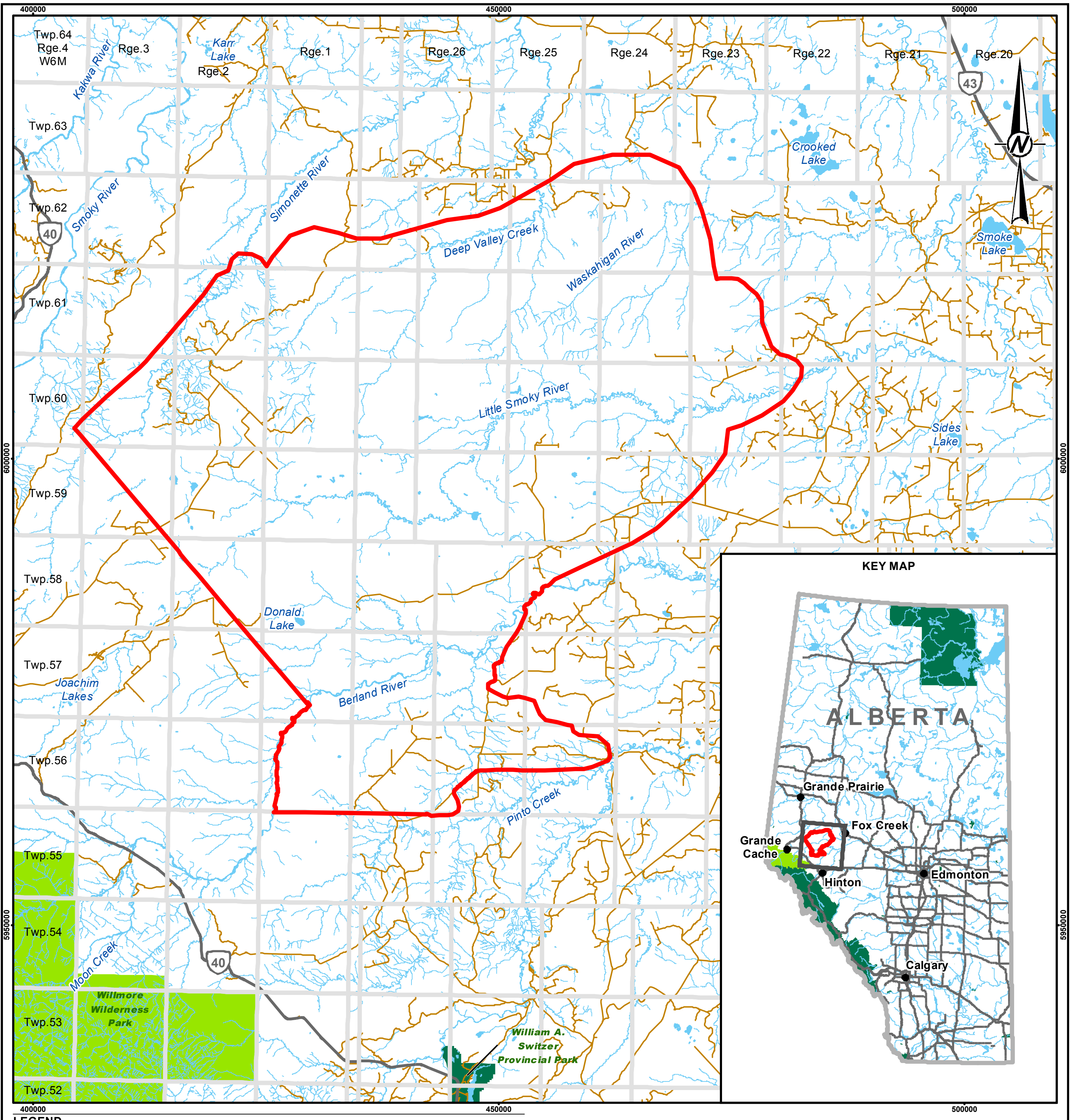
As caribou habitat restoration initiatives have become more widespread across Alberta in the last decade, key uncertainties have been recognized regarding what treatment types are appropriate for habitat restoration, how to measure success, and timelines to reach functional habitat. A trajectory for restored habitat has not been clearly defined in either provincial or federal caribou recovery strategies.

To that end, a collaborative research initiative was initiated by Golder Associates with support from the FLMF, PTAC and the Government of Alberta in 2015 to monitor the vegetation attributes on previously treated sites (from 2001 to 2007) from the CRRP in the Little Smoky caribou range. The treatment sites selected had 9 to 13 growing seasons since initiation of treatment. The purpose of this study is to provide a basis for answering the question of whether or not treating historic linear disturbances through mechanical site preparation, planting and/or seeding of tree species, as well as implementing access control measures, is an effective means of accelerating the natural rate of vegetation recovery on linear disturbances. Understanding the effectiveness of past treatment initiatives is of considerable importance, as vegetation height has been shown to be a significant factor in reducing both human and predator use of linear disturbance features (Dickie 2015; Finnegan et al. 2014). Secondly, understanding the rate of vegetation recovery following the implementation of treatments will inform the time required to achieve functional habitat restoration (e.g., 15 to 25 years for the purposes of meeting critical habitat goals in range planning, as opposed to 40 years).

Given the lack of long-term monitoring results for habitat restoration treatments implemented throughout Alberta, the data collected from treated CRRP sites also provides valuable information that can be used to determine the growth trajectory expectations of seedlings across a range of site conditions (i.e., ecosites) and treatment types.

3.0 STUDY AREA

The area selected for this study is represented by the Little Smoky caribou range, which is located along the eastern slopes of the Rocky Mountains in west-central Alberta, extending from near Fox Creek, Alberta west to Grande Cache, Alberta (Figure 1). The study area encompasses approximately 30 townships from Township 62, Range 22 to 27, W5M to Township 59, Range 23 to 27, W5M and Townships 58 to 62, Ranges 1 to 2, W6M (Figure 1). This area is a highly disturbed landscape as a result of intensive land use including forestry, oil and gas exploration and production, and recreation. The area is also transected by an intensive historical seismic footprint, as well as numerous pipelines, roads and trails.



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●	POPULATED PLACE	🟩	NATIONAL OR PROVINCIAL PARK
—	LOCAL ROAD	🟥	STUDY AREA
—	PRIMARY HIGHWAY	🟦	WATERBODY
—	WATERCOURSE	🟩	WILLMORE WILDERNESS PARK

0 25 50

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REFERENCES

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DATUM: NAD83 PROJECTION: UTM ZONE 11

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CONSULTANT

Golder Associates

YYYY-MM-DD	2015-12-18
DESIGNED	LV
PREPARED	AA
REVIEWED	VC
APPROVED	PB

PROJECT

SEISMIC LINE MONITORING
LITTLE SMOKY

TITLE

STUDY AREA LOCATION

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The study area is primarily located within the Upper Foothills Subregion, with a small section intersecting with the Lower Foothills Subregion to the north and the Subalpine Subregion to the west (Natural Regions Committee 2006). As the study area spans three different subregions, there is wide variability in topography and landscape conditions, ranging from gentling undulating to rolling hills in the Lower Foothills to rolling and inclined landscapes in the Subalpine (Natural Regions Committee 2006). Upland vegetation in the Upper Foothills Subregion is predominantly comprised of closed coniferous forests dominated by pure or mixed stands of lodgepole pine, black spruce and white spruce. In the Lower Foothills these sites typically contain a greater proportion of deciduous or mixedwood stands in association with lodgepole pine (Natural Regions Committee 2006). Upland sites in the Subalpine Subregion are similar to that in the Upper Foothills Subregion and are typically comprised of closed lodgepole pine forests. Wetlands in the both the Upper and Lower Foothills subregions are characterized by a mix of stunted black spruce and larch stands, interspersed with shrubby or graminoid fens (Natural Regions Committee 2006).

4.0 METHODOLOGY

4.1 Approach and Sampling Design

The initial premise behind this study was to compare treated sites ranging in age from 9 to13 years to a range of naturally revegetated sites to determine if there were significant differences in vegetation height, specifically tree species regeneration (regen) height and Robel pole value. Detailed vegetation data by strata, as well as soils and age since disturbance data were collected within the Little Smoky caribou range on naturally revegetated seismic lines in 2008 through a wildlife use study initiated by ConocoPhillips Canada (CPC), Suncor Energy Inc. (Suncor) and CAPP (Golder 2009). While this study primarily involved the use of remote cameras to assess how natural revegetation along linear disturbances affect caribou, predator and alternate prey species mobility and use of these disturbed landscape features, detailed vegetation and soils data were collected on selected sites to provide a broader context for evaluating the vegetation attributes relative to wildlife use. Power analyses using robel pole value and tallest seedling regeneration height data from the 2008 study (Golder 2009) were completed to determine the number of plots per sample unit that needed to be collected in order to have sufficient power for statistical analysis for this study. Both analyses utilized a beta value of 0.20 and an alpha level of 0.05. Sites were split into upland and lowland groups to reduce the amount of within group variability associated with ecological site conditions, resulting in four treatment groups (treatment/control x upland/lowland). Based on the results of the power analysis, it was recommended that 40 plots per sample unit be collected in order to detect a 2 m difference in the tallest regeneration height between treatment groups, and a 100 cm difference in Robel pole value. Thus, a total of 160 plots were recommend for monitoring; 80 treated sites and 80 untreated (natural revegetation) sites, both groups to be split into upland and lowland, for a total of 40 plots per treatment group. For natural revegetation untreated sites, data from 2013 was provided from the fRI. However, as the data collected on untreated sites by fRI was intended for a different use (i.e., human and wildlife use of seismic lines relative to vegetation height), the variables collected were at a different level of resolution than that collected at treated sites and no specific information on age, tree species or vegetation strata were provided. Thus, statistical comparisons of regeneration height between treated and untreated sites using the variables identified in the power analysis could not be completed.

However, an alternative approach focusing primarily on data collected on treated sites was used to understand how planted and naturally ingressing tree seedling species (black spruce and lodgepole pine), responded to site treatment in order to answer the following questions:

- Are planted seedlings significantly taller compared to naturally ingressing seedlings on treated sites?
- Is the average current year's leader growth significantly greater for planted seedlings compared to naturally ingressing seedlings on treated sites?
- Are planted seedlings, or naturally ingressing seedlings, on treated sites significantly taller than seedlings on untreated naturally recovering lines?

Thus, the hypotheses being tested were that both tree seedling height and leader growth will be greater for planted trees compared to naturally ingressing trees and that seedling height on treated lines will be taller compared to untreated naturally recovering lines.

Additionally, growth patterns (i.e., individual tree height-age trajectories) were modelled for both planted and naturally ingressing tree species on treated sites using mean leader growth, mean height and age to determine their respective trajectories. These trajectories provide a basis for comparing the time it takes to reach a specific height threshold, which provides insight into how effective planting is as a treatment option. The mean maximum age and height of lodgepole pine and black spruce from untreated natural recovery sites were also calculated to provide a relative comparison that could be plotted on the respective height – age growth trajectories.

4.2 Data

4.2.1 Data Sources

Data used for the analysis were compiled from the following sources:

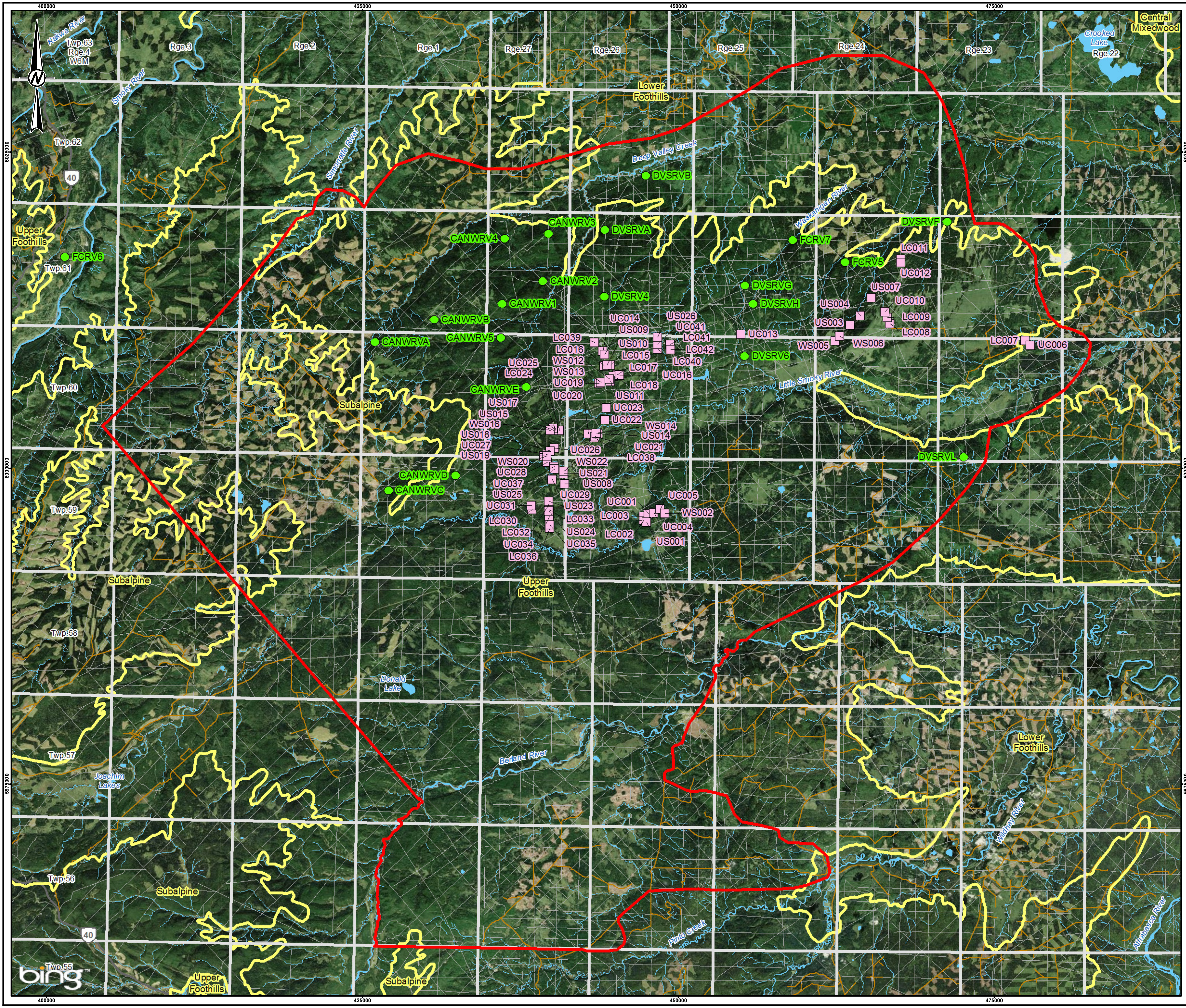
- Wet Areas Mapping (WAM) data (Government of Alberta 2014);
- Data collected in 2015 on treated seismic lines (68 plots);
- Data collected in 2015 on naturally revegetating seismic lines (3 plots); and
- Data from the 2008 ConocoPhillips, CAPP and Suncor Project (Golder 2009) on naturally revegetating seismic lines with mean vegetation heights greater than 1.5 m, black spruce presence and location within the Upper Foothills subregion (13 plots).

In addition, CRRP documents and data were reviewed to incorporate information on treatment date, treatment type (i.e., site preparation and planting method), species planted, planting density and stocking type (where available).

The location of plots in the study area is provided on Figure 2, with associated historical treatment types provided on Figures 3a and 3b.

4.2.2 Data Collection Methods

Treated sites were selected from the range of sites treated under the CRRP program. Selection of treated sites to revisit in 2015 was determined through a review of information on the locations of existing treatment sites in the Little Smoky Range (CRRP 2007b; 2007c; 2007d), along with sampling data collected through the fRI caribou program, in conjunction with a review of recent imagery to identify the most suitable monitoring locations. Sites were selected to be a minimum of 200 to 300 m apart to reduce the effects of spatial dependence, where possible.



LEGEND

- ● 2008 SAMPLE PLOT (NATURALLY REGENERATING)
- ■ 2015 SAMPLE PLOT (TREATED)
- — SEISMIC LINE
- ▭ NATURAL SUBREGION
- ▭ STUDY AREA

BASE DATA

- — LOCAL ROAD
- — PRIMARY HIGHWAY
- — WATERCOURSE
- ■ WATERBODY

0 10 20

1:300,000 KILOMETRES

REFERENCES

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CLIENT

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PROJECT

SEISMIC LINE MONITORING
LITTLE SMOKY

TITLE

LOCATION OF 2015 (TREATED) AND 2008 (NATURALLY REGENERATING) SAMPLE PLOTS

CONSULTANT

Golder Associates

YYYY-MM-DD	2015-12-18
DESIGNED	LV
PREPARED	AA
REVIEWED	VC
APPROVED	PB

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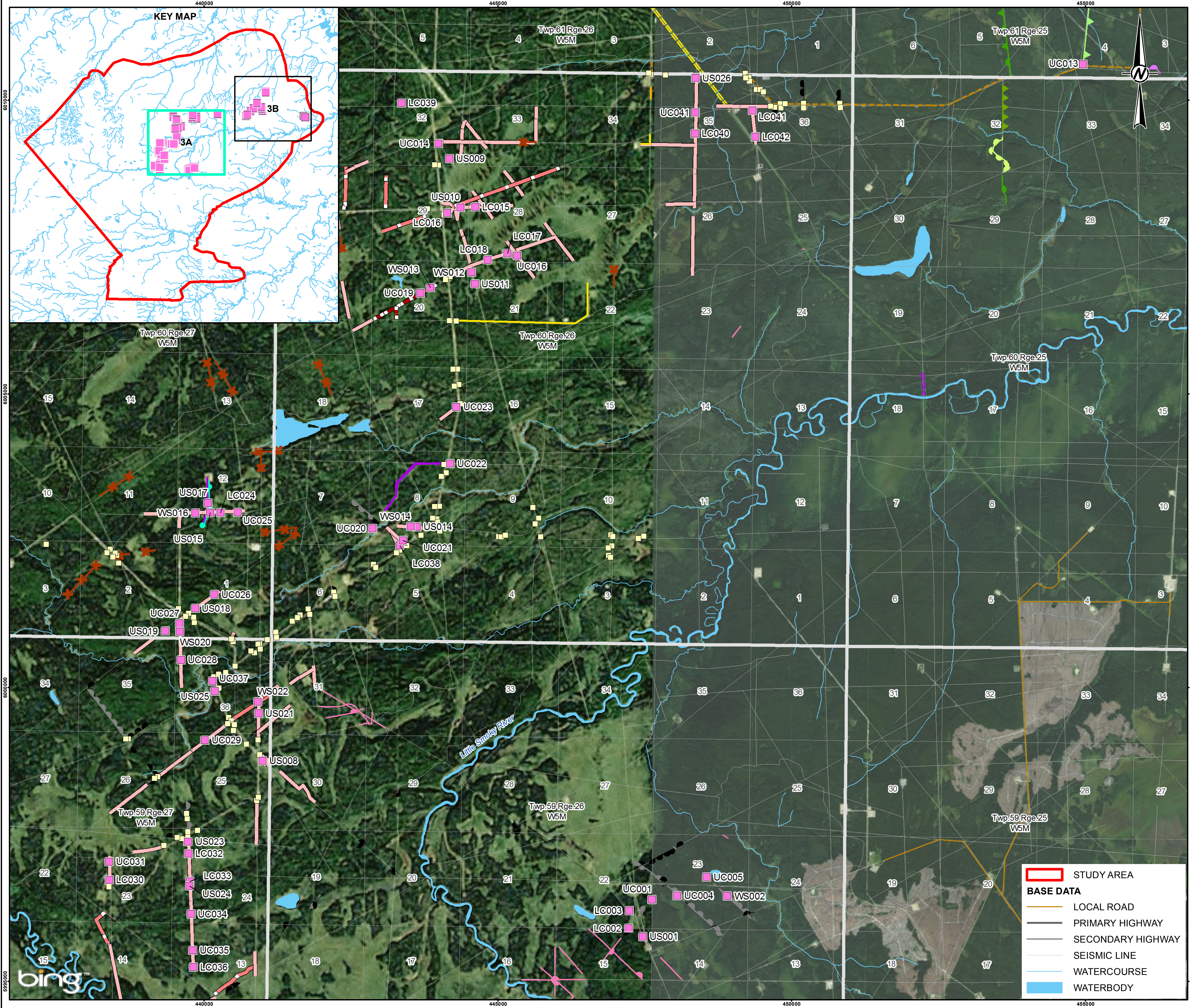

STUDY AREA

BASE DATA

LOCAL ROAD
PRIMARY HIGHWAY
SECONDARY HIGHWAY
SEISMIC LINE
WATERCOURSE
WATERBODY

LEGEND

■ 2015 SAMPLE PLOT (TREATED)

TREATMENT TYPE

PLYWOOD FENCE LOCATION
2001 SUMMER PLANTED
2001 SUMMER PLANTED: PIPELINE
2002 EXCAVATOR MOUNDED
2002 EXCAVATOR MOUNDED: 2003 SPRING PLANTED
2002 EXCAVATOR MOUNDED: 2005 SUMMER PLANTED
2002 SUMMER PLANTED
2002 SUMMER PLANTED: LEASE ROAD
2002 RIPPER TOOTH
2002 RIPPER TOOTH: 2005 SUMMER PLANTED
2002/2003 4 m AVOIDANCE/WOODY DEBRIS: 2003 SUMMER PLANTED
2002/2003 4 m AVOIDANCE/WOODY DEBRIS
2002/2003 TRADITIONAL SEISMIC/WOODY DEBRIS
2003 EXCAVATOR MOUNDED: 2003 SUMMER PLANTED
2003 SPRING PLANTED
2003 SPRING PLANTED: AVOIDANCE
2003 SPRING PLANTED: PIPELINE
2003 SUMMER PLANTED
2003 SUMMER PLANTED: PIPELINE
2003 WOODY DEBRIS/TRADITIONAL SEISMIC: 2003 SUMMER PLANTED
2005 SUMMER PLANTED
DUAL PATH MOUNDER
DUAL PATH MOUNDER 1 PASS
DUAL PATH MOUNDER 3 PASS
EXCAVATOR MOUNDED
FELLED TREES
MOUNDING
PLANTED AS IS
WINTER ACCESS
WOODY DEBRIS/EXCAVATOR MOUNDED

0 2 4
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REFERENCES

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CLIENT
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PROJECT
SEISMIC LINE MONITORING
LITTLE SMOKY

TITLE
DEEP VALLEY 2015 MONITORING PLOTS ON TREATED SITES

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-12-18
DESIGNED	BC
PREPARED	AA
REVIEWED	VC
APPROVED	PB

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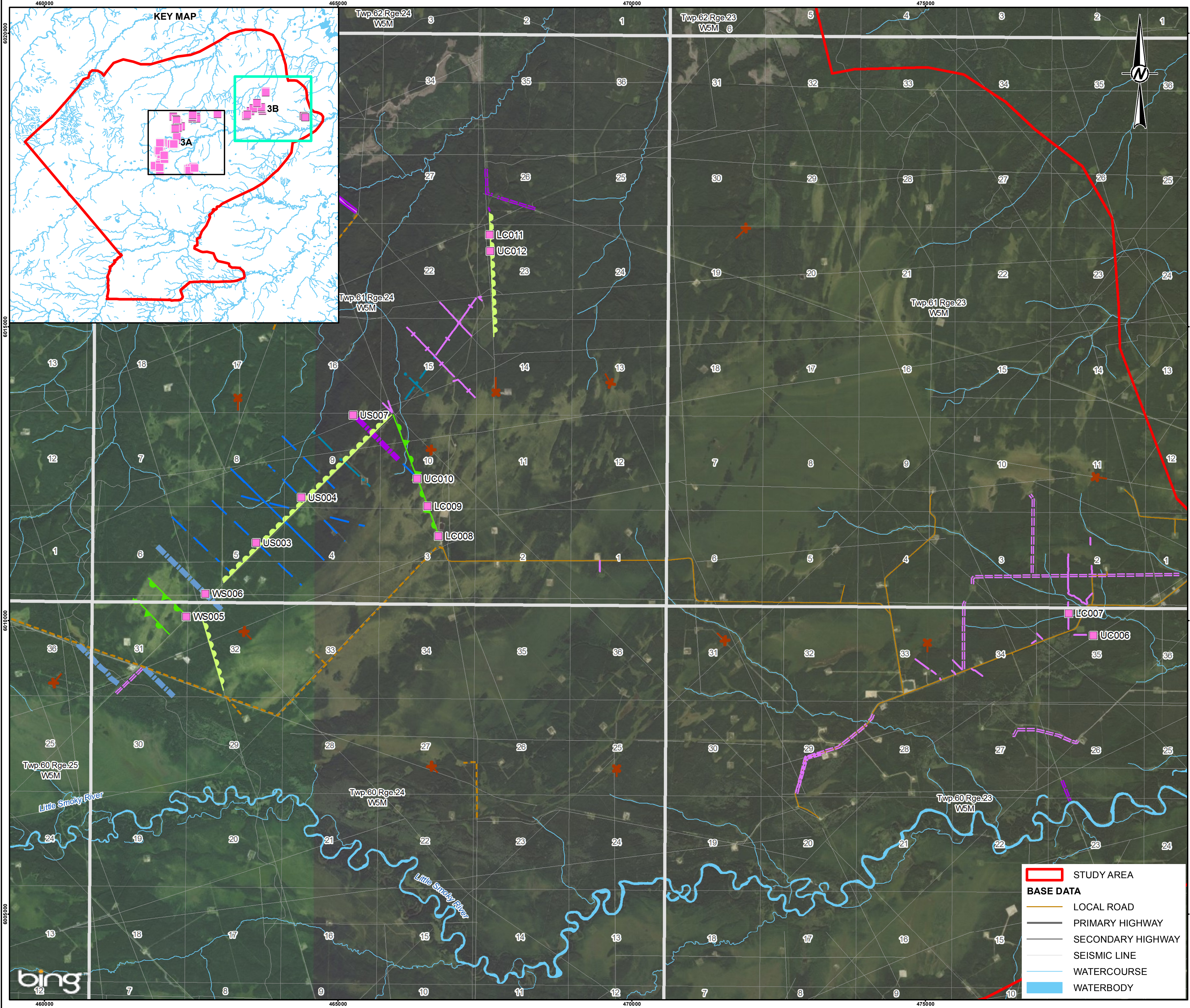

STUDY AREA

BASE DATA

LOCAL ROAD
PRIMARY HIGHWAY
SECONDARY HIGHWAY
SEISMIC LINE
WATERCOURSE
WATERBODY

LEGEND

2015 SAMPLE PLOT (TREATED)

TREATMENT TYPE

PLYWOOD FENCE LOCATION
2001 SUMMER PLANTED
2001 SUMMER PLANTED: PIPELINE
2002 EXCAVATOR MOUNDED
2002 EXCAVATOR MOUNDED: 2003 SPRING PLANTED
2002 EXCAVATOR MOUNDED: 2005 SUMMER PLANTED
2002 SUMMER PLANTED
2002 SUMMER PLANTED: LEASE ROAD
2002 RIPPER TOOTH
2002 RIPPER TOOTH: 2005 SUMMER PLANTED
2002/2003 4 m AVOIDANCE/WOODY DEBRIS: 2003 SUMMER PLANTED
2002/2003 4 m AVOIDANCE/WOODY DEBRIS
2002/2003 TRADITIONAL SEISMIC/WOODY DEBRIS
2003 EXCAVATOR MOUNDED: 2003 SUMMER PLANTED
2003 SPRING PLANTED
2003 SPRING PLANTED: AVOIDANCE
2003 SPRING PLANTED: PIPELINE
2003 SUMMER PLANTED
2003 SUMMER PLANTED: PIPELINE
2003 WOODY DEBRIS/TRADITIONAL SEISMIC: 2003 SUMMER PLANTED
2005 SUMMER PLANTED
DUAL PATH MOUNDER
DUAL PATH MOUNDER 1 PASS
DUAL PATH MOUNDER 3 PASS
EXCAVATOR MOUNDED
FELLED TREES
MOUNDING
PLANTED AS IS
WINTER ACCESS
WOODY DEBRIS/EXCAVATOR MOUNDED

0 2 4
1:65,000 KILOMETRES

REFERENCES

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DATUM: NAD83 PROJECTION: UTM ZONE 11

CLIENT
FOOTHILLS LANDSCAPE MANAGEMENT FORUM,
GOVERNMENT OF ALBERTA, AND
PETROLEUM TECHNOLOGY ALLIANCE CANADA

PROJECT
SEISMIC LINE MONITORING
LITTLE SMOKY

TITLE
FOX CREEK 2015 MONITORING PLOTS ON TREATED SITES

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-12-18
DESIGNED	BC
PREPARED	AA
REVIEWED	VC
APPROVED	PB

PROJECT NO.	CONTROL	REV.	FIGURE
1529431	10	0	**3B**

PATH: I:\2015\1529431\MXD\Wildlife\B_03A_03B_Wildlife_2015Treatments_Mapbook_Rev0_20151218.mxd PRINTED ON: 2015-12-18 AT: 10:59:43 AM

Field surveys were completed by two crews (comprised of one Golder Vegetation Ecologist and one Aseniwuche Environmental Corporation [AEC] assistant) between August 27 and September 3, 2015. The majority of the treatment sites in the Deep Valley area (CRRP 2007c) were accessed by truck and foot via the Deep Valley Road, while remote sites in the area furthest to the east and southeast (CRRP 2007b) were accessed by helicopter. Data were collected on a total of 71 plots (36 upland and 35 lowland plots), 68 plots which occurred within treated sites (Figure 2). Data collection methods for treated sites followed the same protocols as used in the previous monitoring studies (CRRP 2007e; Golder 2009). Information collected at each treated site in 2015 included:

- ecosite phase (classified according to Beckingham and Archibald (1996) or wetland type (according to Halsey et al. 2004) within the adjacent forest stands on either side of the seismic line;
- width of linear feature and visual measurement of line of sight (using Robel pole);
- tree revegetation data (mean height, number of stems, diameter of tallest tree, age of tallest tree,% crown closure) within a 1.78 m radius plot;
- vegetation data (mean height and cover class by strata; species identification and cover estimates of shrubs and dominant understorey vegetation, as well as terrestrial lichens);
- cursory soils information (as soil disturbance on seismic lines, related to various techniques used over the years, may have affected vegetation growth) from a representative location;
- wildlife sign (trail, pellets, browsing), presence of game trails and their estimated usage levels; and
- human activity on line (e.g., all-terrain vehicle [ATV] trail).

A summary of general site information collected at each plot is presented in Appendix A, while photos of each treatment site are provided in Appendix B. Appendix C provides photos of access restriction fences and their condition, as well as other relevant observations.

4.3 Data Analyses

4.3.1 Overview

As the study area spans three natural subregions, all data on treated and naturally revegetating (2008 and 2015) sites used in the analyses were restricted to the Upper Foothills Natural Subregion to reduce the amount of variability in the data that could be attributed to differing vegetation growth patterns from one subregion to another. Additionally, all data were grouped into two site types (upland and lowland) to reduce the amount of within group variability associated with ecological site conditions. The upland site type was restricted to moisture regimes ranging from dry to mesic, while the lowland site type was restricted to moisture regimes ranging from subhygric to hydric. A Geographic Information System (GIS) was also used to determine the seismic line orientation at each plot.

Seventy-one plots were visited, of which three plots (US009, US011 and WS012) were removed from the treated sites as these were identified initially within the CRRP database as ‘to treat’, but upon further review following the field visit were in fact not treated by the CRRP, resulting in 68 treated plots (35 upland and 33 lowland) for analysis. For the purpose of analysis, treatment types were not separated out as the majority of sites were mounded and planted. The primary response variables were mean black spruce height and mean black spruce leader growth (current year) of planted and naturally ingressing seedlings. Mean lodgepole pine height and leader growth (current year) were also analyzed, though only for naturally ingressing seedlings, as lodgepole pine was generally not included in the CRRP planting regime for these sites.

For the untreated, naturally revegetating sites, the 21 potential plots from the 2008 data were filtered based on location within the Upper Foothills subregion as well as for presence of black spruce. This yielded a total of 13 plots from 2008 for inclusion within this analysis. These plots were grouped into 6 upland and 7 lowland plots. In addition to the 13 plots from 2008, three plots (one upland and two lowland) were situated on untreated lines from the 2015 field program. This resulted in 7 upland and 9 lowland naturally regenerating plots for analysis. Mean maximum age and height of lodgepole pine and black spruce were calculated to provide a relative comparison that could be plotted on the respective height – age growth trajectories.

4.3.2 Black Spruce Height and Leader Growth Analysis on Treated Sites

A mixed-effects regression model using R (R Core Team 2015) and the lme4 package (Bates *et al*. 2012) was used to analyze the relationship between black spruce seedling type (i.e., planted or natural ingress), as well as environmental factors on; (a) seedling height and (b) leader height for treated sites. This analysis was only completed for black spruce seedlings, as no comparisons could be made between planted and natural ingress lodgepole pine.

Following tests for normality using the Shapiro-Wilk test, both seedling height and leader growth of black spruce were log transformed prior to running models. Explanatory variables that were entered into the model included seedling type, site type (i.e., upland vs lowland), depth to water from ground surface (derived from WAM data), and percent cover of shrubs. A plot was included as a random effect in the model, at least two observations per plot were required for the model to determine both a residual variance and a within-plot variance. Thus, only treated sites and plots that had at least two individual measurements for black spruce seedlings were included in the model, resulting in a sample size of 51. This value was significantly less than what was prescribed in the 2008 power analysis (i.e., 80 treated plots and 80 reference plots) due to limitations in the reference plot (naturally revegetating) data and the absence of black spruce seedlings at several upland treatment plots.

Competition with understory vegetation has been identified as an important factor in determining the growth and success of conifer seedlings (Brandeis et al. 2001; Caccia and Ballere 1998; Dodet et al*.* 2011). Percentage of total cover for the shrub layer at each monitoring plot was quantified in the field during data collection. For analysis, shrub percentage cover was converted into cover class ([<1%]; [1-5%]; [6-25%]; [26-50%]; [51-75%]; [76-95%]; and [>95% cover]) and included in the model as a fixed effect. Depth to water from ground surface was attributed to each plot, converted into one of five depth categories ([0-0.10m]; [0.10-0.25m]; [0.26-0.50m]; [0.50-1.00m] and [>1.00m from ground surface to water]), and entered into the model as a fixed effect. Time in years since planting or treatment occurred was included as a covariate in the model as seedling height was predicted to be directly related to the age of the treatment (i.e., the time since seedlings were planted or natural ingress occurred). Finally, to account for variability in seedling height within seismic lines, sample plot was included in the model as a random effect. P-values for each of the fixed effects were calculated through likelihood ratio tests whereby the “full” model containing the effect in question was compared to a “null” model with the effect in question absent (Winter 2013).

A mixed-effects multiple regression analysis was also used to determine if there was a significant difference in average black spruce seedling height between treated and untreated (reference) seismic lines. Average black spruce seedling height (included both natural and planted individuals) was calculated for each treatment plot sampled in 2015 (66 plots with black spruce) and each reference plot sampled in 2008 (13 plots with black spruce). An additional three reference plots surveyed in 2015 were included in the analysis in order to bolster the reference sample size, bringing the total to 16 plots. Site type and shrub cover class were included in the models as fixed effects and time in years since disturbance (age) was also included as a covariate. Following tests for normality, average seedling height was square-root transformed prior to running the regression analysis.

4.3.3 Height – Age Trajectory Models for Treated Sites

Height – age trajectory models using mean height and leader growth parameters were developed for planted and natural ingress black spruce seedlings, on upland and lowland site types, as well as natural ingress of lodgepole pine seedlings on upland sites. In order to predict height using leader growth, the annual incremental increase in mean leader growth had to be derived, as leader growth is not constant over time but is presumed to incrementally increase on an annual basis as a tree grows larger.

Mean leader growth was calculated on a plot basis, rather than using individual seedling leader growth, as age data was not available for every seedling. Age was determined by counting the whorls on the seedling's stem (each whorl represents one year of growth), typically for the tallest tree, thus age represents the maximum age of seedlings on a plot. Data was subset to those plots where data was available for both leader growth and maximum age for natural ingress, as age information was not recorded for all naturally ingressing seedlings and not all plots had natural ingress. This resulted in a reduced sample size from which model equations for the annual incremental increase in mean leader growth were derived (31 plots for black spruce analysis and 15 plots for lodgepole pine analysis).

A natural log regression of age and mean leader growth was used to derive the equation to predict the annual incremental increase in mean leader growth for natural ingress of black spruce and lodgepole pine seedlings (Table 1). Site type and organic matter depth were included as explanatory variables in the regression model for black spruce to increase the explanatory power of the model. Although site type and organic matter depth may be related to each other, adding organic depth measurement provided a finer-scale indication of how the environmental conditions may affect leader growth. The lodgepole pine regression model was run with organic matter depth explanatory variables included, but without the site type variable as all plots sampled for pine occurred in upland habitat. Although, seismic line orientation was initially included as an explanatory variable in both the black spruce and lodgepole pine models it did not explain much variation, so it was removed.

As planted seedlings did not have sufficient variability in age (e.g., the majority of planted seedlings were determined to be 9 or 10 years of age) the annual incremental increase in mean leader growth could not specifically be derived for planted species. Thus, the equation derived for naturally ingressing seedlings was applied to the planted seedlings and used to build the resulting height – age trajectory models. This represents a conservative approach as it is likely that leader growth on planted seedlings would increase at a faster rate compared to naturally ingressing seedlings.

Table 1: Model equations for predicting annual incremental increase of leader growth for naturally ingressing tree species.

Tree Species	Site Type	Equation	Sample Size	R^2	P-Value
Black Spruce (Sb)	Upland	y = 1.6397+0.839*(ln(age))+0.0194(Avg. Organic Depth of All plots)	31	0.3072	0.018
Black Spruce (Sb)	Lowland	y = 1.6397+0.839*(ln(age))+ 1.319(1) +0.0194(Avg. Organic Depth of All plots)			
Lodgepole Pine (Pl)	Upland	y = 2.425+4.147*(ln(age))+[(-.4697)(Avg. Organic Depth)]	15	0.6108	0.003

where: y = predicted annual incremental increase in mean leader growth
x = age
ln = natural log.

The predicted annual leader growth was then modelled over time using mean leader growth and mean maximum age of tree seedlings as the start point from which the predicted leader growth per year was determined by site type (upland or lowland) using the following formulas (where x=mean maximum age of tree seedlings).

- Predicted annual leader growth of natural ingress black spruce (age x+1) on upland sites = mean leader growth of natural ingress black spruce (age x) on upland sites + predicted annual incremental increase in mean leader growth of natural ingress black spruce (age x+1) on upland sites.
- Predicted annual leader growth of planted black spruce (age x+1) on upland sites = mean leader growth of planted black spruce (age x) on upland sites + predicted annual incremental increase in mean leader growth of natural ingress black spruce (age x+1) on upland sites.
- Predicted annual leader growth of natural ingress black spruce (age x+1) on lowland sites = mean leader growth of natural ingress black spruce (age x) on lowland sites + predicted annual incremental increase in mean leader growth of natural ingress black spruce (age x+1) on lowland sites.
- Predicted annual leader growth of planted black spruce (age x+1) on lowland sites = mean leader growth of planted black spruce (age x) on lowland sites + predicted annual incremental increase in mean leader growth of natural ingress black spruce (age x+1) on lowland sites.
- Predicted annual leader growth of natural ingress lodgepole pine (age x+1) on upland sites = mean leader growth of natural ingress lodgepole pine (age x) on upland sites + predicted annual incremental increase in mean leader growth of natural ingress lodgepole pine (age x+1) on upland sites.

A similar process was used to build the height – age trajectory model using the following equations (where x=mean maximum age of tree seedlings).

- Predicted height of natural ingress black spruce (age x+1) on upland sites = mean height of natural ingress black spruce (age x) on upland sites + predicted annual leader growth of natural ingress black spruce (age x+1) on upland sites.
- Predicted height of planted black spruce (age x+1) on upland sites = mean height of planted black spruce (age x) on upland sites + predicted annual leader growth of natural ingress black spruce (age x+1) on upland sites.
- Predicted height of natural ingress black spruce (age x+1) on lowland sites = mean height of natural ingress black spruce (age x) on lowland sites + predicted annual leader growth of natural ingress black spruce (age x+1) on lowland sites.
- Predicted height of planted black spruce (age x+1) on lowland sites = mean height of planted black spruce (age x) on lowland sites + predicted annual leader growth of natural ingress black spruce (age x+1) on lowland sites.
- Predicted height of natural ingress lodgepole pine (age x+1) on upland sites = mean height of natural ingress lodgepole pine (age x) on upland sites + predicted annual leader growth of natural ingress lodgepole pine (age x+1) on upland sites.

Lower and upper 95% confidence intervals were calculated for each height – age trajectory model.

5.0 RESULTS

5.1 General Observations

A total of 68 treated sites (35 upland and 33 lowland sites) were visited in 2015. Overall, treated lines were found to have little to no recent signs of ATV/UTV use and more than half of the wooden fences installed for access control were found to be in relatively good condition (Appendix C). Wildlife sign, including tracks or scat, were recorded at 38 of the 68 treated sites visited. A total of 14 of these sites with wildlife sign also had established game trails. Mounding was the primary site treatment applied to these lines (69% of upland sites and 85% of lowland sites) (Table 2) and black spruce was the primary species planted on the mounds. One observation noted from the field was that mounds degraded over time and were more obvious in upland sites compared to lowland sites. Mounding also provided suitable microsites for natural ingress and both planted and natural ingress species could be present on mounds, which made it challenging to discern planted from natural ingress as planted seedlings were not tagged or marked in any way.

Field observations of planted black spruce seedlings noted increased mortality and necrotic symptoms in planted seedlings associated with very dry or very wet sites. Conversely, planted and natural ingress seedlings were found to be doing very well in transitional sites (e.g., h1 Labrador-tea subhygric lodgepole pine-black spruce ecosites). However, in several cases it was noted that black spruce seedlings planted on mineral soil often had necrotic symptoms and occasionally poor lateral root development, likely arising from a lack of adventitious root development (e.g., Photos C-16 and C-17, Appendix C) (Tim Vinge, pers. com). These observations are likely reflective of the drier site conditions present in upland sites, as well as the relative lack of organic matter, and possibly lower light regimes. The mounds in particular tended to be very dry which would inhibit rooting, as evidenced by the lack of lateral rooting on many of the planted seedlings on the upland mounds. Upland sites tended to have a greater percent cover of mineral soil and cobbles and stones (11.20% and 4.63%, respectively) compared to lowland sites (0.03% and 0.03%, respectively). Organic matter depth was also considerably less on upland sites (1.69 cm) compared to lowland sites (53.73 cm) (Table 2). In general, the upland sites had greater canopy closure than the lowland sites. As black spruce was the primary tree species planted on both upland and lowland treated lines, the poor growth on upland sites may be attributed to the nature of the treatments applied to these sites (e.g., mounding and planting of black spruce on the mounds) in combination with other factors, such as reduced solar insolation, and decreased moisture or nutrient availability for the planted black spruce (Lavoie et al. 2007b).

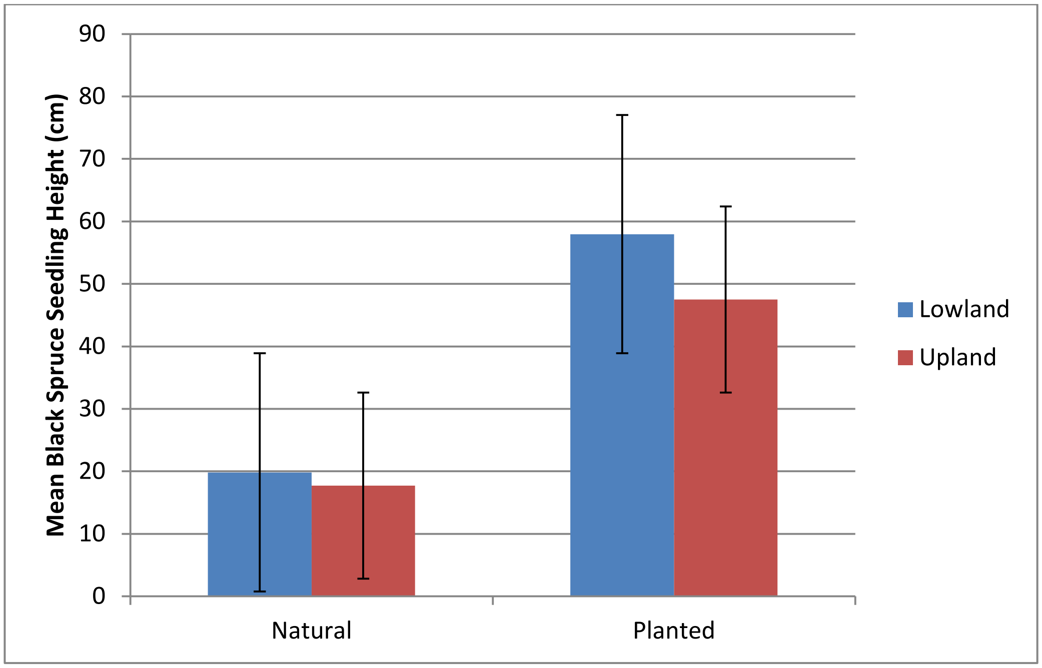
Table 2: General Site Characteristics and Treatments Applied to Treated Upland and Lowland Sites.

Site Characteristics	Upland	Lowland
Sample Size	35	33
Associated Ecosites	d1 Labrador-Tea Mesic PL-Sb [31]	h1 Labrador-Tea Subhygric PL-Sb [14]
	e1 Tall Bilberry/Arnica Pl [3]	Wooded Bog [1]
	e3 Tall Bilberry/Arnica Sw [1]	Wooded Fen [18]
Drainage	rapid to moderately well	imperfectly to poorly
Moisture Regime	3-subxeric to 5-mesic	6-subhygric to 9-hydric
Mean Depth of Organic Layer (cm)	1.69	53.73
Mean Percent Surface Water	0.00	0.73
Mean Percent Mineral Soil	11.20	0.03
Mean Percent Cobbles & Stones	4.63	0.03
Mean Percent Organic Matter	80.89	97.70
Mean Percent Decaying Wood	3.91	1.52
Seismic Line Orientation		
E-W	10	11
NE-SW	9	6
N-S	9	12
NW-SE	7	4
TREATMENT TYPE SUMMARY (Number of sites per treatment type)		
Mound - No Plant	1	1
Mound+Plant	24	28
Mound+Slash Rollback+Plant	1	1
Plant	6	1
Rip+Plant	1	0
Slash Rollback	1	1
Slash Rollback+Plant	1	1

5.2 Height and Leader Growth Response on Treated Sites

The results of the mixed effect regression model comparing the heights of planted seedlings to naturally revegetating seedlings along treated seismic lines indicated that planted black spruce seedlings were significantly taller (mean height = 53.80 ± 1.81 [SE] cm) compared to naturally regenerating seedlings (mean height = 18.70 ± 0.69 cm) ($X^2_{(1)}$ = 307.78, p <0.001). Site type had a significant effect on black spruce seedling height ($X^2_{(1)}$ = 6.85, p = 0.009). Individual planted seedlings associated with lowland sites were significantly taller (mean height = 29.90 ± 1.51 cm) than individuals growing in upland sites (mean height = 24.56 ± 1.01 cm). Overall, lowland sites on average had taller seedlings, with planted individuals being taller than naturally ingressing individuals, as shown in Figure 4.1. Treatment age, shrub cover and depth to water did not have a significant effect on the height of all black spruce seedlings (planted and natural ingress) measured on seismic lines.

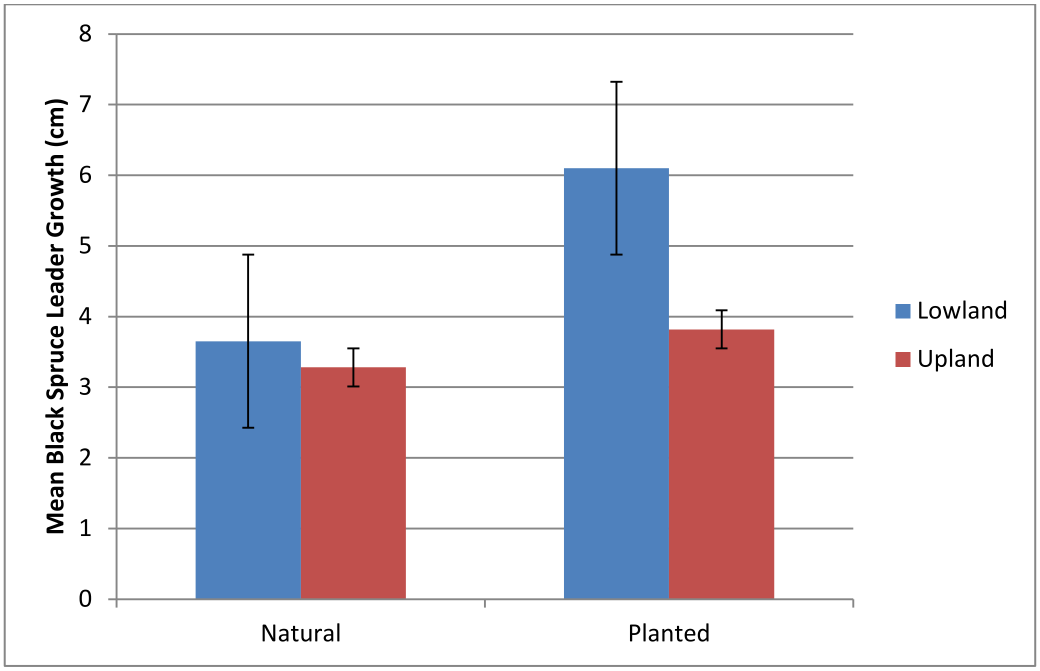
Figure 4.1: Comparison of Planted and Natural Black Spruce Seedling Mean Height +/- Standard Error on Lowland and Upland Sites.



Leader growth of black spruce seedlings showed similar patterns to those observed in the total height analysis. Black spruce seedling type ($X^2_{(1)}$ = 20.64, p <0.001) was found to have a significant effect on leader growth with planted individuals showing greater leader growth (4.98 ± 0.28 cm) than natural ingress (3.45 ± 0.13 cm). Leader growth was also significantly affected by site type ($X^2_{(1)}$ = 4.62, p = 0.03) with greater leader growth recorded at lowland sites (4.36 ± 0.23 cm) compared to upland sites (3.42 ± 0.10 cm). Overall, lowland sites on average had greater seedling leader growth, with planted leader growth greater than naturally ingressing leader growth, as shown in Figure 4.2.

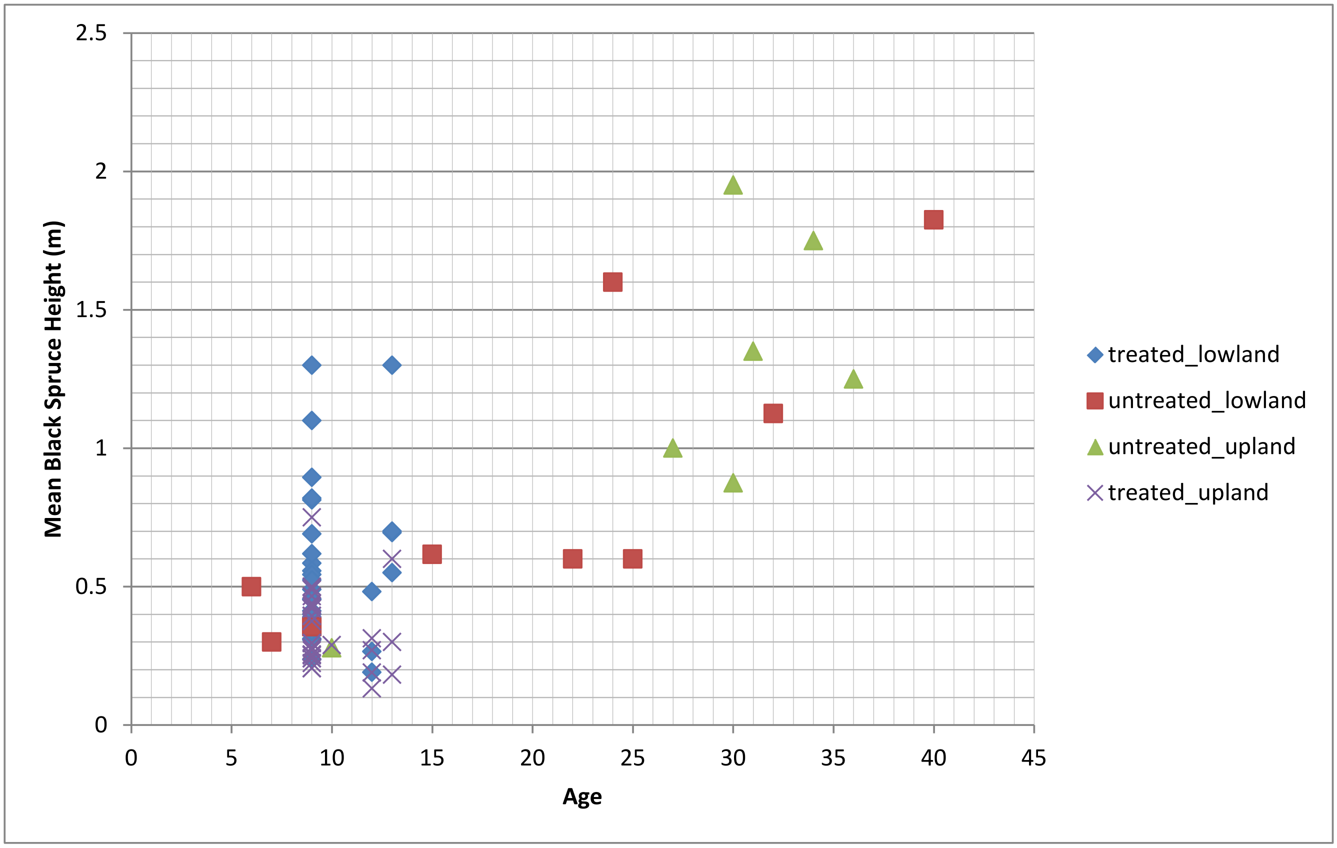
When the model for leader growth was initially run, shrub cover class showed a significant effect on leader growth in black spruce seedlings ($X^2_{(3)}$ = 38.81, p <0.001). Upon closer inspection, the effect appeared to be largely driven by measurements for two outliers occurring in plots with <1% shrub cover. As these two seedlings were the only individuals recorded that occurred at sites with less than 1.0% shrub cover, the points were removed from the dataset and the model was re-run. Model results following the removal of the two outlier points indicated that shrub cover did not have a significant effect on leader growth ($X^2_{(2)}$ = 1.94, p <0.38). Treatment age and depth to water were also found to not have a significant effect on the leader growth of black spruce seedlings (planted and natural ingress).

Figure 4.2: Comparison of Planted and Natural Black Spruce Mean Leader Growth +/- Standard Error on Lowland and Upland Sites.



The results of the multiple regression model indicated that black spruce seedlings growing at treated plots (mean height = 44.67 ± 24.26 [SE] cm) were not significantly taller ($t_{(74)}$ = 0.445, p = 0.657) than seedlings growing in untreated naturally revegetating plots (mean height = 99.85 ± 56.94 cm). As expected, time since disturbance (e.g., age) had a significant effect on seedling height ($t_{(74)}$ = 5.421, p <0.001) and explained the majority of the variability in the model, as height increases over time (Figure 4.3). However, site type did show a significant effect on mean seedling height ($t_{(75)}$ = 3.143, p <0.001). Mean height for seedlings associated with lowland plots were significantly taller (mean height = 62.07 ± 36.80 cm) than individuals growing in upland plots (mean height = 48.82 ± 41.32 cm). Shrub cover did not have a significant effect on mean seedling height. The strong influence of age as a significant factor in the model, coupled with the high degree of variability in the data and limited sample size for untreated naturally revegetating sites may be one reason why significant differences in mean black spruce height on treated versus untreated plots could not be detected.

Figure 4.3: Comparison of Black Spruce Mean Height and Age on Treated versus Untreated Naturally Revegetating Lowland and Upland Sites.



5.3 Height – Age Trajectory Models for Treated Sites

The results of the height – age trajectory models for black spruce and lodgepole pine provides a means for evaluating the relative amount of time (i.e., years) that it will take a seedling to reach specific height thresholds. As these predicted height – age trajectory models are based entirely from modelling the annual incremental change in leader growth and applying that model to the mean leader growth present at the current age of the trees to predict height, these models are not intended to be used in the same manner as traditional site index curves or growth intercept models. However, these models were compared to provincial subregion based site index curves for black spruce (Huang 1997) and lodgepole pine (Huang et al. 1997) to assess if the predicted height – age trajectory models were in line with the standard approach (i.e., were not grossly under or overestimating the height – age trajectory).

Additionally, height thresholds of 1.4 m and 2.7 m were chosen as potential key indicators that influence the use of seismic lines by predators such as wolves, and human use. Research by both Dickie (2015; 2015 pers. comm.) and Finnegan et al. (2014) has reported that once vegetation height reaches certain heights, the vegetation either slows down predators and/or acts as a deterrent to both human and predator use. Finnegan et al. (2014) summarized that at vegetation heights greater than 1.4m movement rates of both wolves and adult grizzly bears decreased by 70%, and that a change point in human use occurs at vegetation heights of approximately 2 m after which human use decreases dramatically. Within the Little Smoky caribou range, Finnegan et al. (2014) classified seismic lines with vegetation heights less than 1.4 m as high human/predator use, vegetation heights between 1.4 m and 2 m as moderate human/predator use, and seismic lines with vegetation height greater than 2 m as low human/predator use. Dickie (pers. comm. 2015) found that wolves changed their movement on linear features with increasing vegetation height, with a breakpoint of 1 m in summer and 2.7 m in winter. When travelling on linear features, wolf travelling speed decreased by 20% after linear features reached a height of 1m in summer, and travelling speed decreased by 26% after lines reached 2.7 m in winter (M. Dickie pers. comm.). When on linear features, wolves selected and moved faster on linear features with shorter vegetation. Although vegetation reaching a height beyond 1 m on linear features reduced movement in summer, Dickie (2015) reported that vegetation did not decrease wolf travelling speed in winter until it exceeded 5 m. Compared to linear features with vegetation heights less than 1 m, wolves moved 24% and 13% slower when vegetation reached 1 - 2 m and 2 - 5 m, respectively, in summer. However, Dickie (2015) also noted that wolves moved 20% faster when vegetation was 1 - 2 m tall compared to linear features with vegetation heights less than 1 m in winter. In winter, wolves did not move slower on linear features with taller vegetation until the feature exceeded 5 m in vegetation height (44% slower travel speed).

5.3.1 Black Spruce

The results of the height – age trajectory models for black spruce on both lowland and upland sites appear to provide a reasonable estimate of height when compared to the provincial site index curves for black spruce in the Upper Foothills Subregion (Huang 1997), as the predicted height of approximately 5.5 m (natural) to 7.0 m (planted) at age 50 for lowland sites and 5.0 m (natural) to 7.0 m (planted) at age 50 for upland sites is within the boundaries of the predicted site index at age 50, which range from 3 m to 26 m (Huang 1997). However, as these results fall towards the lower bound of the site index curve for black spruce in the Upper Foothills Subregion, this may indicate that the predicted height – age trajectory model is underestimating growth of black spruce. This may be attributed to the fact that the majority of the sites sampled are located in more nutrient poor ecosystems (e.g., d1 Labrador-tea mesic lodgepole pine-black spruce ecosites) under low light regimes and are often lacking in required levels of organic matter. Additionally, the model used to predict annual incremental change in leader growth is based on a small sample size and only explains about 30% (R^2=31) of the variability in leader growth, though the model was significant (p=0.018).

The results show that planted black spruce seedlings on lowland sites have better growth potential compared to natural ingress and generally is predicted to be an average of 0.4 m taller than natural ingress black spruce seedlings at younger ages (e.g., 10 to 15 years). This height differential increases over time with planted black spruce seedlings predicted to be on average, 1.5 m taller than natural ingress black spruce seedlings at age 50 (Figure 4.4). Based on these results, planted black spruce are predicted to reach a height of 1.4 m an average of 5 years earlier than natural ingress. The time to reach 2.7 m is also reduced in planted black spruce seedlings (22 years) compared to natural ingress black spruce seedlings (29 years). Both planted and natural ingress of black spruce on treated sites are predicted to reach the 1.4 m height threshold a minimum of 5 to 10 years earlier than what is observed on naturally recovering seismic lines (Figure 4.4).

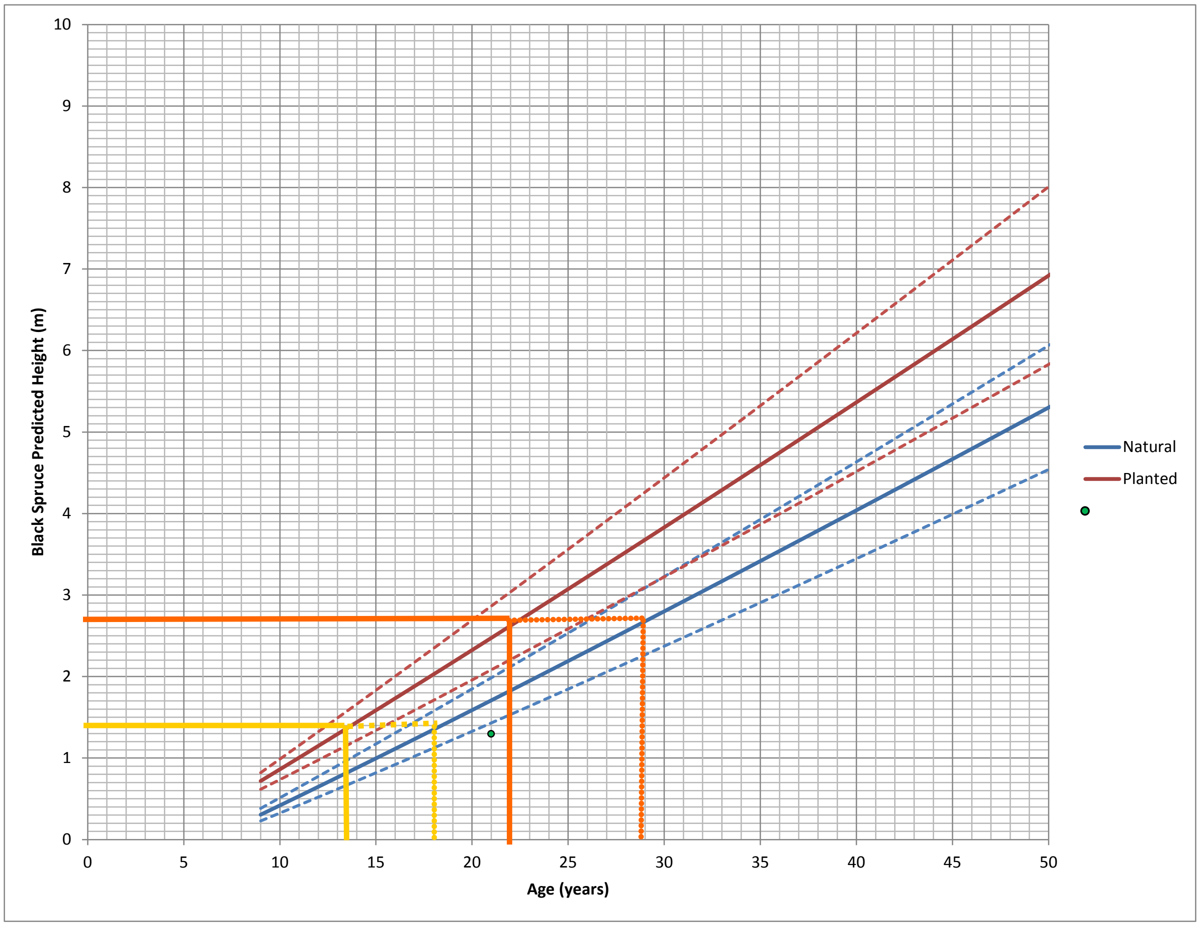
A similar, though less definitive, trend was observed for predicted black spruce height on upland sites for planted and natural ingress black spruce seedlings (Figure 4.5). In general, planted black spruce seedlings are predicted to be an average of 0.4 m taller than natural ingress black spruce seedlings, with minimal change in growth rates. Based on these results, planted black spruce are predicted to reach a height of 1.4 m an average of 4 years earlier than natural ingress. The time to reach the 2.7 m height is also reduced in planted black spruce seedlings (37 years) compared to natural ingress black spruce seedlings (42 years). However, a comparison with mean height and age of black spruce on naturally recovering seismic lines (2.1 m at age 28) seems to indicate that treated upland sites do not appear to accelerate the rate of recovery using the data from this study (Figure 4.5).

5.3.2 Lodgepole Pine

The results of the height – age trajectory model for lodgepole pine on upland sites appear to provide a reasonable estimate of height when compared to the provincial site index curves for lodgepole pine in the Upper Foothills Subregion (Huang et al. 1997), as the predicted height of approximately 10 m at age 50 is within the boundaries of the predicted site index at age 50, which range from 6 to 28 m (Huang et al. 1997). Although the explanatory power of the annual incremental change in leader growth model for lodgepole pine is quite high (R^2=61, p=0.003), the results of the height – age trajectory model fall towards the lower bound of the site index curve for lodgepole pine in the Upper Foothills Subregion, which may indicate that the predicted height – age trajectory model is underestimating growth of lodgepole pine. This may also be attributed to the fact that the majority of the sites sampled are located in more nutrient poor ecosystems (e.g., d1 Labrador-tea mesic lodgepole pine-black spruce ecosites).

The results presented are only for natural ingress of lodgepole pine on treated upland sites, as lodgepole pine was not part of the treatment regime applied by the CRRP to the majority of the treated sites in the study area. Based on the height – age trajectory model, lodgepole pine is predicted to reach 1.4 m height by age 11 and 2.7 m height by age 17 (Figure 4.6). When compared to the mean height and age of lodgepole pine on naturally recovering seismic lines (4.1 m at age 27) there is little difference in the predicted time it takes natural ingress lodgepole pine to reach 4.1 m (approximately one year earlier than lodgepole pine on untreated naturally recovering seismic lines) (Figure 4.6). However, these results are preliminary as the sample size for lodgepole pine on untreated naturally recovering seismic lines is very low (n=6) and likely does represent the range of variability one would expect on naturally recovering seismic lines for that age. Thus, no definitive conclusions can be drawn regarding the effect of site preparation on natural ingress of lodgepole pine on treated upland sites.

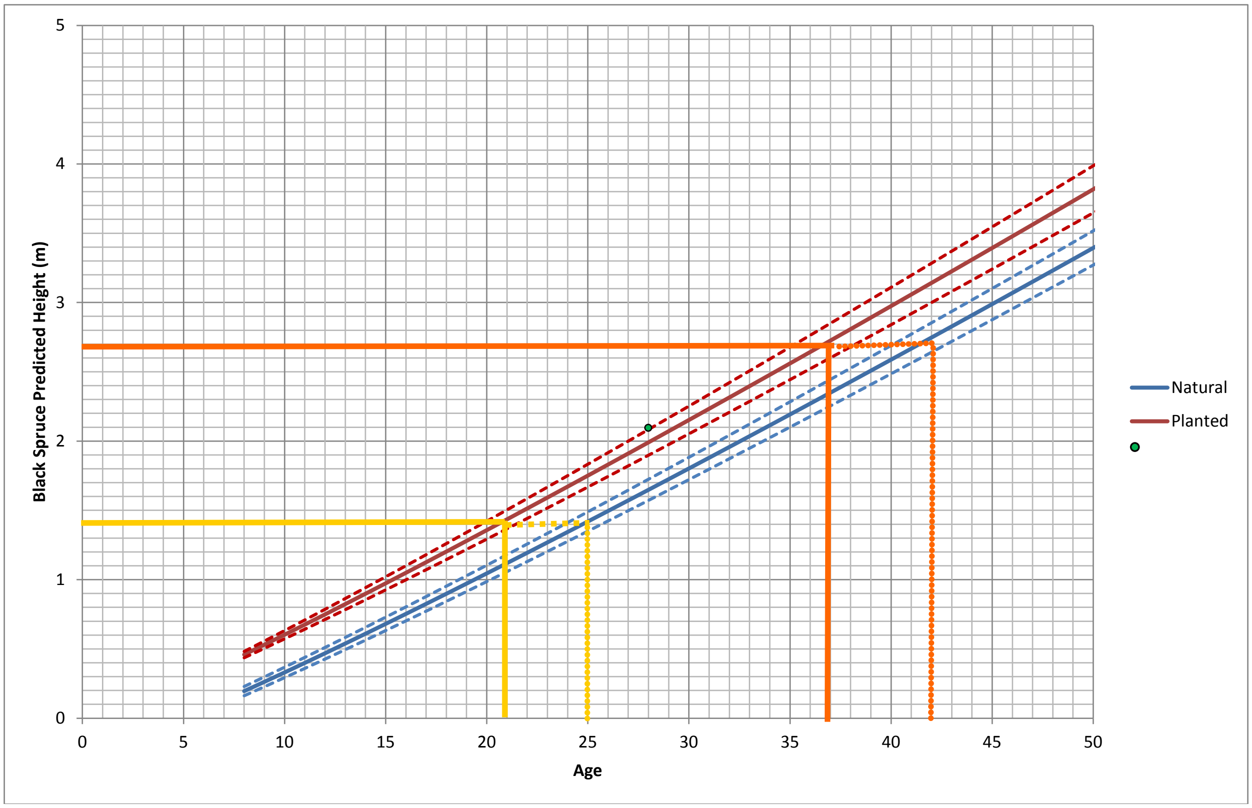
Figure 4.4: Height – Age Trajectory Models for Planted and Natural Black Spruce on Lowland Sites



Notes:

Red and blue solid lines represent predicted height-age trajectory for planted and natural ingress, respectively;
Red and blue dashed lines represent upper and lower 95% CI around predicted height-age trajectory for planted and natural ingress, respectively;
Orange solid and dashed line represents illustrates predicted age to reach 2.7 m height threshold for planted and natural ingress, respectively;
Yellow solid and dashed line represents illustrates predicted age to reach 1.4 m height threshold for planted and natural ingress, respectively; and
Green circle represents mean maximum height and age of black spruce on naturally recovering lines that were not treated.

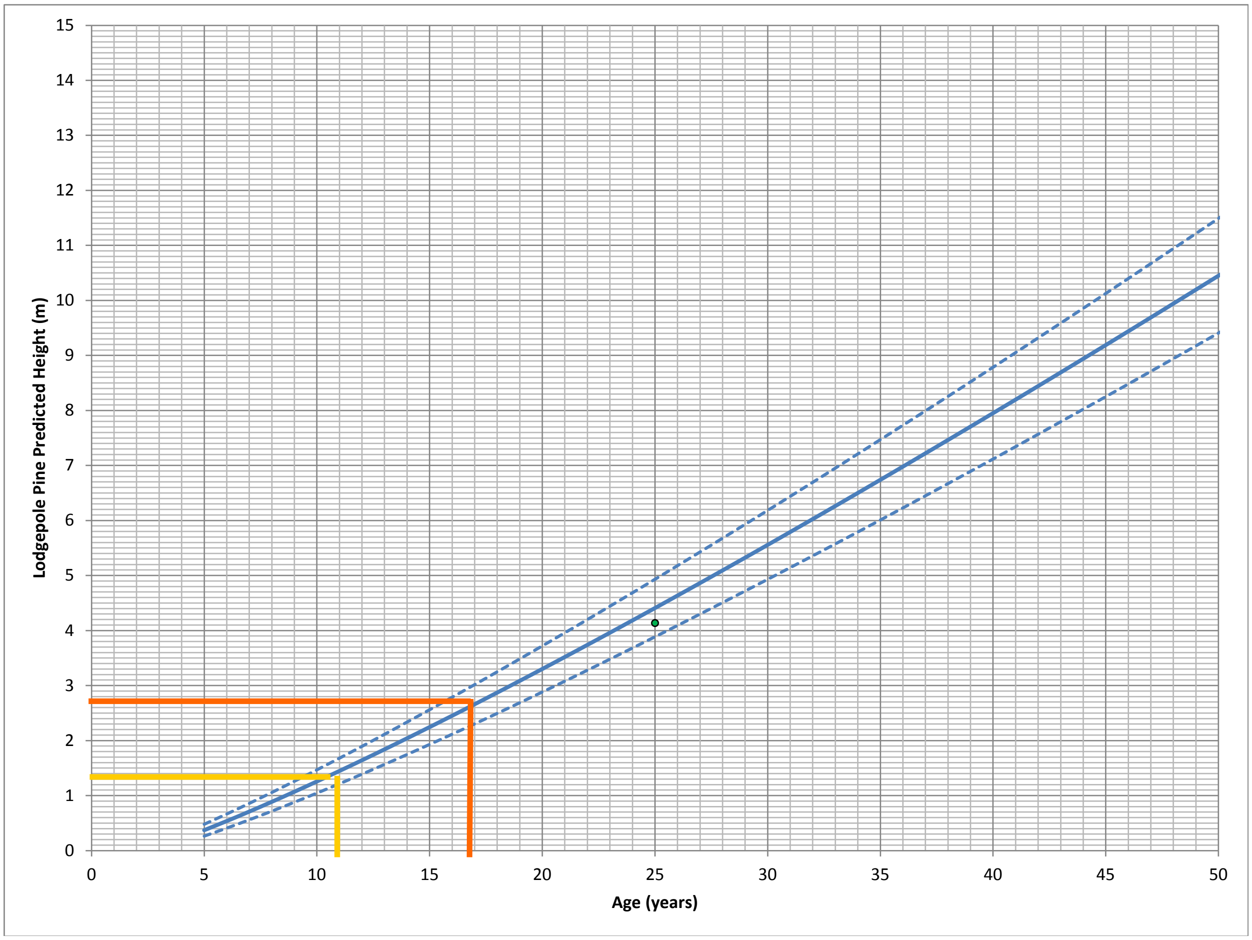
Figure 4.5: Height – Age Trajectory Models for Planted and Natural Black Spruce on Upland Sites



Notes:

Red and blue solid lines represent predicted height-age trajectory for planted and natural ingress, respectively;
Red and blue dashed lines represent upper and lower 95% CI around predicted height-age trajectory for planted and natural ingress, respectively;
Orange solid and dashed line represents illustrates predicted age to reach 2.7 m height threshold for planted and natural ingress, respectively;
Yellow solid and dashed line represents illustrates predicted age to reach 1.4 m height threshold for planted and natural ingress, respectively; and
Green circle represents mean maximum height and age of black spruce on naturally recovering lines that were not treated.

Figure 4.6: Height – Age Trajectory Models for Natural Lodgepole Pine on Upland Sites



Notes:

Blue solid lines represent predicted height-age trajectory natural ingress;
Blue dashed lines represent upper and lower 95% CI around predicted height-age trajectory for natural ingress;
Orange solid and dashed line represents illustrates predicted age to reach 2.7 m height threshold for natural ingress;
Yellow solid and dashed line represents illustrates predicted age to reach 1.4 m height threshold for natural ingress; and
Green circle represents mean maximum height and age of lodgepole pine on naturally recovering lines that were not treated.

6.0 DISCUSSION

Although few comprehensive long-term studies have been completed on the natural recovery of seismic lines, a study by Revel et al. (1984) in the Boreal Foothills, Boreal uplands and Sub-alpine ecoregions found that the natural recovery of trees on seismic lines was generally poor as evidenced by slow growth rates. Few conifer seedlings attained a height of 2.0 m in the period of 10 to 30 years, primarily a result of the cutting or re-shooting of lines. Additionally, growth rates of regenerating trees on seismic lines was much lower compared to trees in clear cuts, as regenerating lodgepole pine and black spruce seedlings on seismic lines reached a maximum height of 0.47 m and 1.32 m, respectively at age 11, compared to 6.5 m and 2.5 m (at age 15), for regenerating lodgepole pine and black spruce on a clear cut (Revel et al. 1984). In general, natural recovery and regeneration of tree cover along seismic lines is affected by competition from ground cover such as grasses and shrubs, time since disturbance, method of disturbance during seismic line creation, species composition of adjacent forest and human/wildlife use of the lines (Revel et al. 1984). More recent research by van Rensen et al. (2015) investigating the factors influencing natural regeneration of trees and shrubs on seismic lines found that there was an inverse relationship between regeneration to 3 m and terrain wetness, line width, proximity to roads (as a proxy for human use) and lowland ecosites. Model predictions of future regeneration rates on seismic lines also suggested that regeneration of trees and shrubs on at least one-third of existing seismic lines would fail to reach 3.0 m height after 50 years (van Rensen et al. 2015), which illustrates the importance of accelerating natural recovery trajectories on seismic lines.

Much of the research to date has focused on understanding wildlife use and response to linear disturbance features (James and Stuart-Smith 2000; Oberg 2001; Golder 2009; Latham et al. 2011a, 2011b, Finnegan et al. 2014; Dickie 2015). However, very few studies have focused on assessing the effectiveness of restoration measures in accelerating vegetation recovery, particularly with regards to what treatments (e.g., access control, site preparation, planting seedlings, seeding) are applied, where, and under what conditions. The premise behind treating an area is to accelerate the rate of vegetation recovery, specifically of trees and shrubs, to reduce the amount of time it takes to reach a height that can be considered functional habitat from a caribou perspective.

Recent research by Dickie (2015) has shown that that vegetation height is a significant factor affecting wolf selection of seismic lines. On average, wolf travelling speed decreased with increasing vegetation height and wolves were found to select lines with shorter vegetation compared to taller vegetation. Of particular note, wolf travelling speed in summer decreased by 20% once vegetation reached a height of 1.0 m and wolf travelling speed in winter decreased by 26% once vegetation reached a height of 2.7 m (Dickie pers. comm.). Once vegetation reached a height of 5.0 m, wolves no longer selected these lines for travel (Dickie 2015). Finnegan et al. (2014) also reported similar results, where the movement rates of both wolves and grizzly bears decreased by up to 70% on seismic lines where vegetation height exceeded 1.4 m. Additionally, human use of seismic lines was significantly affected by vegetation height, with moderate to high intensity use by humans declining markedly once vegetation height exceeded 2.0 m (Finnegan et al. 2014). Both studies used GPS collar data to estimate changes in predator travel speeds but identified different vegetation height thresholds, possibly due to differences in the study area location. Finnegan et al. (2014) conducted their study in west-central Alberta, in the same areas as this present study, whereas Dickie's (2015) study was located in northeastern Alberta. Thus, the results from this research provide a preliminary benchmark for when seismic lines can be considered to influence predator movement rates along revegetating linear disturbances, which can then be applied as preliminary threshold values to evaluate if treatment of seismic lines can accelerate the recovery time of vegetation, specifically as it pertains to tree regeneration.

The identification of preliminary vegetation height benchmarks (i.e., 1.4 m and 2.7 m) and this study's findings on time to achieve these heights has direct implications for resource managers preparing range-level habitat planning under the federal recovery strategy for boreal woodland caribou (EC 2012). Specifically, the study findings on vegetation heights over time suggest that vegetation height should be a criterion considered when defining and mapping linear disturbances (for caribou). Environment Canada's methods for mapping habitat disturbance defined anthropogenic disturbances as "any human-caused disturbance to the natural landscape that could be identified visually from Landsat imagery at a scale of 1:50,000" (EC 2011, p.16). This study provides quantitative estimates of time required for trees to grow in order to reduce predator movements (i.e., habitat that no longer enhances predator use). Environment Canada (2012) currently does not provide a definition for 'restored habitat' but does indicate that critical habitat presents biophysical attributes required to support caribou life processes (EC 2012). Knowing that planted black spruce on treated lowland sites reaches 1.4 m by age 14 and 2.7 m by age 22, and that previously burned areas are considered critical habitat 40 years post-fire (EC 2012) suggests that linear disturbances could be considered critical habitat 40 years after restoration treatments, though benefits of improved habitat condition would presumably be realized before 40 years.

Based on the results of this study, treating seismic lines with mechanical site preparation is an effective approach to accelerating revegetation on seismic lines. The mean height of planted tree seedlings was found to be significantly taller compared to natural ingress seedlings, with significantly greater annual leader growth. Results were found to be most beneficial on lowland sites, where mounding and planting of black spruce was found to accelerate the rate of natural recovery to reach a height of 1.4 m by approximately 4 to 5 years compared to natural ingress of black spruce on treated lines and potentially 10 years earlier than on naturally recovering (untreated) lines. This represents the minimum estimate of time to reach 1.4 m, as the height-age trajectory for planted seedlings is based on a conservative model using the predicted annual leader growth from naturally ingressing black spruce on treated lines. It is expected that the annual growth, as measured by the leader growth, of planted black spruce on mounded sites would exceed that of naturally ingressing trees, as results from this study showed that planted black spruce had significantly greater leader growth compared to natural ingress black spruce. Though these results are only based on leader growth from one growing season at ages 9 to 10, a study by Macadam and Bedford (1998) on mounding in the Sub-boreal Spruce Zone of west-central British Columbia reported that increased growth rates in hybridized white spruce were associated with mounded sites compared to untreated sites with moist to wet moisture conditions.

These results also appear to indicate that mechanical site preparation alone (e.g., mounding with no planting component) for lowland sites may accelerate revegetation by providing suitable microsites for natural ingress, as natural ingress of black spruce on treated sites reached a mean height of 1.4 m by age 18, compared to black spruce on naturally recovering (untreated) seismic lines with >1.5 m vegetation height, which reached a mean height of 1.3 m by age 23 (Golder 2009). Forestry research on silvicultural practices have shown that site preparation such as mounding is an effective treatment for increasing survival and growth of spruce species, as site preparation creates a better substrate and drainage for tree growth and can also decrease competition and increase soil temperature (Macadam & Bedford 1998; Roy et al. 1999; Londo and Mroz 2001; MacIsaac et al. 2004; Thiffault et al. 2010; Lafleur 2011). This is also supported by research conducted by Vinge and Lieffers (2011) in the same area, which found that mounding lowland sites encouraged natural ingress of black spruce.

Conversely, mounding and planting black spruce on upland sites was not found to be as effective as there was little difference between the height-age trajectories for planted versus natural ingress black spruce on treated sites. This was also observed by Vinge and Lieffers (2010) in their study in the same area, where black spruce was found to have relatively poor growth on both treated (e.g., mounded) and untreated sites. This may be due to limiting site factors, which may have been exacerbated by planting black spruce on the top of mounds (B. Coupal pers. comm.), as these upland sites tended to be very dry, with very thin organic matter depths and greater exposed mineral soils, as well as predicted lower light regimes due to increased shade from the adjacent tree canopy. Not all microsites that are conducive for the establishment of black spruce are the same as those required for optimal growth, as indicated by Lavoie et al. (2007a). In particular, the growth of black spruce has been shown to be strongly influenced by both moisture and nutrient conditions, with poorer growth occurring on dry, gravelly sites or wet peaty sites (Lowry 1974; Lavoie et al. 2007b).

The effect of site preparation on natural ingress of lodgepole pine on treated upland sites was found to be inconclusive, as there was insufficient data to evaluate height and growth responses of planted lodgepole pine. Comparisons of the predicted height of natural ingress lodgepole pine on treated upland sites to mean lodgepole pine height on naturally recovering (untreated) seismic lines with >1.5 m vegetation height showed little difference in the predicted time it takes natural ingress lodgepole pine to reach 5 m (approximately one year earlier than lodgepole pine on untreated naturally recovering seismic lines). In a study completed by Vinge (1997) on regenerating cutblocks, juvenile growth curves for lodgepole pine in cutblocks had a predicted height of approximately 2 m by age 10, which is considerably higher than the predicted height of 1.4 m at age 11 from this study. Revel et al (1984) also noted that regenerating lodgepole pine seedlings on naturally recovering seismic lines reached a maximum height of 0.47 m by age 11, which is considerably lower than the predicted height of 1.4 m at age 11 from the height-age trajectory for natural ingress lodgepole pine developed using the data from this study. These results of reduced lodgepole pine growth on seismic lines may be a factor of light availability and level of coarse-woody debris, as lodgepole pine is a shade intolerant species that grows best in open conditions and though well suited to dry upland conditions may not fare so well on seismic lines with taller adjacent canopies. Conversely, lodgepole pine seeded on more open pipeline disturbances has shown good establishment and growth is expected (Vinge and Lieffers (2011).

One underlying result that can be drawn from this study is that the site specific conditions on seismic lines are a significant driver affecting the establishment and growth of vegetation, specifically tree seedlings. Some of the more pertinent limiting factors on these sites include, competition from understorey vegetation, cool soils, low sunlight exposure (leading to cool soils), loss of microsites including organic matter due to clearing, and moisture limitations (e.g., too much moisture in lowland sites, or insufficient moisture in upland sites as reported by van Rensen et al. (2015)). In the Upper Foothills Subregion, insufficient moisture can be a limiting factor on upland sites where soil textures can be coarser.

Upland sites may also experience nutrient limitations, particularly on nutrient poor upland sites, where the duff layer is very thin. This has implications for the successful establishment and growth of specific tree species (e.g., black spruce), as appropriate microsites may not be available. For example, optimal growth of black spruce is associated with moderately drained soils and moderate organic layer (to provide nutrients), as opposed to mineral soil substrates (Lowry 1974; Lavoie et al. 2007b), which may not be present in upland areas. In such, cases where exposed mineral soils are more common, lodgepole pine may be more successful at establishing. However, seismic lines are also potentially subject to increased shading on upland sites due to taller trees in the adjacent canopy, which can result in lower light penetration to the ground. This is strongly influenced by the orientation of the line as reported by Revel et al (1984). East-west lines are likely to be shadier with less light penetration, and the highest light penetration occurring near sunrise and sunset, while north-south lines will receive the greatest light during mid-day (Revel et al. 1984). This reduced penetration of sunlight can affect seedling growth through reduced light availability for photosynthesis and also through the creation of cooler soils, which can reduce growth.

Moisture can be a limiting factor on upland sites, with the loss of organic material and tree roots from the trees at the adjacent ecosite drawing water contributing to deficiencies (Vinge pers. comm.) Using site preparation on these sites such as ploughing the lines and breaking up the soil will allow moisture to penetrate deeper into the soil and site profile (Vinge pers. comm). Deep plowing can also sever the tree roots from the adjacent ecosite, contributing to less moisture loss. Wood applications either from spreading coarse woody debris across the site, felling trees, and/or applying mulch will help create micro-sites that will retain moisture (Vinge pers. comm.).

Planting on top of mounds in uplands was generally implemented as a strategy by the CRRP to increase available growing degree days for seedlings, as the top of the mounds warm up earlier in the spring compared to the adjacent ground. However, as indicated by this study, where black spruce was planted on top of mounds in very dry, nutrient poor sites it tended to have poor growth, as evidenced by poor lateral root growth, poor color and relatively low leader growth rates. As mounds are elevated sites in a relatively dry environment, there may have been increased potential for moisture stress arising from increased dryness in the absence of organic material. Planting seedlings lower down on the interface of mounds or in the mound holes may improve growth by addressing moisture limitations. Mounding could continue to be used as a site preparation technique on uplands where human access control is a consideration, such as at intersections with roads. In areas where access control is less of a concern, consideration for treatment sites to be ripped up, creating troughs and hollows to capture moisture and create microsites, and woody debris applications incorporated.

Taking all these factors into consideration, the treatment of sites must be tailored to site conditions and site limiting factors to achieve the best results in the most cost effective manner possible. Combinations of treatments should be employed and tailored to meet the objectives of the area in question and planted species should be tailored to the site conditions. For example, in this study area, mounding and planting was found to be an effective treatment approach for lowland sites, though there is a need to perhaps be more strategic about where black spruce is planted, such as targeting transitional h1 Labrador-tea subhygric lodgepole pine – black spruce sites and potentially drier fens. Consideration for planting other species should employed, such as planting larch on lowland sites or given the site specific conditions that may limit revegetation on upland sites such as a lack of moisture and sufficient organic layer, planting or seeding early-seral stage species such as pine and alder. Pine may not thrive in conditions with less sunlight, but does well on nutrient and moisture deficient sites. Alder can also be planted which is a fast growing low shrub that fixes its own nitrogen (Bayne et al., 2011), allowing it to establish on severely disturbed sites. Alder could also help create a functioning organic layer quickly. Applying both woody debris and mounding treatments will re-create hump and hollow terrain that is common on undisturbed lowland sites and may limit human travel that will help protect planted seedlings and natural revegetation.

Implementing mechanical site preparation and planting seedling is relatively expensive, therefore how and where treatments are applied needs to be carefully considered. Site limiting factors need to be identified, and treatments recommended that are tailored to address those factors, with an emphasis on promoting the natural restoration processes.

7.0 RECOMMENDATIONS

Given the change in direction from the initial study design and analysis approach, there are a number of recommendations that should be considered for future analyses.

- Model height - age curves (as opposed to annual incremental increase in leader growth) for both black spruce and lodgepole pine as a comparison model to determine which approach is more reflect of the growth patterns of these species at young ages.
- Collect additional data on natural recovery sites and develop height - age trajectories for untreated sites. Ideally, it would be valuable to revisit naturally recovering lines that were assessed by Greenlink in 2006 in the study area to obtain the age of ingressing trees on these seismic lines. A similar sample size as initially proposed (e.g., 40 lowland and 40 upland sites) would be sufficient for subsequent analyses.

Additionally, through the course of completing this monitoring study a number of key learnings and recommendations around the general program, including specifics on the monitoring protocol, data collection, data management, and sample design, have been identified to facilitate the implementation of future programs. These learnings and recommendations are outlined below.

- In this study the best effort was made to compare vegetation data from treated and natural regeneration vegetation, but a lack of standardized data collection protocols made statistical comparisons in data challenging. Standardized monitoring protocols, including level of detail in data to collect, should be developed and applied to facilitate comparison of data and results from different sources, which would allow for greater understanding of the effectiveness of restoration treatments on vegetation growth trajectories.
- Vegetation growth trajectories take time to develop. To address uncertainties around trajectories and timelines to reach thresholds, data should be stored in a centralized location that can be easily accessible and updated through time. Having a fully compiled dataset, which includes age of treatments, treatment details, age of trees on naturally regenerating plots, and site conditions should be incorporated to the monitoring data.
- Permanent sampling plots (i.e., plot centre) should be established so that treatment and natural regenerating sites can be re-monitored over time. Permanent sample plots should consider a paired sampling design (e.g., treated and untreated plots established on the same line which control for age since disturbance, type of disturbance, line orientation, and site type). Sampling design should also consider size of plots and number of plots to account for variability along narrow seismic lines.
- Tagging planted trees (use zip ties) to reduce the difficulty in identifying planted versus natural ingress, particularly in older sites will become increasingly important.

8.0 CONCLUSION

In summary, planted black spruce on treated sites was significantly taller and had significantly greater leader growth compared to natural ingress black spruce. Additionally, black spruce on treated lowland sites was found to be significantly taller and had significantly greater leader growth than upland sites. Percent shrub cover, treatment age and depth to water had no effect on black spruce leader growth or height. No significant differences in mean black spruce height on treated versus untreated naturally revegetating plots could be detected, which is likely a result of the strong influence of age as a significant factor in the model, coupled with the high degree of variability in the data and limited sample size for untreated sites.

The results from the height-age trajectory models showed that the predicted height of black spruce and lodgepole pine on upland or lowland sites, respectively, tended to be at the lower end of the provincial site index curves for the Upper Foothills Subregion, indicating a conservative model. Treating seismic lines on wetter sites through mounding and planting of black spruce indicated an acceleration of recovery times by a minimum of 4 to 5 years compared to natural ingress on treated lines and 10 years compared to naturally recovery on untreated lines. Planted black spruce on treated lowland sites reached 1.4 m by age 14 and 2.7 m by age 22, compared to natural ingress black spruce which reached 1.4 m by age 18 and 2.7 m by age 29.

In contrast, using the CRRP treatment design, treated upland sites do not appear to accelerate the rate of recovery over natural vegetation recovery for either lodgepole pine or black spruce. Although growth rates were similar or inconclusive for upland planted or natural ingress black spruce seedlings, it should be noted that the CRRP used mounding with the planting of black spruce on the top of the mounds within these treatment sites. These results suggest that treatment needs to be more targeted to natural regenerative systems and applied based on an understanding of site limiting factors and conditions to achieve the most optimal results. Thus, consideration for whether an upland site should be planted with seedlings, seeded, or left for natural seed ingress, as well as which species to introduce within upland sites of higher mineral and lower moisture content, and the use of coarse woody debris, or placement of seedlings lower down in a mound, should be considered in future restoration trials within upland sites.

The results from this research provide a preliminary benchmark for the timeline needed for historical seismic lines to be considered habitat which slows down or influences predator movements. The results could be applied as preliminary targets to evaluate if treatment of seismic lines can accelerate the recovery time of vegetation, specifically as it pertains to tree revegetation. The study findings suggest that vegetation height should be a criterion considered when defining and mapping linear disturbances (for caribou).

Report Signature Page

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https://capws.golder.com/sites/ptacopportunityptacseismicmonitoringlittlesmoky/6000 reporting/final/ptac_caribou range restoration treatment sites report_2015-12-22.docx

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