2018 COSIA LAND EPA

# In Situ Research Report

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# INTRODUCTION

**This report is funded by members of the Canada's Oil Sands Innovation Alliance (COSIA) Land Environmental Priority Area (EPA):**

Canadian Natural Resources Limited
Cenovus Energy Inc.
ConocoPhillips Canada Resources Corp.
Devon Canada Corporation
Imperial Oil Resources Limited
Nexen Energy ULC
Suncor Energy Inc.
Syncrude Canada Ltd.
Teck Resources Limited

COSIA publishes two reports, 2018 COSIA Land EPA - Mine Research Report and 2018 COSIA Land EPA - In Situ Research Report. This report summarizes progress for projects related to in situ reclamation of the COSIA Land EPA.

This project summaries included in this report do not include all projects completed under the Land EPA.

Please contact the Industry Champion identified for each research project if any additional information is needed.

2018 COSIA Land EPA - In Situ Research Report. Calgary, AB: COSIA Land EPA.



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# WETLANDS

# H38 Wetland Carbon Flux Research Project

**COSIA Project Number:** LJ0290

**Research Provider:** University of Waterloo, Northern Alberta Institute of Technology (NAIT)

**Industry Champion:** Imperial Oil Resources Limited

**Status:** Year 2 of 3

## PROJECT SUMMARY

Imperial Oil Resources Limited's Cold Lake Operations commenced a wetland reclamation trial in 2008 at Mahihkan H-38 pad. The pad was constructed in 2002 with 38 800 $m^3$ of borrow fill material on a treed rich fen that had an average depth of 148 cm of organic material (peat). This wetland reclamation trial included partial and complete pad removal. The reclaimed wetland was allowed to naturally re-vegetate.

Water chemistry, vegetation and wildlife use have been monitored annually at this site from 2010 to 2015. Given that greenhouse gas (GHG) exchange is an important peatland ecosystem function, a study was initiated in 2016 to understand how reclamation activities (partial and complete pad removal) impact these GHG fluxes. Only preliminary measurements were conducted in 2016, with expanded sampling in summer 2017 and 2018. The well pad has sections where the clay fill has been completely removed, partially removed (treatment sites) and left in place (control site). Sampling of vegetation and GHG exchange at dominant vegetation communities within each treatment is being conducted. These results will be compared to adjacent, undisturbed peatlands (reference sites) with plots in both a forested and shrubby fen.

The specific objectives of the project are to:

1. Determine the growing season flux of $CO_2$ (carbon dioxide), $CH_4$ (methane) and $N_2O$ (nitrous oxide) on a well pad, reclaimed four to five years prior to the study under various civil earthwork treatments (complete removal, partial removal) compared to adjacent undisturbed peatland.
2. Evaluate ecohydrogical controls (e.g., plant cover and type, water table position, C/N ratio) on the rate of GHG flux and how these vary between treatments, and between the reclaimed and undisturbed peatland.
3. Determine aboveground and belowground net primary production and organic matter accumulation at the same treatments where GHG fluxes are determined.
4. Evaluate differences in dissolved organic carbon concentration and chemistry, microbial community structure and nutrient availability between treatments on the reclaimed pad and the natural peatland and links between these variables and GHG fluxes.
5. Evaluate how well plant community composition, as evaluated under the peatland well-site reclamation criteria, correspond to biogeochemical function and GHG flux.
6. Correlate site history, construction methods, and reclamation techniques with current site progress and carbon status and develop best management practices (BMPs) for future sites.

## PROGRESS AND ACHIEVEMENTS

Measurements have been made to address all objectives. Data analysis for $CO_2$, $CH_4$ and $N_2O$ fluxes are ongoing with only preliminary results on $CO_2$ and $N_2O$ to report at this time. Biomass and Net Primary Production (NPP) samples will be collected during year three to coincide with removal of litterbags installed for litter decomposition. A laboratory incubation experiment was conducted to measure soil respiration rates in vitro for areas on H38; where no pad removal was completed (control), where the pad was completely removed, and areas with partial pad removal (i.e., scraping to meet the elevation of the adjacent peatland). Rates were compared to those measured in reference peatlands and other well pads restored with partial removal (SKEG as described in Vitt et al., 2011) and inversion techniques (IPAD, Sobze et al., 2012). Results will be available in early 2019.

Progress is reported here related to objective one on $CO_2$ fluxes, objective four on nutrient pools, and the vegetation surveys that will be used to address objectives five and six.

### Carbon Dioxide Exchange

Under full light conditions, the net exchange of $CO_2$ (NEE) in reclaimed areas of the well pad were similar to natural reference fen rates (Table 1). Most sites had $CO_2$ uptake (noted as a negative to indicate removal from the atmosphere), with generally greater uptake at reclaimed plots than at the control where no pad removal occurred. The exception was the flooded area within the complete pad removal zone; these plots were sources of $CO_2$ to the atmosphere, likely due to the low vegetation cover (see Vegetation recovery section below). Future work will determine carbon uptake by the overstory at the treed fen to incorporate all components of $CO_2$ exchange at that site.

**Table 1: Mean net ecosystem exchange (NEE) of $CO_2$ at all measured treatments[a]**

| Treatment | Mean NEE $CO_2$ [g $m^{-2}$ $d^{-1}$] | ± SE |
|---|---|---|
| Natural shrubby fen (DRY) | -4.14 | 2.02 |
| Natural shrubby fen (WET) | -14.79 | 4.64 |
| Natural treed fen (DRY) | -4.39 | 2.03 |
| Natural treed fen (WET) | -14.8 | 6.62 |
| Partially Removed (DRY) | -10.42 | 2.7 |
| Partially Removed (WET) | -13.47 | 4.55 |
| Partially Removed (Equisetum) | -8.9 | 2.95 |
| Complete Removal (DRY) | -6.77 | 2.41 |
| Complete Removal (WET) | 5.74 | 0.96 |
| Control[b] | -5.43 | 1.74 |

a. Measurements were made between May and August, 2018 and negative values indicate uptake of $CO_2$ by the ecosystem (i.e., a sink for $CO_2$)
b. Control plots are areas where no pad removal occurred.

## Nitrogen Pools

Extractable (with KCl) $NO_3$ and $NH_4$ from soil cores taken on the pad were lower than those from the reference peatland (Figure 1). In general, concentrations were higher from the near surface samples (0 cm - 5 cm) than deeper (30 cm - 40 cm). Despite differences in mineral N pools, $N_2O$ emissions were low, and usually negligible across all sample plots. This is similar to reports of minimal $N_2O$ emissions from boreal peatlands (e.g., Wray and Bayley, 2007; Brummell et al., 2017).

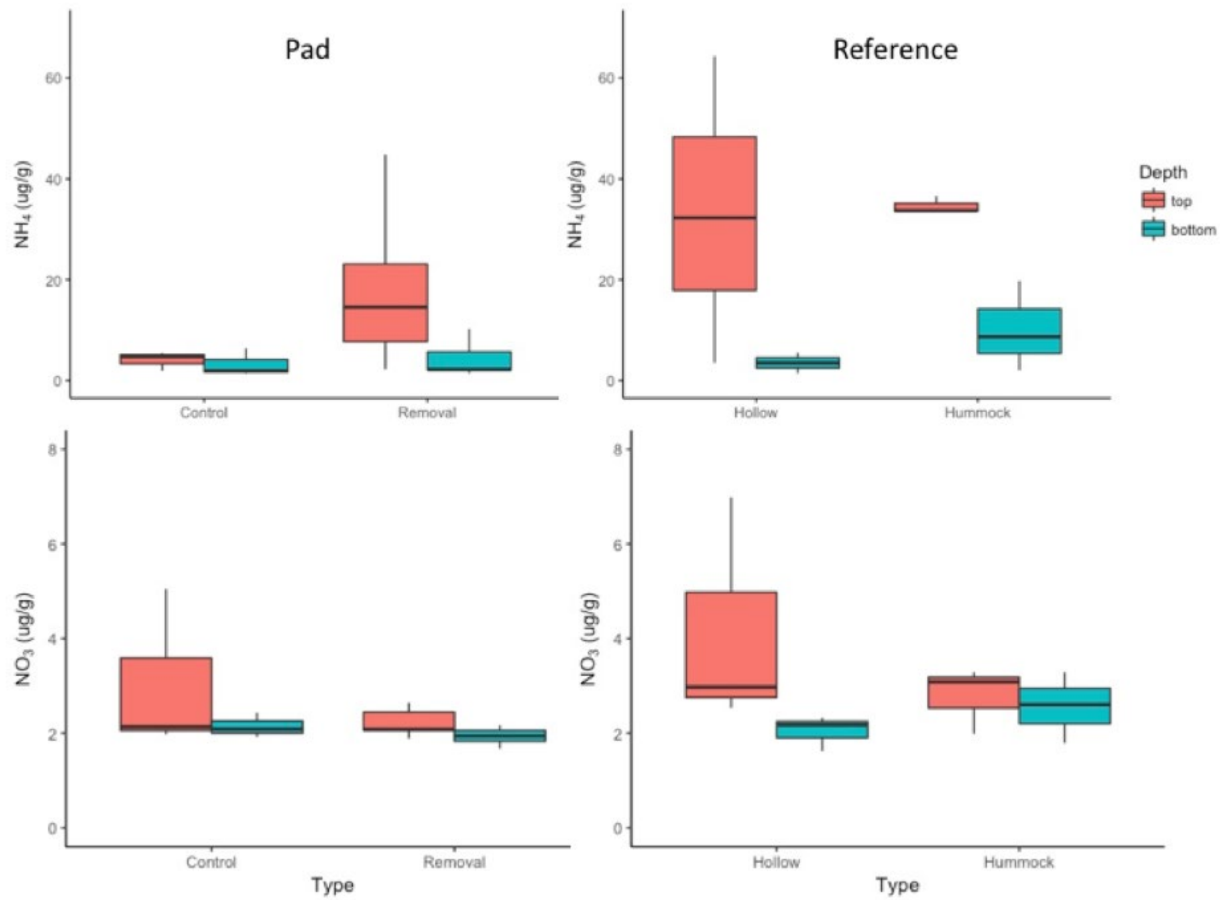


**Figure 1:** Mineral nitrogen pools extracted from cores collect on the pad with no removal (control) and partial to complete removal (removal) compared to the adjacent undisturbed shrubby fen (reference). Top samples are from 0 cm - 5 cm depth and bottom from 30 cm - 40 cm. Mineral nitrogen pools were extracted with 2 M KCl and are expressed per gram wet weight of soil.

## Vegetation Recovery

Vegetation surveys were completed in reclaimed areas of the pad using the Alberta Peatland Criteria (Figure 2). Although 100% of species surveyed were hydrophytes, three distinct wetland communities have formed. Applying the peatland criteria to all, only Grid 1 would be certifiable, although Grid 2 was reclaimed using the same method (partial pad removal). Both Grid 2 and Grid 3 failed for landscape, desirable species cover, and woody stem counts, due to presence of large open water areas. Grid 3 also failed for high undesirable species cover (Table 2). While Grid 3 was assessed with this peatland criteria, it should be noted that the objective of the complete pad removal treatment was to reclaim to a shallow water body and not a peatland.


**Figure 2:** Diagram of the three grids surveyed in 2018. The yellow area passed the peatland criteria while alternative wetland criteria are recommended for red areas.

**Table 2: Peatland Criteria assessment results**

| | Grid 1 | Grid 2 | Grid 3 |
|---|---|---|---|
| Landscape Parameter | Pass | Fail | Fail |
| Species Richness | Pass | Pass | Pass |
| Desirable Species Percent Cover | Pass | Fail | Fail |
| Undesirable Percent Cover | Pass | Pass | Fail |
| Woody Stems | Pass | Fail | Fail |
| **Site Performance Using Peatland Criteria** | **Pass** | **Fail** | **Fail** |
| Reclamation Technique | Partial Removal | Partial Removal | Complete Removal |
| Wetland Classification | Fen | Emergent Marsh | Shallow Open Water Wetland |
| Criteria Should Assess With | Peatland | Other Wetland | Other Wetland |

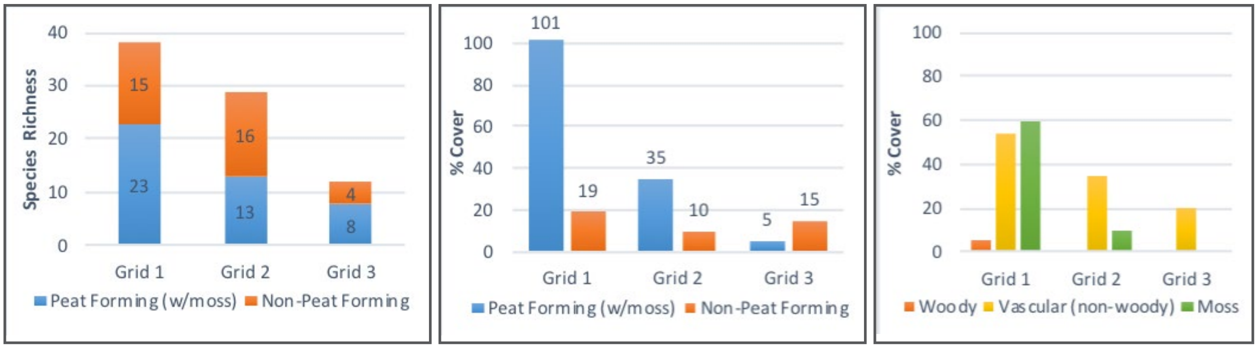


**Figure 3:** Vegetation survey summary by each grid.

Grid 1 had the highest species richness (38) and highest number of peatland species (23), while Grid 3 had the lowest number of species (12). Grid 1 also had the highest cover by peat forming species, while Grid 3 had only 5% cover of peat forming species. Grid 1 was the only area with significant woody species cover and had almost 60% of moss cover, while Grid 3 lacks both moss and woody species cover.

## LESSONS LEARNED

Almost all treatments measured on the reclaimed well pad had net $CO_2$ exchange under full light conditions that were similar to the adjacent undisturbed fen. Complete pad removal leading to deep inundation prevents the recovery of plant cover resulting in these plots remaining sources of $CO_2$ to the atmosphere. Complete pad removal should be avoided in order to more rapidly return carbon sink function post-reclamation.

Remnant fill left during well pad reclamation to peatland does not appear to result in large mineral N pools or elevated $N_2O$ emissions. This indicates that partial pad removal is likely a viable reclamation option considering biogeochemical function.

Partial pad removal leaving remnant fill in place does not hinder peatland vegetation, particularly moss, development if the surface is suitably saturated. Pad H38 borders a wet fen to the north. Water flows freely around the reclaimed areas, bringing propagules for natural revegetation. Open water areas are too deep for most wetland species to establish, although floating moss mats start to occur along the edges in some areas. Achieving proper surface elevation and restoring hydrological connectivity is critical in order to reclaim mineral material well pads like H38. Deep open water should be avoided as much as possible.

Industry can use stratified approaches when assessing a reclaimed site with different levels of vegetation cover. Large areas of open water with non-peat forming wetland species failed the peatland criteria but may be able to pass a mineral wetland criteria instead.

## LITERATURE CITED

Brummell ME, Lazcano C, Strack M. 2017. The effects of *Eriophorum vaginatum* on $N_2O$ fluxes at an extracted peatland. Ecological Engineering, 106: 287-295.

Sobze J-M, Schoonmaker A, Rochefort L. 2012. Wellsite clay pad removal and inversion – a peatland restoration pilot project. Canadian Reclamation, 12: 10-13.

Vitt DH, Wieder RK, Xu B, Kaskie M, Koropchak S. 2011. Peatland establishment on mineral soils: Effect of water level, amendments and species after two growing seasons. Ecological Engineering, 37: 354-363.

Wray HE, Bayley SE. 2007. Denitrification rates in marsh fringes and two boreal peatlands in Alberta, Canada. Wetlands, 27: 1036-1045.

## PRESENTATIONS AND PUBLICATIONS

No public presentations or publications in 2018.

## RESEARCH TEAM AND COLLABORATORS

Institution: University of Waterloo

Principal Investigator: Maria Strack

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
|---|---|---|---|---|
| Bin Xu | Northern Alberta Institute of Technology (NAIT): Boreal Research Institute | College Industrial Research Chair | | |
| Line Rochefort | Laval University | Professor | | |
| Martin Brummell | University of Waterloo | Post-Doctoral Fellow | 2017 | 2017 |
| Meike Lemmer | Laval University | PhD Student | 2017 | 2021 |
| Arohi Dixit | University of Calgary | Visiting Student | 2018 | 2018 |

# Removing the Wellsite Footprint (iFROG)

**COSIA Project Number:** LJ0216

**Research Provider:** Circle-T Consulting Inc.

**Industry Champion:** ConocoPhillips Canada Resources Corp.

**Industry Collaborators:** AOC Lesimer Corner Partnership, Canadian Natural Resources Limited, Cenovus FCCL Ltd., Devon Canada Corporation, Husky Oil Operations Ltd., Japan Canada Oil Sands Limited, MEG Energy Inc and Nexen Energy ULC

**Status:** Year 2 of 6

## PROJECT SUMMARY

The purpose of the industrial Footprint Reduction Options Group (iFROG) is to develop, fund, and implement a balanced portfolio of boreal wetlands research projects that:

- follow the fundamental guiding principles of land stewardship, intelligent research, and collaboration;
- demonstrate iFROG members are meeting the intent of the majority of the wetland research approvals in their respective EPEA Approvals (for in situ projects);
- contribute to reducing the impacts to wetlands during operations; and
- increase the knowledge base for, and confidence in, future wetland reclamation efforts.

In 2018, three projects were funded: Canadian Natural Resources Limited (Canadian Natural) pad reclamation, Japan Canada Oil Sands Limited (JACOS) road reclamation, and the Devon Canada Corporation (Devon) best practice road construction.

### Canadian Natural Pad Reclamation (future data collection t.b.d.)

A pad built in a fen peatland was reclaimed in 2011 by almost complete removal of the clay fill, which was returned to borrow. The remaining pad material was "mounded" or churned over with an excavator, producing a mixed surface of organic and clay mineral substrate. Subsequently, microtopographic variability was reduced on portions of the surface to compare performance of severely rough versus smoother surfaces for peatland vegetation establishment. Vegetation treatments were applied to the reclaimed pad in 2012 and included the application of salvaged surface peat (live moss transfer) vs. no peat, and planted black spruce, Labrador tea, and sedges vs. no planting. Site recovery was assessed in 2012, 2013, and 2017.

This project's objective is to assess the suitability of the mounded mixed substrate surface for establishing peatland vegetation. Other comparisons include examining differences between rough and smooth soil surfaces, and responses to three revegetation approaches (moss/peat transfer, planting, natural recovery).

### JACOS Road Reclamation Study (year one of three)

The JACOS Road Reclamation Study, involves the continuation of reclamation work initiated in 2010. The reclamation work involved the partial removal of fill material from a road constructed through a peatland.

Three treatment blocks were established and approximately 80 cm of fill was removed from each block. This was followed by the establishment of study plots where a number of revegetation treatments were applied. Vegetation recovery was assessed in 2012 and 2013. In addition, offsite hydrology, vegetation, GHG dynamics, and nutrient dynamics were studied from 2010 through 2014.

Two of the treatment blocks were prone to prolonged flooding, while the third showed some promise for the establishment of natural revegetation. Therefore, the follow-up reclamation work planned included reworking the two flood-prone treatment blocks along with the remainder of the road.

The road was divided into two study areas, one for the study of revegetation on a peat substrate and the other for revegetation on a mineral substrate. The peat substrate study will examine revegetation treatment response on varying depths of peat substrate. The mineral substrate study evaluates revegetation response to surface treatments aimed at moderating surface moisture. Both treatment types aim to inform reclamation practices regarding amendment application and substrate type. Hydrologic responses to the reclamation treatments, as well as to drainage structures installed to facilitate hydrologic connectivity across the road, will also be evaluated.

### Devon Best Practice Road Construction (year one of three)

Devon has constructed a road bisecting several areas of deep fen peat that are each approximately 180 m long. Timber corduroy was used as road foundation over the soft peat sections in conjunction with several culverts that were closely spaced within each section. High density polyethylene (HDPE) pipe culverts or log bundles were installed among the culverts to facilitate additional drainage. Seventeen culverts and seven bundles were installed along the 1.5 km length of road.

Study objectives are to:

- determine whether or not the road allows water to pass through effectively as a result of the corduroy and drainage conduit installations;
- characterize flow rates and patterns in the vicinity and through the road to assess the effectiveness of the type and number of conduits; and
- assess road performance in the corduroy sections as indicated by progressive road settlement over time and identify any problem areas.

## PROGRESS AND ACHIEVEMENTS

### Canadian Natural Pad Reclamation

Plot maintenance activities only in 2018.

### JACOS Road Reclamation Study

This study is in the early stages of establishment (road removal earthworks).

### Devon Best Practice Road Construction

The preliminary data collected along five transects, indicates that the road bed does not presently seem to be impeding water flow from one side of the road to the other. This suggests that the increased number and close spacing of drainage conduits within this road (when compared to other road construction approaches through peatlands) has contributed to greater hydrologic connectivity across it.

The choice of conduits may matter less if there are an increasing number of them, but the mix of drainage conduits used within the road probably also contributed to enhanced drainage by targeting both surface and shallow subsurface flows. HDPE pipe bundles appeared to perform as effectively as log bundles. Therefore, HDPE pipe could be a viable alternative to logs. Using a mix of materials or conduit types may not be necessary if a range of sizes or depths are used for a given conduit. Also, since outflow from the downstream side of the road was observed through the corduroy section nearest the Pad TT, the corduroy itself may be contributing to hydrologic connectivity across the road where it has been used as road foundation. It would be useful to better understand how each feature (corduroy, culverts, bundles) performs in contributing to adequate flow in order develop better road construction prescriptions over a range of conditions.

## LESSONS LEARNED

### Canadian Natural Pad Reclamation

Plot maintenance activities only in 2018, therefore no lessons learned to report this year.

### JACOS Road Reclamation Study

Early stages of experiment establishment (earthworks), therefore no lessons learned to report in 2018.

### Devon Best Practice Road Construction

Preliminary observations from the Devon road study appear to indicate that the installed drainage features allow sufficient water to pass through/under the road and that the road is not impeding local hydrology.

## PRESENTATIONS AND PUBLICATIONS

No public presentations or publications were released in 2018.

## RESEARCH TEAM AND COLLABORATORS

Institution: Circle-T Consulting, Inc.

Principal Investigator: Terry Osko

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
|---|---|---|---|---|
| Clayton Gilles | FP Innovations | Senior Researcher | | |
| Dr. Line Rochefort | Université Laval | Professeure Titulaire | | |

Research Collaborators: Maria Strack, University of Waterloo; Bin Xu, Northern Alberta Institute of Technology; Natural Sciences and Engineering Research Council of Canada (NSERC)

# SOILS & RECLAMATION MATERIAL

# Cold Lake Topsoil Depth Experiment

**COSIA Project Number:** LJ0208

**Research Provider:** Paragon Soil & Environmental Inc.

**Industry Champion:** Imperial Oil Resources Limited

**Status:** Year 4 of 5

## PROJECT SUMMARY

Many older wellsites in Northern Alberta do not have sufficient salvaged topsoil (A horizon material + LFH) to meet the minimum 80% replacement criteria as specified in the *2010 Reclamation Criteria for Wellsites and Associated Facilities for Forested Lands* (ESRD 2013). This is due to a combination of factors including loss of topsoil during salvage and placement in early wellsite establishment, as well as compaction of LFH during soil handling. This project was initiated to determine whether less than 80% of an original ground topsoil replacement depth allows for successful reclamation to an equivalent land capability.

The primary goal of the project is to evaluate the progression and success of research plots through vegetation response to topsoil depth treatments at 80% (Control) and 50% of reclamation replacement depth as well as response to peat or biochar amendment on the 50% replacement depths.

Reclamation research plots were established in 2015 at a site at Imperial Oil Resources Limited's Cold Lake Operations and includes three replicates of four treatments (12 plots total, each 20 m X 20 m) incorporating two topsoil replacement depths and two soil amendments.

The treatments established were:

1. 80% Topsoil Replacement Depth (TSRD; Control);
2. 50% TSRD;
3. 50% TSRD with a peat amendment (50% TSRD + peat); and
4. 50% TSRD with a biochar amendment (50% TSRD + biochar).

Baseline soil sampling of each plot was conducted. Tree (trembling aspen [*Populus tremuloides*], balsam poplar [*Populus balsamifera*], white spruce [*Picea glauca*], white birch [*Betula papyrifera*]) and shrub (saskatoon [*Amelanchier alnifolia*], green alder (*Alnus veridis*), red osier dogwood (*Cornus sericea*)) planting in the plots occurred following plot establishment and treatment application. Following planting, the seedlings were mapped and tagged.

The key annual objectives for this study are as follows:

- Evaluate topsoil chemical and physical properties;
- Assess vegetation composition and planted tree growth/survival to determine if treatments have an effect on vegetation establishment and performance; and
- Compare soil and vegetation parameters from the previous monitoring years.

## PROGRESS AND ACHIEVEMENTS

Topsoil composite samples were collected from each of the plots from 12 discrete locations to obtain an overall representative composite sample for each plot. Topsoil samples were analyzed for total Kjeldahl nitrogen (TKN), total organic carbon (TOC), and available nitrogen (N), phosphorus (P), potassium (K), and sulphur (S). Duplicate samples for bulk density analyses were also taken. Final analysis and results of the 2018 soil monitoring program were not available at the time this report was prepared and will be included in the 2019 report.

Key results of the 2018 vegetation monitoring program are summarized below.

### Vegetation Parameters

Vegetation cover assessments and planted tree/shrub measurements were completed in all four quadrants for each of the 12 plots. Seedling performance in each treatment was evaluated in the form of seedling height, health, and percent survival. Vegetation parameters recorded in the field were used to calculate species and weed richness, Shannon Diversity Index (SDI), and evenness. Key results for 2018 are below:

- The survival rates of balsam poplar, green alder, red osier dogwood, saskatoon, and white birch were not affected by topsoil depth, but topsoil depth did influence white spruce. White spruce survival in the 50% TSRD treatment was significantly lower than in the 80% TSRD (Control) treatment.
- Diversity is considered to be high (SDI >1.5) for all treatments, but SDI in the 50% TSRD + peat treatment was found to be significantly higher than the 50% TSRD + biochar treatment. The SDI calculated for the 50% TSRD + biochar treatment was statistically similar to the SDI calculated for the unamended 50% TSRD treatment.
- The 50% TSRD + biochar plot has the lowest vegetation performance based on the vegetation parameters measured.
- Vegetation community indices in the 50% TSRD + peat treatment were generally higher than in the 50% TSRD + biochar treatment.
- Percent cover of vegetation in the 50% TSRD + biochar treatment was significantly lower than the 50% TSDR + peat treatment.
- Evenness in the 50% TSRD + biochar was significantly lower than evenness in the 50% TSRD + peat amended treatment but was statistically similar to the 50% TSRD treatment.
- Weed cover was significantly higher in the peat treatment than the other 50% TSRD treatments.

Average Survival, Height and Health parameters for the treatments (2015-2018) is shown in the figures below. Statistical analysis on this data set is currently being performed and was not available for this report. In this study, there were some instances of slight increases in survivorship from one year to another for several species. It is likely that some seedlings were obscured by dense cover of pioneer species one year and rediscovered the next, resulting in an artificial increase in survivorship.

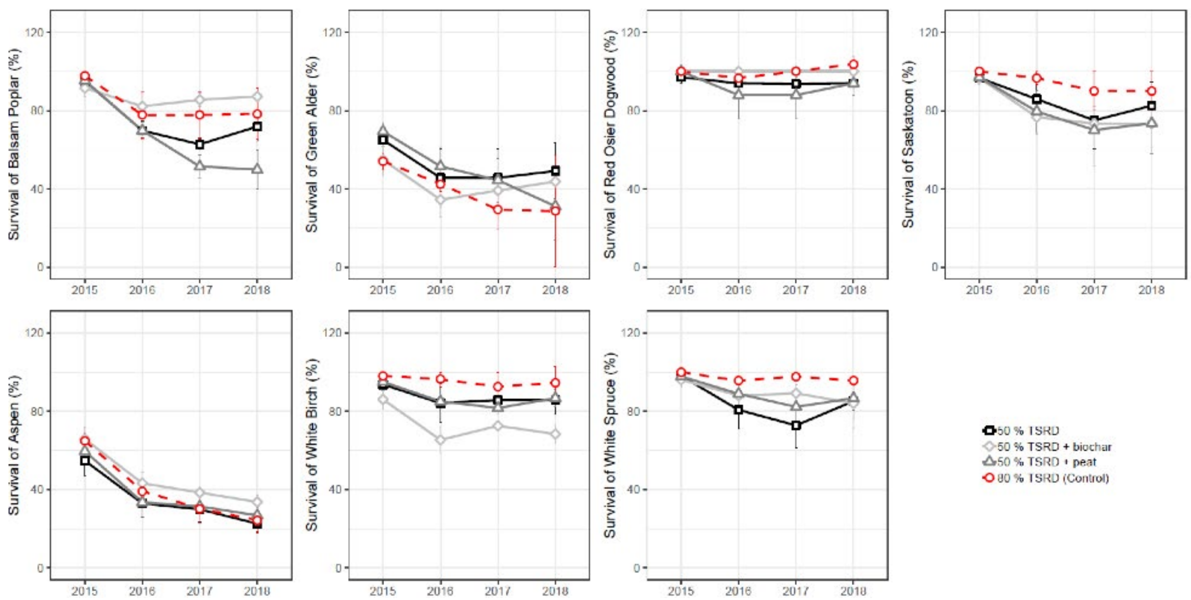


**Figure 1:** Survival

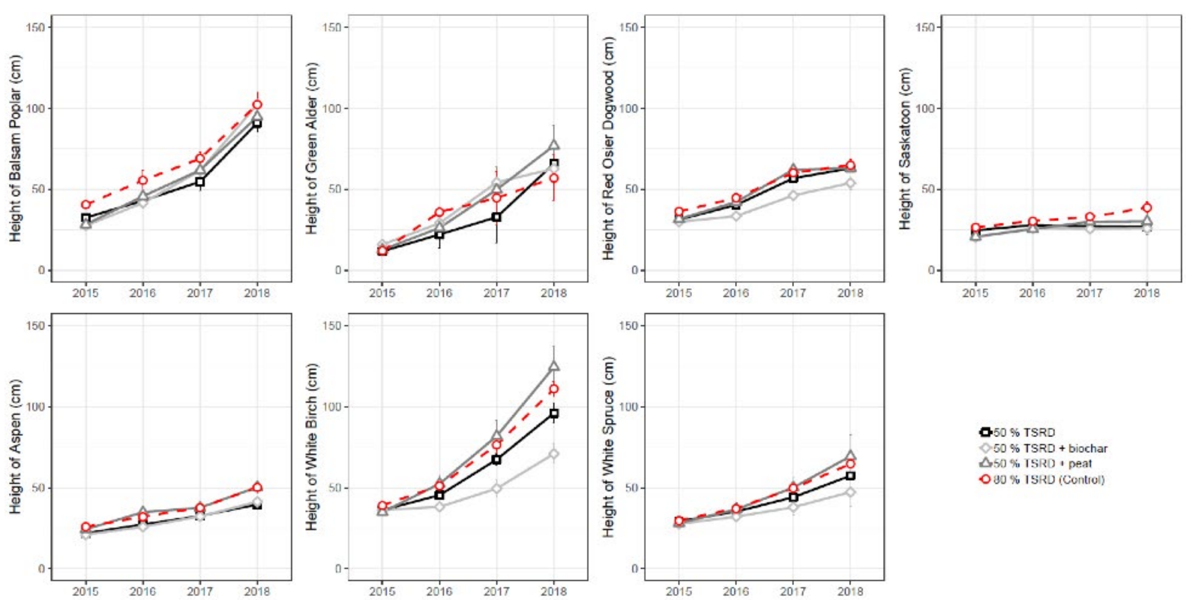


**Figure 2:** Height

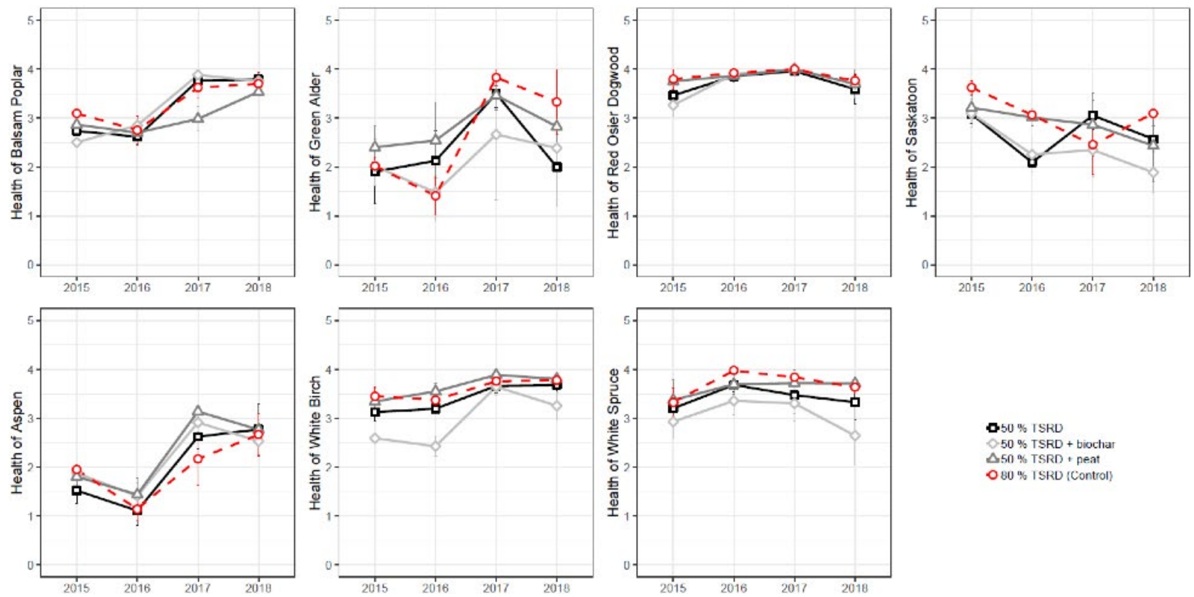


**Figure 3:** Health

## LESSONS LEARNED

Once results have been synthesized in the final year of the study (2019), lessons learned will be shared.

## LITERATURE CITED

Environment & Sustainable Resource Development (ESRD). 2010 Reclamation Criteria for Wellsites and Associated Facilities for Forested Lands (Updated July 2013). Edmonton, Alberta. 81 pp

## PRESENTATIONS AND PUBLICATIONS

There were no public publications or presentations in 2018.

## RESEARCH TEAM AND COLLABORATORS

Institution: Paragon Soil & Environmental Inc.

Principal Investigator: Brittany Flemming, Ph.D.

# REVEGETATION

# Cluster Planting

**COSIA Project Number:** LJ0314

**Research Provider:** Northern Alberta Institute of Technology: Centre for Boreal Research (NAIT-CBR)

**Industry Champion:** ConocoPhillips Canada Resources Corp.

**Industry Collaborators:** Nexen Energy ULC

**Status:** Year 2 of 4

## PROJECT SUMMARY

The current knowledge and best practices for tree establishment in Alberta, are founded on practices developed in the forest industry that optimize productivity of commercial forest trees intended for merchantable harvest. However, the goal of many reclamation operations, as directed by current regulatory criteria, is less focused on merchantable timber (though this is often still an objective) and rather more on whether a functional, resilient, native vegetation community becomes established on the reclaimed site. Regeneration of deciduous tree species after other commonly occurring disturbances, such as fires and forest harvesting, is often patchy with uneven distribution of trees. Establishing these species in a similar manner on disturbed industrial sites will likely lead to a more natural, heterogeneous landscape with diversity in vegetation structure. This diversity in structure may allow other native species to ingress, leading to faster site recovery and vegetation resilience. Due to slower growth rates of nursery stock deciduous seedlings, non-native and fast growing ruderal species may achieve site occupancy first and compromise reclamation success. Using cluster planting (i.e., the overwhelming of portions of a site with native tree species), may therefore be a viable alternative approach that could preclude the development of ruderal species and enhance regeneration capacity of other native species ingressing over time.

The concept and evaluation of cluster-planting is being tested at the plot scale within recently reclaimed industrial sites. Comparisons of tree establishment, early growth and surrounding vegetation development around uniformly planted (non-clustered) seedlings and cluster planted seedlings are being undertaken.

This trial will evaluate two factors to answer questions related to the size of a cluster and spacing of deciduous tree seedlings within clustered planted arrangements - Three sizes (dimensions) of clusters where tree seedlings will be planted at 0.75 m spacing, in clusters of 3 m x 3 m, 5 m x 5 m or 7.5 m x 7.5 m. The performance of the seedlings in the clusters will be compared against seedlings planted singly at a conventional spacing of ~1.4 metres. The effect of seedling spacing within a cluster is tested by spacing seedlings at 0.5, 0.75 or 1.0 m in the same size cluster of 5 m x 5 m. Each treatment will be replicated seven times for the cluster size factor and four times for the seedling spacing factor. Treatment factors will be randomly assigned within replicate blocks across each the two study locations. The following three deciduous tree species will be combined within all cluster treatment types noted above:

- Aspen (Populus tremuloides), 25% composition
- Paper birch (Betula papyrifera), 50% composition
- Balsam poplar (Populus balsamifera), 25% composition

Different cluster sizes and within-cluster plant spacing will be evaluated based on the following :

1. Does the physical size (dimensions) of a cluster of deciduous trees impact the early growth and development of individual trees? Is there a difference in understory vegetation development within and adjacent to differently sized clusters?
2. Is it better to create clusters with tighter plant spacing (shortening time to canopy closure but increasing space between clusters)?
3. Does the clustering of deciduous woody species improve the growth and survival of those trees compared to single seedlings?
4. Does cluster planting support the establishment, maintenance and ingress of desirable native plant species?
5. Does cluster planting prevent or reduce the dominance of undesirable non-native plant species?

This project is replicated within two operating in-situ facilities: Canada Resources Corp.'s Surmont facility (ConocoPhillips) and (2) Nexen Energy ULC Long Lake facility (Nexen). These operations are within 15 km of each other and approximately one hour southeast of Fort McMurray. Two recently reclaimed borrow pits (hereafter borrow pit #1 and #5) will form the study location within the ConocoPhillips operations. Reclamation of borrow pit #1 occurred in summer 2016 and at borrow pit #5 in November 2016. The second study location, a 2.5 hectare reclaimed sump, was established within the Nexen Long Lake facility. Reclamation of this site occurred in November 2017.

All sites utilized similar reclamation practices though emphasis was placed on roughly placing topsoil as much as was practical. In addition, at the Nexen site, a dozer with a six-way blade furrowed the entire site where the individual furrows were spaced approximately two to three metres apart. The objective of furrowing was to create greater surface heterogeneity. Field establishment of seedlings occurred at the ConocoPhillips site in spring 2017 and at the Nexen site in spring 2018. In addition, a pre-emergent herbicide was also incorporated into the study design at the Nexen site based on concerns regarding vegetation competition which was observed at the ConocoPhillips location.

## PROGRESS AND ACHIEVEMENTS

Although this field study is in the early stages of development, some initial observations related to seedling establishment have been made. The greatest differences associated with growth and survival were between the deciduous tree species planted at each site. Across sites, total height and survival of seedlings of individual species were greatest in paper birch (Betula papyrifera), followed by balsam poplar (Populus balsamifera), and lowest in aspen (Populus tremuloides).

At the ConocoPhillips site, there were differences between cluster sizes in terms of height growth. Seedlings planted within the 5 m x 5 m cluster were significantly taller than those inside the 3 m x 3 m and 7.5 m x 7.5 m clusters. Seedlings in the control plot (non-clustered) were intermediate in height between the other three cluster treatments. There were no differences in total height between different size clusters at the Nexen site (this was only the first growing season for this site). For both study sites, there was no difference in seedling survival rate for clusters of varying size across. Changing the spacing between tree seedlings (0.5, 0.75, or 1.0 m spacing) did not result in a significant difference in total height or survival rate at either site.

Interestingly, we observed that total height of the paper birch and aspen seedlings at the Nexen site has already exceeded those at the ConocoPhillips site (despite this site being established one year earlier). Soil preparation activities and the timeline between site reclamation and planting were similar amongst the study sites. Therefore, this difference was most likely due to reduced initial herbaceous plant competition (as the clustered plots had a pre-emergent herbicide applied immediately prior to planting). This project is linked to LJ0226 Interim Reclamation, Study 2, Page 34.

## LESSONS LEARNED

At this stage of the project, it is too early to draw any conclusions or recommendations regarding efficacy of cluster-planting as a forest reclamation tool.

## PRESENTATIONS AND PUBLICATIONS

No public presentations or publications in 2018.

## RESEARCH TEAM AND COLLABORATORS

Institution: Northern Alberta Institute of Technology | Centre for Boreal Research

Principal Investigator: Dr. Amanda Schoonmaker

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
|---|---|---|---|---|
| Dr. Mark Baah-Acheamfour | Northern Alberta Institute of Technology, Centre for Boreal Research | Research Associate | | |
| Carlee Ikert | Northern Alberta Institute of Technology, Centre for Boreal Research | Student Research Assistant | 2016 | 2018 |
| Brandi Charette | Northern Alberta Institute of Technology, Centre for Boreal Research | Student Research Assistant | 2016 | 2018 |
| Sofia Toledo | Northern Alberta Institute of Technology, Centre for Boreal Research | Student Research Assistant | 2017 | 2019 |
| Matt Engleder | Northern Alberta Institute of Technology, Centre for Boreal Research | Student Research Assistant | 2017 | 2020 |
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Research Collaborators: Dr. Brad Pinno, University of Alberta (formerly Canadian Forest Service); Dr Simon Landhäusser, University of Alberta

# Optimizing Weed Control

**COSIA Project Number:** LE0044

**Research Provider:** NAIT Centre for Boreal Research, InnoTech Alberta

**Industry Champion:** ConocoPhillips Canada Resources Corp.

**Industry Collaborators:** Canadian Natural Resources Limited, Cenovus Energy Inc., Devon Canada Corporation, Imperial Oil Resources Limited, Nexen Energy ULC, Suncor Energy Inc., Syndrude Canada Ltd., Teck Resources Limited

**Status:** Year 1 of 1

## PROJECT SUMMARY

In Alberta, there are 75 regulated weed species (46 prohibited noxious and 29 noxious) listed in the *Weed Control Regulation* (Government of Alberta, 2010a) under the *Weed Control Act* (Government of Alberta, 2008). These weeds need to be destroyed (prohibited noxious) or controlled (noxious), as undesirable species. The concern with having weeds establish is that they can; (1) out-compete and displace local native grasses, forbs, shrub and tree seedlings; (2) alter natural habitats and reduce local biological diversity; (3) hybridize with native species; and (4) change local nutrient cycling, water chemistry and hydrological regimes.

Alberta Environment and Sustainable Resource Development (2012) describes the concern with weeds on industrial developments as:

1. Fire hazards in non-vegetated areas
2. Competition with desirable plant species
3. Economic challenges of controlling the weeds both onsite and offsite
4. Non-compliant with the *Weed Control Act*

Some of these concerns are more pertinent for the settled portions of Alberta (White area) and may be less of a risk for the forested portion (Green area). However, there is currently no comprehensive documentation to support or refute this. Observations from years of field work on disturbed and reclaimed forested sites have indicated that, at least some of the weeds currently regulated by the *Weed Control Act* may pose less risk to native plant establishment, succession and ultimately reclamation success in a boreal ecosystem. The issues with continuing to manage regulated weeds, which are interpreted to be of low risk, while aiming to achieve reclamation closure include the following: increased time and resources spent on weed management; increased herbicide application into the environment; unintentional mortality of desirable native species from accidental herbicide overspray; and a delay in reclamation certification application by at least one growing season (Government of Alberta, 2013).

The overall goal of this project was to attempt to assess whether noxious weeds in the boreal forest are significantly impacting boreal succession. The assessment was performed using publicly available literature, available vegetation survey data and field experience of oil sands operations practitioners.

Current regulations require operators to control or eradicate noxious or prohibited noxious weeds, respectively. Presently, this is accomplished through the use of herbicides and manual labour (e.g., hand-pulling). This project aimed to demonstrate whether, under certain site conditions, there is a third (potentially more cost effective) alternative – utilizing successional processes and forest vegetation development to better address some of the issues raised above.

Project objectives were:

1. To compile current information on weed status and management programs in the boreal ecosystem, for both mining and in-situ oil sands operations.
2. To determine the risk factors of the regulated weeds that have been observed in the boreal ecosystem, with this objective being addressed by:
    a. Developing fact sheets summarizing key characteristics that have historically made these species problematic: their known distribution in Alberta and tolerance, known impacts to environment, and current management options.
    b. Completing a retrospective case study on available data sets where vegetation monitoring had occurred for at least three years to examine whether noxious weeds appeared to influence the development of woody vegetation and if these species were persistent over time.
    c. Developing a risk analysis framework based on the results from the literature review and retrospective case study and with consideration of a risk analysis tool - that was developed by Alberta Agriculture and Forestry. (Alberta Agriculture and Forestry, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/prm13262)
3. To determine whether the current approach to weed management (i.e., active control and eradication) of these regulated weed species is necessary in boreal reclaimed sites or if other methods could be used (i.e., monitoring).
4. To identify whether there is enough evidence to reduce the number of weeds requiring active management in the boreal ecosystem.

## PROGRESS AND ACHIEVEMENTS

### Current Information on Weed Status and Management

Noxious weeds are more prevalent within in situ and mineable oil sands sites than prohibited noxious weeds. Of those designated in the 2010 *Weed Control Regulation*, the top four noxious weeds managed by oil sands operations include perennial sow thistle, scentless chamomile, Canada thistle and common tansy. These species are predominantly transported to sites via equipment and machinery. The movement of salvaged or stockpiled soil infested with noxious weed populations, is the major cause of spreading infestations over large areas.

A retrospective case study was conducted to quantitatively examine patterns in forest vegetation and non-native development using six oil sands data sets provided by the industry participants and existing research data managed by the authors, and included data sets where vegetation monitoring had occurred for at least three years. Correlation analyses completed across the six reclamation sites did not find strong evidence of a negative association between woody cover and noxious weeds (by group or by species); this was measured across multiple years of measurement. The only significant correlations between these parameters were in fact positive associations between woody cover and noxious weeds (by group and by species including perennial sow thistle and Canada thistle). This analysis was supported by changes in relative dominance favouring woody vegetation as individual sites aged. However, the relative dominance of noxious weeds varied over time and there was no consistent trend amongst the sites.

### Risk Factors

A risk analysis framework was developed based on the results from the retrospective case study and with consideration of a currently available risk analysis tool that was developed by Alberta Agriculture and Forestry. The risk analysis tool was not useful for determining effects thresholds, though it has utility for its core purpose which is to effectively triage and prioritize invasive species in terms of management considerations. The authors developed a conceptual risk analysis framework using the risk analysis tool as a starting point but using a more quantitative approach to evaluation.

The proposed Reclamation Risk Analysis Tool is a two-part evaluation:

1. First, the user provides data on relative dominance by vegetation category, site age, tree and shrub height, as well as management risk. It would then calculate an exposure risk (risk of site not becoming a forest) showing thresholds in relative dominance between vegetation cover types and stand age.
2. The second part of the evaluation includes a short questionnaire that rated aspects of environmental risk to generate a single number score. The exposure and environmental risk could then be plotted, and conceptually the combined value would be expressed in the standard way risk-analysis are shown (green, yellow or red). Considerable research is required to support both components of the Reclamation Risk Analysis Tool.

### Native Vegetation as Weed Management Approach

The correlations in this study, based on multiple datasets from oil sands operators, showed relative density of woody species increased through time on reclaimed sites. The effect on noxious weeds was inconclusive. More work is required to determine if native vegetation and boreal succession processes are an effective control of weeds in a boreal reclamation context.

## LESSONS LEARNED

While the correlations in this study showed relative density of woody species increased through time on reclaimed sites in all data sets, the effect on noxious weeds was inconclusive. To determine the conditions under which native plants outcompete noxious weeds on reclaimed sites, and how long that might take, will require longer-term studies designed specifically for this purpose.

## LITERATURE CITED


Alberta Environment and Sustainable Resource Development. 2012. Weed Management on Industrial Sites. Alberta Environment and Sustainable Resource Development, Edmonton, Alberta. Alberta Environment and Sustainable Resource Development R&R/12-01. 7 pp. https://open.alberta.ca/dataset/4f56c8ed-e0de-4378-90d7-887c927784b0/resource/71847f4b-f9d7-4822-aaba-6f680b366cf8/download/weedmanagementindustrialsites-fs-jul2012.pdf

Government of Alberta. 2013. *2010 Reclamation Criteria for Wellsites and Associated Facilities for Forested Lands (Updated July 2013).* Government of Alberta, Edmonton, Alberta. 65 pp. Available at: https://open.alberta.ca/dataset/9df9a066-27a9-450e-85c7-1d56290f3044/resource/09415142-686a-4cfd-94bf-5d6371638354/download/2013-2010-Reclamation-Criteria-Wellsites-Forested-Lands-2013-07.pdf.


## PRESENTATIONS AND PUBLICATIONS

### Reports & Other Publications

Small, C., D. Degenhardt, B. Drozdowski, S. Thacker, C.B. Powter, A. Schoonmaker and S. Schreiber. 2018. Optimizing Weed Control for Progressive Reclamation: Literature Review. InnoTech Alberta, Edmonton, Alberta. 48 pp.

A. Schoonmaker, S. Schreiber, C.B. Powter, and B. Drozdowski. 2018. Optimizing Weed Control for Progressive Reclamation: Retrospective Case Study and Risk Framework. InnoTech Alberta, Edmonton, Alberta. 69 pp.

## RESEARCH TEAM AND COLLABORATORS

Institution: InnoTech Alberta / NAIT Centre for Boreal Research

Principal Investigator: Bonnie Drozdowski / Amanda Schoonmaker

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| Sarah Thacker | InnoTech Alberta | Junior Researcher | | |

# Improving Establishment Success and Early Growth of Trembling Aspen

**COSIA Project Number:** LJ0255

**Research Provider:** Canadian Forest Service, Natural Resources Canada

**Industry Champion:** Imperial Oil Resources Limited

**Status:** Year 4 of 6

## PROJECT SUMMARY

The purpose of this project is to address observations that trembling aspen (*Populus tremuloides* Michx.) seedlings planted on newly reclaimed in-situ oil sands sites often have poor survival after outplanting, and when they do survive, exhibit poor growth and form. It is hypothesized that the lack of appropriate soil fungi (mycorrhizae) could be contributing to these observations.

These studies are focused on characterizing fungal communities in natural and reclaimed sites and to determine if inoculation of the roots with isolates of root associated fungi can improve aspen growth in the reclaimed area.

### Background

In the fall of 2015, the community of fungi associated with aspen roots at undisturbed (natural) and reclaimed sites (NN-Borrow and D-East Borrow) at Imperial Oil Resources Limited's Cold Lake Operations was assessed using traditional culturing techniques, greenhouse studies and next-generation DNA sequencing. A total of 51 species of fungi were cultured from aspen root systems, the majority of which were saprophytes, but ectomycorrhizal fungi were also observed.

In 2016, the fungal communities present at the D-East Borrow site were studied along transects from 10 m inside the interior of undisturbed forest, across the edge and 40 m into the reclaimed area. Differences in fungal communities were observed at different points along the transects. Within the interior of the forest, ectomycorrhizal fungi were more common, while in the reclaimed areas arbuscular mycorrhizae and saprophytes were more common. These field assessments have demonstrated that soil fungal communities do exist within the root systems of aspen growing in reclaimed areas, that they may improve aspen survival, and that natural areas of adjacent undisturbed forest can act as a source of ectomycorrhizal fungi that can disperse into reclaimed areas.

In 2017, two greenhouse studies were conducted at the Northern Forestry Centre (NoFC) in Edmonton, Alberta. In each study, root associated fungi that were collected at the Imperial Oil Resources Limited site, as well as isolates from the NoFC culture collection, were inoculated onto aspen seedlings. In both studies the growth responses were highly variable, resulting in no statistically significant difference between treatments. However, during the experiment, it was observed that the uninoculated controls did not grow as well, or survive, compared with the aspen that were inoculated.

## PROGRESS AND ACHIEVEMENTS

In the summer of 2018, three hundred and sixty aspen seedlings were inoculated with five species of root associated fungi that were collected in 2015 and improved the aspen performance in the 2017 greenhouse trials. The seedlings were inoculated in the greenhouse at NoFC and then outplanted in three blocks at D-East Borrow in late June. An uninoculated control treatment was also included in the study. An ectomycorrhizae trap seedling experiment was also set up to monitor the dispersal of ectomycorrhizal fungi from within the adjacent undisturbed forest into the reclaimed area at D-East Borrow. This was done through planting of aspen and white spruce seedlings along transects extending from within the undisturbed forest into the reclaimed area. The seedlings were assessed in September 2018 to confirm establishment and will be measured and harvested during the summer of 2019 to assess the community of fungi present on their roots.

## LESSONS LEARNED

To date, it has been confirmed that adjacent natural areas can act as source populations for important fungal symbionts. Previous greenhouse experiments using fungi collected from these sites have shown increased survival of trembling aspen, relative to the uninoculated controls. These greenhouse research results have been used to guide the current study.

## PRESENTATIONS AND PUBLICATIONS

There were no reports or publications released in this reporting year.

## RESEARCH TEAM AND COLLABORATORS

Institution: Canadian Forest Service, Natural Resources Canada.

Principal Investigators: Tod Ramsfield and Richard Krygier

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| Colin Myrholm | Natural Resources Canada | Technician | | |
| Bradley Tomm | Natural Resources Canada | Technician | | |
| Richa Patel | Natural Resources Canada/ University of Alberta | BSc Student (Summer Intern 2018) | | |

# Restoration of Native Tree and Shrub Species on Reclaimed Grassy Sites

**COSIA Project Number:** LJ0291

**Research Provider:** Natural Resources Canada, Canadian Forest Service

**Industry Champion:** Imperial Oil Resources Limited

**Status:** Year 3 of 6

## PROJECT SUMMARY

The objective of the study is to determine the most effective site treatment for legacy (20-30 year old) sites in the boreal forest that were reclaimed using non-native grass and herbaceous species. These sites have grass as the only or predominant plant growing on the site. The intent is to establish desirable boreal tree and shrub species so that these sites can be restored to forest ecosystems.

In the spring of 2016, a field study was designed to test a range of mechanical and chemical site preparation treatments on the establishment and growth of tree and shrub seedlings. The field study was established at D63 Borrow which is located at Imperial Oil Resources Limited's Cold Lake Operations. The site was divided into forty, 9 m x 30 m plots in two rows of twenty oriented north/south along the short access of the plot. Treatments were assigned randomly to each plot.

The treatments (four site preparation techniques and an untreated control) being tested are:

1. Non-selective herbicide (glyphosate) patch spray followed by planting the next year, installation of a 40 cm tall biodegradable waxed paper tree shelter supported by a wooden stake after planting, and an additional application of a non-selective herbicide (glyphosate) around the tree shelter if required;
2. Excavator mounding of soil (mounds 30 cm wide by 25 cm long), followed by planting;
3. Excavator mounding of soil followed by the application of a non-selective herbicide (glyphosate) only over themound area in the year of treatment, followed by herbicide before planting if needed;
4. High speed soil mixing (160 cm wide x 140 cm long patches) followed by the application of a non-selective herbicide (glyphosate) only over the mixed area in the year of treatment, followed by herbicide before planting if needed; and
5. Untreated control.

Prior to the establishment of the research trial, a soil chemical analysis was conducted to determine nutrient status of soils at the site. The analysis showed that available nitrogen and phosphorus was less than 4 ppm while available potassium ranged between 70 ppm and 120 ppm. Given the poor nutrient availability, fertilizer tablets (Forestry Suppliers 20-10-5 21 gram) were placed by each seedling/cutting in half of the plots (randomly selected) of each site treatment. There were four replications of each site treatment/fertilizer combination.

Eighteen seedlings of white spruce (*Picea glauca* Moench Voss.) and green alder (*Alnus viridis* [Chaix] DC.), and eighteen 20 cm long balsam poplar cuttings (*Populus balsamifera* L.) were planted in June of 2017 in each of the treatments. Seedlings/cuttings were planted on the top of the mounds or in the middle of the mixed bed. Planting spot was randomly assigned to each seedling.

In 2018 two additional sites at Cold Lake Operations (J10, P3) were included in the study.

## PROGRESS AND ACHIEVEMENTS

Establishment success assessed four weeks after planting for alder and white spruce was greater than 93% for all treatments. Establishment success for the balsam poplar cuttings was greater than 92% for all treatments except the control with fertilizer where it was only 85%.

At the end of the first growing season, alder survival ranged between 76% and 100% with the least effective treatments being the mixing with fertilizer, and the best mounding with herbicide and no fertilizer. Black poplar survival ranged between 29% and 98% with the poorest result occurring in the control with fertilizer and the best in the herbicide treatment with no fertilizer. White spruce survival at the end of the first growing season was greater than 97% for all treatments.

By the end of the second growing season, alder survival ranged between 22% and 90%, the poorest treatment being the mixing with fertilizer and the best being the herbicide treatment with no fertilizer. Balsam poplar survival ranged between 11% and 87% with the lowest performance occurring in the control with fertilizer and the best in the herbicide only treatment without fertilizer. White spruce survival was greater than 88% with the poorest performance occurring in the control with no fertilizer.

Fertilizer application is impacting seedling survival for alder and balsam poplar. Within a treatment, seedling survival was always lower when fertilizer was used. By the end of the second growing season, alder survival was between 5% and 58% less where fertilizer tablets were used. For balsam poplar, survival was between 21% and 77% less when fertilizer tablets were used. The impact of fertilizer tablets on white spruce survival was much less, ranging only between 3% and 15%.

Mortality increased the most for the mixing and mounding treatments between the first and second growing season with or without fertilizer. This was most likely caused by vegetative competition and snow press from Dutch white clover. These treatments disturbed the seed bank and created a favourable growing site for germination and luxuriant growth. Glyphosate herbicide applied prior to planting controlled grass but the clover germinated after planting so was not controlled. The amount of clover germination at the site was unexpected given there were very few plants at the time of site treatment. Vegetation cover around each seedling was assessed but the data has not been analyzed at the present time.

Statistical analysis of, height and stem diameter at soil level at the end of the first and second growing season, was not completed at the time of report preparation. A cursory review of the means shows that stem diameter and height was greatest for white spruce and poplar on the herbicide with tree shelter treatment. Differences between treatments for alder were less pronounced. There is no consistent response of stem diameter or height to the application of fertilizer within a treatment. This is based on the average of four replicates (statistical analysis not complete).

## LESSONS LEARNED

The major lesson learned thus far relates to planting site preparation. It appears that any soil disturbance (e.g., mounding, mixing) on legacy sites will disturb the weed seedbank (e.g., Dutch white clover) resulting in high numbers of weed seedlings and vegetative competition with planted seedlings. Weed control in the form of post-emergence herbicide application after germination and before planting, or pre-emergent herbicide application after planting is likely required.

## PRESENTATIONS AND PUBLICATIONS

There are no presentations or publications as this study is still in the early stages of being conducted.

## RESEARCH TEAM AND COLLABORATORS

Institution: Natural Resources Canada, Canadian Forest Service, Canadian Wood Fibre Centre

Principal Investigator: Richard Krygier

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
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# Mounding 2.0: Quantifying Plant Response to Silviculture Treatment

**COSIA Project Number:** LJ0183

**Research Provider:** Woodlands North, NAIT Boreal Research Institute, University of Alberta

**Industry Champion:** Cenovus Energy Inc.

**Status:** Year 10 of 20

## PROJECT SUMMARY

Information or collective experience related to forest regeneration of treed bog and fen ecosites following anthropogenic disturbance is limited. However, it is known that in-situ oil sands exploration disturbs all types of forest. Several major in-situ projects are located in areas that are comprised of more than 50% forested peatlands. Decades following disturbance, many former exploration sites show little evidence of returning to forest cover. In general, standard minimal disturbance techniques used to construct exploration leases and seismic lines on wet forest types result in a loss of microtopography as well as heavy herbaceous vegetation and brush competition. The construction also results in a lowered land surface, creating wetter soil conditions and limited seedbed for trees. Regeneration failure on these sites creates a serious business risk to oil sands companies through degradation of caribou habitat, failure to meet stakeholder expectations, interruption of carbon sequestration, and other potential issues.

Silviculture is commonly used to achieve forest management objectives. These objectives often include increasing the predictability of plantation survival and increasing growth rates. In this study, we hypothesize that silviculture can be used to resolve the problems that lead to regeneration failure on former exploration sites (leases and seismic lines).

The overall study objective is to complete comparative tests between the use of silviculture and passive management using a range of objective measurements; findings will be used to develop further decision support information for environmental managers. It is expected that results will demonstrate marked increase in tree survival and growth rate following silvicultural treatment. This contrasts with a failure to regenerate under the standard passive approach. As part of the return to forest cover, treated locations will be returned to a condition of carbon sequestration as opposed to carbon emission.

In 2018 detailed work conducted on Mounding 2.0 was completed under two separate work scopes by the University of Alberta and the NAIT Boreal Research Institute (NBRI), both with support from the environmental consulting firm, Woodlands North Ltd.

The specific objectives of the NBRI work are to:

- Evaluate ecological functions on oil sands exploration leases under both passive recovery and silvicultural treatment relative to surrounding forest peatland;
- Assess restoration techniques when compared to the provincial peatland reclamation criteria as well as measures of carbon flux, and better understand associated vegetation development and greenhouse gas (GHG) dynamics; and
- Develop recommendations for best management practices for the construction, restoration and monitoring of oil sands exploration sites.

The specific objectives of the University of Alberta work are:

- To evaluate the response of trees (planted and from natural ingress) to different restoration treatments; and
- To understand the interaction, if any, between treatment and site factors such as surrounding stand characteristics, edaphic factors, line orientation, etc.

## PROGRESS AND ACHIEVEMENTS

Noteworthy 2018 NBRI progress and findings include:

- Additional seasons of $CO_2$ flux measurements were captured from alternative microsites on each treatment area
- Faster growth rates of trees is associated with mounding.
- Some differences have been found in total understory percent cover and in the type of functional group between silvicultural treatments and the surrounding undisturbed forest.

$CO_2$ flux measurements in 2018 were similar to those from 2017. In 2017 it was found that approximately 10 years following silviculture treatment, sites were once again acting as a carbon sink (absorbing more $CO_2$ from the atmosphere than they were releasing). Variances in $CO_2$ sequestration rates were found to be due to differences in tree growth among reference areas (treatment vs non-treatment vs background).

Noteworthy results from the University of Alberta work include:

- At treated lines, tree density is 1.6 times higher (approximately 3.8 years following treatment), as compared to non-treated lines (average 22 years since disturbance).
- Treatment response differed between ecosite types; and tree density response on poor fens was not significantly better than that found on untreated lines.

## LESSONS LEARNED

Early results documenting improved tree growth and survival in the Mounding 2.0 project have been shared publicly at various conferences including some that pre-date COSIA. The patterns that were apparent in early results are consistent with the interim results reported by both the NBRI (final reporting is not yet complete) and the University of Alberta.

The University of Alberta results underscore the potential for, successional stagnation and slow tree growth on conventional seismic lines through treed peatlands, and the potential benefit of site preparation and planting.

The NBRI results elucidate the importance of microtopography and planting for forest regeneration, and reveal how sites where microtopography has been lost may not return to forest cover in a predictable manner.

Collectively, these results have been influential in the development of standards and practices for forest restoration that are reflected in the draft Caribou Habitat Restoration Criteria. Increasingly, the importance of tree stocking as a basic management target is recognized. In addition, GHG flux is an important consideration in all types of environmental management, including in the revegetation of exploration sites. Although it is too early to speculate on final results as the NBRI final report is not finished, interim results suggest that silvicultural techniques lead to $CO_2$ sequestration.

## LITERATURE CITED

Provincial Restoration and Establishment Framework for Legacy Seismic Line in Alberta (2018). Alberta Environment and Parks, Government of Alberta, Edmonton. October 2018 Draft.

## PRESENTATIONS AND PUBLICATIONS

### Journal Publications

Filicetti AT., Cody M and Nielsen SE (2019) Caribou Conservation: Restoring Trees on Seismic Lines in Alberta, Canada. (in print). Forests.

### Conference Presentations/Posters

Wisdom and Knowledge Transfer in Restoration; the Cenovus Caribou Habitat Restoration Project, February 13-17, 2018. Burnaby, British Columbia.

## RESEARCH TEAM AND COLLABORATORS

Institution: NAIT Boreal Research Institute / University of Alberta and Woodlands North Ltd.

Principal Investigators: Bin Xu / Angelo Filicetti

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| Geoff Sherman | Woodlands North Ltd. | Ecologist | | |

# Interim Reclamation

**COSIA Project Number:** LJ0226

**Research Provider:** Northern Alberta Institute of Technology: Centre for Boreal Research (NAIT-CBR)

**Industry Champion:** ConocoPhillips Canada Resources Corp.

**Status:** Year 5 of 10

## PROJECT SUMMARY

This program of research encompasses study topics of (1) interim reclamation (also known as temporary reclamation) as well as (2) final reclamation. Although, it should be recognized that much of the interim reclamation research is applicable to final reclamation. Each study (and projects therein) is described below:

### Study 1: Interim Reclamation of a Facility Soil Stockpile

Industrial site disturbances, whether in the mining or oil and gas sector, typically result in the clearing of forests and stockpiling of surface soils during the development and operational phases. Ongoing management of these stockpiles is required until the site is decommissioned and final reclamation is undertaken. This is where the facilities are removed, the site is re-contoured and stockpiled soils are spread. Historical and current practices include seeding with grasses and the use of chemical herbicides to eradicate or control noxious weeds. Temporary reforestation of soil stockpiles is an alternative, though not widely utilized practice, that may better fit the fundamental long-term final reclamation goals in forested settings, which is to re-establish a functional forest.

The overall purpose of this study is to advance interim reclamation a step beyond historical re-contouring and seeding practices to include the establishment of woody species on non-active areas of an in situ project (e.g., soil stockpiles) during the life of the facility. It is hypothesized that this would speed forest cover and reduce the need for ongoing and repeated weed management.

Goals and outcomes of this work include:

- Provide a bank of root and seed propagules for final reclamation
- Provide coarse woody material for final reclamation
- Maintain the ‘health’ of stored soil
- Long-term control of erosion on stockpiled soil
- Reduce the invasion/influx of undesirable or weedy vegetation
- Increase biodiversity and habitat
- Evaluate treatments by the degree to which they achieve a ‘reclaimed and reforested’ target
    - Target to include the baseline regulatory requirement as well as broader ecological resiliency target
- Transfer the learnings from interim reclamation into best management practices for final reclamation
    - Quantify the cost-benefit impact of applying different reclamation and re-vegetation treatments

This interim reclamation project is situated on an eight-hectare topsoil and subsoil stockpile that is anticipated to be in place for more than 40 years. Ultimately the broad goal for this study is to determine whether temporary reforestation of a soil stockpile is a good idea/best practice for forested area sites. This is not something that has been commonly implemented at in-situ facilities in the oil sands region. This project provides an on-site demonstration of the effect of site preparation, varying planting densities, and the incorporation of coarse woody material. While much work has been done examining plant community establishment in oil sands, arguably this has been largely focused on mining reclamation contexts which can have different disturbance patterns than those found at in-situ developments. A good portion of the in-situ work has been on exploration sites and other short term disturbances.

Rather than assessing one combination of interim reclamation techniques the experimental trials have been structured to support the development of best practices that will have a high probability of success at final in-situ specific reclamation and will be cost effective to implement.

This project is also designed to question assumptions about species suitability for use in a reclamation context. Industrial disturbances do not necessarily follow the same early vegetation dynamics patterns found after fires or forest harvesting. Industrial disturbances require soil to be moved several times prior to revegetation. This "unnatural" soil handling forces the system into being a largely seed-based regeneration/revegetation system rather than root based. This has consequences for the native species being established and will actually favour those species that are able to tolerate competition as young seedlings. The project is situated on a big hill with lots of soil and aspect variability which should help inform tolerance ranges for each of the planted species in a reclamation context.

The long-term goal of this project is to initiate forest development but in the short-term, three separate projects were initiated at this site in order to ask specific questions related to appropriate planting density, how to include desirable native herbaceous species and alternative methods of planting deciduous trees.

The objectives and questions for these projects are further described below:

***Project 1: Site preparation and establishment density***

1. Compare three densities of container stock planting (2,500, 5,000 and 10,000 stems per hectare) and monitor natural regeneration (within unplanted controls).
    a. Which native tree and shrub species will provide speedy establishment, produce viable seed within the time frame of facility life and have capacity to regenerate aggressively through root fragments following reclamation activities?
    b. Which species are best suited to different combinations of slope position and aspect on reclamation soils?
    c. Is natural regeneration a viable approach for forest plant establishment?
    d. How does the speed of canopy development and structure compare with different densities over time?
    e. Does the overstory density impact development of understory vegetation
    f. Does aspect or slope position interact with plant establishment through these methods?

2. Compare use of soil adjustment to create a rough and heterogeneous soil surface against standard track-packed 'smooth' reclamation approach.
    a. Does soil adjustment impact the growth and production of planted woody species?
    b. Does soil adjustment improve natural ingress and regeneration of desirable woody species?

3. Demonstrate the utility of coarse woody material in conjunction with soil treatments to create a rough and heterogeneous soil surface.
    a. Does coarse woody material impact growth and production of planted woody species?
    b. Does coarse woody material increase the stability of sloped soils and reduce erosion?
    c. Does coarse woody material improve the natural ingress and regeneration of desirable woody species?

4. Examine the impact of wildlife browsing (and presence) on establishment and development of planted woody species.
    a. Which species are preferentially browsed?
    b. What is the impact of browsing on plant performance?
    c. Does browsing significantly impact canopy development?

***Project 2: Cover crop establishment through planting***

5. Evaluate two methods of planting native forbs including: individual planting of container stock and co-planting native forbs with a woody species (produce plants in same plug).
    a. Does the forb develop (increase in vegetation cover) equally well with both approaches?
    b. Is there a positive, neutral or negative impact for the woody species which shares the plug initially?

6. Compare the effect of the addition of native forbs during the early phase of forest development.
    a. Do they facilitate ingress of other desirable species?
    b. Do they reduce ingress of undesirable species?
    c. Do they aid in soil stabilization?
    d. What is incremental cost of planting native forbs?

7. Optimize production of mixed-species container stock for three different woody species (green alder, willow and paper birch) each co-grown with fireweed.
    a. What is the best time to sow the forb into container with woody species?
    b. Is mixed-species container stock appropriate for all woody species or only for specific species?

***Project 3: Aspen establishment through container stock, optimizing plant deployment through grouped planting***

This study was conducted as a pilot project to further the concept of cluster planting of deciduous trees (see project, LJ0314 Cluster Planting, Page 18).

8. The objective of this project was to compare localized cluster planting of aspen with conventional planting at uniform spacing. In this project, the question of how many plants are required for a 'cluster' to positively impact survival and growth of aspen container stock will be addressed.

### Study 2: Vegetation Management Solutions for Final Reclamation

Site occupancy with native plant species is a key objective of reclamation and reforestation of industrial sites. However, noxious weeds and other undesirable vegetation (e.g., sweet clover [*Melilotus* sp.], alsike clover [*Trifolium hybridum*], creeping red fescue [*Festuca rubra*], timothy [*Phleum pretense*] and smooth brome [*Bromus inermis*]) are transported to reclamation sites by a variety of mechanisms. These include; historical presence in the soil seed bank from previous decades of utilization in cover crop mixes, contaminated equipment, wind, wildlife and in some cases intentional broadcasting. Collectively, these undesirable species present challenges to the development of forest plant communities. In northern Alberta, management of aggressive agronomic species is a significant issue to forest development and the certification of reclaimed well sites (Bressler, 2008). Regulatory criteria and legislation clearly define the need to control and eradicate noxious weed species (Weed Control Act, 2010; Environment and Sustainable Resource Development, 2013), as well as undesirable species (Environment and Sustainable Resource Development, 2013). Site preparation, cultural control (cover crop establishment) and chemical management represent a range of approaches to control or eradicate undesirable species.

The objective of this study was to examine the ability of combinations of native plant cultural controls (cover crop) and herbicide-based approaches to reduce and eliminate undesirable plant ingress. In this study, approaches that are appropriate for use in the early stages of revegetation development following soil reclamation will be evaluated. Each of these approaches was initiated in the first year following reclamation with plans to monitor the study for three growing seasons. At the completion of the study, the following questions will be answered:

1. Which approaches are most effective at reducing the initial establishment of undesirable species?
2. By controlling ingress of undesirable plants, are there also differences in native plant establishment through natural ingress?
3. Is there a tradeoff in the growth and productivity of desirable native woody species when utilizing a treatment that is aimed at reducing undesirable plant development?
4. What is the potential return on investment of the vegetation management approaches considering relative benefit/success at managing undesirable species?

## PROGRESS AND ACHIEVEMENTS

### Study 1: Interim Reclamation of a Facility Soil Stockpile

Overall this study is progressing well. Creating surface heterogeneity through furrowing has stimulated the emergence of a wide range of plant species (70+ species). Some of the trees are already exceeding three metres in height after only three growing seasons. Furrowing has also resulted in greater evenness of soil moisture along the slopes of this site; this moisture will promote growth of planted seedlings as well as facilitate seed-based establishment from wind-dispersed seeds over time.

***Project 1: Site preparation and establishment density***

Three planting densities (2,500, 5,000 or 10,000 stems per hectare) and an unplanted control treatment were initiated in this trial. After three growing seasons, the highest density treatment (10,000 stems per hectare) has measurably reduced non-native forb (largely composed of agricultural nuisance species such as sweet clover and alsike clover and some noxious weeds) coverage (30%-50% less) relative to the other densities and control treatments. The 10,000 stems per hectare treatment has also had the highest average woody cover but this difference is lessening with time (the other treatments are catching up) as natural regeneration of woody shrubs and trees (to a lesser extent) are continually ingressing.

***Project 2: Cover crop establishment through planting***

The forest industry has planted tree plugs (small trees grown in nurseries) in commercial reforestation efforts for decades. Traditionally, these were commercial tree species containing one plant per plug. NAIT is developing "hitchhiker" plugs that in addition to the tree, include a herbaceous species, such as fireweed. The hitchhiker plant provides shelter for the slower-growing tree and may prevent invasive weedy species, such as scentless chamomile, from taking hold. Adding a second species may also be a simple way to increase diversity of native plants.

Creating hitchhiker nursery stock composed of a fast-growing forb (in this case fireweed) and a fast-growing deciduous species (green alder, paper birch or Bebb's willow) was not an easy task. For each of these mixtures, there were consistent growth and survival trade-offs if the timing of fireweed introduction into the nursery cavity was either too early or too late. The results from the second growing season in the field indicate that for green alder and paper birch, sowing fireweed into the nursery container two weeks after sowing the woody species resulted in suitable development of the woody and forb species. However, for Bebb's willow, fireweed should be sown concurrent with the willow as this particular species was extremely fast-growing; later sow dates with fireweed led to poor establishment (though the willow grew well).

***Project 3: Aspen establishment through container stock, optimizing plant deployment through grouped planting***

Aspen seedlings were clustered in groups of four, 10 or 20 plants (spaced ~ 25 cm apart within the cluster) or planted singly at a total density of 2,500 stems per hectare. After three growing seasons, there were no statistical difference in mean / maximum height or survival between singly planted aspen and clustered aspen seedlings. However, some emerging trends are noted:

1. On average, cumulative survival has been slightly lower for the largest clusters (groups of 10 or 20 seedlings) and this may be attributable to self-thinning as these cluster sizes also have the largest seedlings (122 cm - 134 cm maximum height per cluster) relative to non-clustered seedlings (113 cm).
2. Total grass, native forb, non-native forb and woody (non-aspen) vegetation cover within and immediately surrounding clustered and non-clustered seedlings was similar.
3. The only vegetation parameter to show a significant difference was vegetation cover of aspen which, not surprisingly, was highest for the largest clusters of 10 or 20 plants relative to the non-clustered seedlings.

## Study 2: Vegetation Management Solutions for Final Reclamation

The key findings after the second growing season were that:

1. Pre-emergent herbicide applications did not significantly impair the growth and development of the deployed target species.
2. Both pre- and post-emergent herbicide treatments were successful in decreasing undesirable herbaceous species cover.
3. High density planting was very effective in improving the growth of the planted woody species but appear to be less successful in preventing the emergence and growth of non-native forbs.

## LESSONS LEARNED

### Study 1: Interim Reclamation of a Facility Soil Stockpile

As only three seasons of growth have been completed, we are far from making final conclusions about these studies and the overall approach of temporary reforestation. However, this study has clearly demonstrated that creating surface heterogeneity (in this case using a dozer to create furrows and backhoe to mound on steeper slopes) can have a stimulating effect on native plant regeneration.

Hitchhiking fireweed with deciduous woody species has proved challenging and the evidence thus far suggests that there is a very narrow window with which both species can be successfully introduced into the same nursery container. Sowing fireweed too early or too late has resulted in either comprised growth of the deciduous species or limited emergence of the fireweed.

There are few differences in terms of plant growth or vegetation development to suggest there is a significant short-term benefit to tight (25 cm spacing) clustering of aspen seedlings. However, continued monitoring of this study is required to quantify the potential effects of this alternate planting approach as perennial forest species are slow to develop.

### Study 2: Vegetation Management Solutions For Final Reclamation

The second growing season of data collection for this study has been completed and though findings are preliminary, strong evidence has been observed that pre-emergent herbicides were both highly effective at controlling undesirable non-native herbaceous species and that they have not negatively affected the survival and growth of planted woody species.

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Albricht R, Schoonmaker A. NAIT Surmont Boreal Reclamation Project. 3rd Annual Industry Research Symposium, Northern Alberta Institute of Technology. October 25-26th, 2018, Edmonton, Alberta. [Presentation]

## RESEARCH TEAM AND COLLABORATORS

Institution: Northern Alberta Institute of Technology | Centre for Boreal Research

Principal Investigator: Dr. Amanda Schoonmaker

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# Creating and Commercializing a Predictive EcoSite Mapping Platform for Alberta

**COSIA Project Number:** LJ0188

**Research Provider:** Alberta Innovates Technology Futures (Now InnoTech Alberta)

**Industry Champion:** ConocoPhillips Canada Resources Corp.

**Industry Collaborators:** Cenovus Energy Inc., Nexen Energy ULC, Suncor Energy Oil Sands Limited Partnership

**Status:** Final year

## PROJECT SUMMARY

Ecological land classification (ELC), is a process for delineating and classifying ecologically distinctive areas and expressing the relationships between vegetation, physical geography, and soils. ELC is a nested, hierarchical system of classification which in Alberta consists of Natural Regions, Natural Subregions, Ecological Sites or Ecosites, and Plant Community Types. Each classification level enables increased management specificity. Although ecosite information is needed by diverse groups of end users (e.g., government, forestry, oil and gas, reclamation planners), and even though work on ecological land classification has been occurring for 40+ years – no provincial scale ecosite information presently exists.

### Phase 1:

This phase of the work was initiated after a technology scoping study was carried out in 2012 and a business case was developed in 2013. The goals of this phase were to:

1. Carry out a pilot project to determine if machine learning techniques could be used to create accurate maps of ecosite information in two pilot areas; and
2. Develop a governance and business model for such a mapping platform to ensure its continued operation over the next 30+ years.

### Phase 2: 2017-18 Predictive Soil Mapping Pilot in NE Alberta

This pilot study focused on addressing two related questions:

1. Can soil layers be mapped predictively and with sufficient accuracy that they could be used to reduce the amount of field sampling required under current pre-disturbance assessments?
2. Can the coarser scale predictions above be used to streamline pre-disturbance assessments for soil by having the mapping platform select sampling locations based on the degree of uncertainty from the predictive model?

## PROGRESS AND ACHIEVEMENTS

Although work for this project has been completed the progress and achievements for prior years is summarized below.

### Phase 1:

1. **Carry out a pilot project to determine if machine learning techniques could be used to create accurate maps of ecosite information in two pilot areas; and**
2. **Develop a governance and business model for such a mapping platform to ensure its continued operation over the next 30+ years.**

The final report (Aumann, 2016) addressed the first goal, while the companion report (Luchkow, 2016) addressed the second. Predicted maps of edatopic moisture and nutrients were produced at a minimal mapping unit of 0.25 ha (50 m x 50 m or 5 pixels x 5 pixels) corresponding to an effective scale of 1:10,000 to 1:20,000.

The predicted maps were created using machine learning models which leveraged:

- data collected at field sites (e.g., from environmental impact assessments and/or pre-disturbance assessments);
- variables which were derived from a LiDAR based digital elevation model; and
- variables derived from a time series of LANDSAT and MODIS imagery.

The predictive models enabled not only predictions about the most likely edatopic moisture or nutrient class at each location, but also measures of uncertainty about the prediction. The quality of the predicted maps was assessed quantitatively using objective criteria and included a cross validation procedure.

*For the northern pilot area (165 km x 148 km, just south of Fort McMurray):*

- Data from 6,500 field sites were available to develop the models.
- Edatopic moisture predictions had a kappa of 0.52 and an accuracy of 0.65, while nutrients had a kappa of 0.43 and an accuracy of 0.63 – values which agree with those found in other studies dealing with forested landscapes.

*For the southern pilot area (195 km x 167 km, just south of Lloydminister):*

- Data from 1,140 and 1,430 field sites were available to develop the moisture and nutrient models, respectively.
- Edatopic moisture predictions had a kappa of 0.31 and an accuracy of 0.47, while nutrients had a kappa of 0.41 and an accuracy of 0.59. The reasons for the lower kappa and accuracy for moisture in the southern pilot area are presently unclear.

In addition, uplands were delineated from lowlands in both pilot areas (using a similar modeling approach) so that future upland ecosite and wetland classifications would not overlap geographically – thereby enabling a single harmonized ecological land classification for the entire landbase.

## Phase 2: 2017-18 Predictive Soil Mapping Pilot in NE Alberta

1. **Can soil layers be mapped predictively and with sufficient accuracy that they could be used to reduce the amount of field sampling required under current pre-disturbance assessments?**

This question is addressed using a predictive mapping approach similar to that used in the Predictive Ecosite Mapping Project (Aumann, 2016). Data from 9,500 field sites were provided by Suncor Energy Inc., ConocoPhillips Canada Resources Corp., and Cenovus Energy Inc., and are used in the current study to predictively map 11 soil attributes.

The soil attributes predictively mapped, and the associated summary accuracy measures obtained are:

1. ORGANIC.DEPTH – (i.e., depth of organic matter in a wetland) had an average standard error of the residuals (ASER) of 52 cm.
2. SUB.SOIL.DEPTH – ASER of 10.7 cm
3. TOP.SOIL.DEPTH – ASER of 10.3 cm
4. DRAINAGE – kappa of 0.54
5. ORDER – kappa of 0.82
6. GREATGROUP – kappa of 0.86
7. SUBGROUP – kappa of 0.77
8. SURFACE.EXP – kappa of 0.55
9. PARENT.MATERIAL – kappa of 0.76
10. PARENT.MATERIAL.TEXTURE – kappa of 0.68
11. SOIL SERIES – kappa of 0.76

With the exception of ORGANIC.DEPTH, these accuracy measures show the ability to predictively map soil attributes. The reasons for not being able to predictively map ORGANIC.DEPTH, stem from issues with the training data currently available and also that different covariates are needed to predict wetland attributes since this attribute is not determined by topography like the other soil attributes. A key learning from the current study is to use the predictions of coarser soil attributes (e.g., Drainage) as covariates in the models used to predict finer soil attributes (e.g., Soil Series).

The conclusion is that all of the above soil attributes can be mapped predictively (with the exception of Organic Depth for the reasons given above). Thus, predictively mapped ecosites (as was found in the Predictive Ecosite Mapping Project), and soil attributes could potentially be used in pre-disturbance assessments, and conservation and reclamation plans. Whether the vegetation information needed for pre-disturbance assessments, and conservation and reclamation plans can also be mapped predictively remains to be examined. Further, it may be that soil attributes and vegetation are effective predictors of ecosites – but this would have to be assessed in a future study.

2. **Can the coarser scale predictions above be used to streamline pre-disturbance assessments for soil by having the mapping platform select sampling locations based on the degree of uncertainty from the predictive model?**

The second question focused on sampling locations and was addressed using a simulation study that compared the deterministic sampling approach used in pre-disturbance assessments with an adaptive sampling approach targeting sampling to areas of higher predictive uncertainty. The predicted soil attribute maps described above are used as the "ground truth" for assessing the relative efficiencies of the two field sampling approaches.

The simulation study showed that an adaptive sampling approach targeting areas of higher predictive uncertainty outperformed pre-disturbance assessment (PDA) style sampling. With further improvements in how adaptive sampling is done, this would only further increase its efficiency relative to PDA style sampling. Another key finding is that it only took ~1,500 samples to achieve kappas > 0.6 for all discrete soil attributes and that the increases in kappa between 1,500 and 5,000 samples are small. Thus, if such accuracy levels are sufficient for supporting operational requirements, the cost savings across this study area used could be significant.

## LESSONS LEARNED

In 2018 a report on the Predictive EcoSite Mapping Project was produced (Aumann, 2017).

### Phase 1:

The main conclusions from this pilot project phase are:

1. The predictive mapping approach is an accurate way to create higher resolution maps than have been created with traditional mapping approaches.
2. The computerized mapping platform has numerous advantages including:
   a. Ongoing continuous improvement in the quality of the maps over time, since the costs of updating the maps are small and such updates can be done in near real time;
   b. Quantification and spatial representation of mapping error; and
   c. Opportunities to create greater environmental value from data collected to meet regulatory requirements, while simultaneously making it possible to reduce regulatory compliance costs for industry.
3. There are no technical reasons why the mapping platform piloted in this study could not be expanded to the rest of the province.
4. There is a need for ongoing improvements in the ecosite classification field guides.

Realizing such benefits will require a number of changes to the current regulatory system which will need to be carefully orchestrated and implemented.

### Phase 2: 2017-18 Predictive Soil Mapping Pilot in NE Alberta

An adaptive sampling approach targeting areas of higher predictive uncertainty, outperformed PDA style sampling. Further improvements to adaptive sampling methods would only further increase its efficiency relative to PDA style sampling.

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## PRESENTATIONS AND PUBLICATIONS


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## RESEARCH TEAM AND COLLABORATORS

Institution: Alberta Innovates Technology Futures

Principal Investigator: Craig Aumann

Research Collaborators: Alberta Biodiversity Monitoring Institute; Alberta Economic Development and Trade (EDT); Alberta Environment and Parks (AEP); Alberta Innovates (through Bio Solutions and Energy and Environment Solutions); Alberta Pacific Forest Industries Inc (AL-Pac); AltaLIS Ltd.

# Faster Forests

**COSIA Project Number:** LJ0019

**Industry Champion:** ConocoPhillips Canada Resources Corp.

**Industry Collaborators:** Nexen Energy ULC, AOC Leismer Corner partnership, Suncor Energy Oil Sands Limited Partnership, MEG Energy Corp., Husky Oil Corporation, Cenovus FCCL Ltd., and Devon Canada Corporation

**Status:** Year 2 of 5

## PROJECT SUMMARY

Exploration activities required to locate subsurface energy resources result in the clearing of vegetation on exploratory well sites prior to development. Returning land to a functioning boreal ecosystem can take decades. Historic reclamation practices typically involved seeding disturbances with grass and allowing trees and shrubs to grow back on their own. Often these sites became ecologically stagnant with grasses impeding the establishment of shrubs and trees. The Faster Forests program has led to wider adoption of planting sites soon after disturbance, improved reclamation practices and the planting of trees and shrubs to accelerate site recovery.

A number of studies out of the University of Alberta have focused on understanding the factors affecting site recovery and recommended practices for construction and reclamation. ConocoPhillips Canada Resources Corp., with Nexen Energy ULC., Statoil Canada, Suncor Energy Inc. and Total E&P, implemented recommendations from these studies to create Faster Forests, an aggressive reclamation pilot program.

Reclamation of in situ oil sands exploration (OSE) wells and access trails may include planting of tree and shrub seedlings (although some sites are able to recover naturally) in an effort to reduce the time it takes for these disturbances to recover. While the amount of land directly disturbed through OSE programs is a relatively small percentage of the total area, large contiguous patches of wildlife habitat are fragmented when the trees on these sites and associated access routes are cleared. There is a need to restore ecological structure and ecosystem functions at these sites within a shorter period of time. Construction practices have a strong influence on the reclamation outcomes on OSE sites.

The objective of Faster Forests is to accelerate OSE sites along a trajectory to self-sustaining boreal forest ecosystems. This will be accomplished through promoting the best practices gained through research and knowledge sharing.

## PROGRESS AND ACHIEVEMENTS

### Knowledge Sharing Achievements

2018 was a productive year for the Faster Forests group. Major accomplishments were the development of “A Visual Guide to improved construction and reclamation practices on oil sands exploration sites” along with a more detailed Technical Guide. The Visual Guide is being tested in the field during the 2018/2019 OSE construction and reclamation season.

In recent years significant progress has been made in testing and documenting new approaches to the reclamation of oil sands exploration (OSE) sites within Alberta. Many oil sands companies now recognize that many traditional reclamation approaches, which often originated in non-forested areas of the province, may not be as useful on forested sites as previously thought.

The *Visual Guide to improved construction and reclamation practices on oil sands exploration sites*, and the *Technical Guide* were developed based on the following considerations:

**Planning for Success**
Successful return to natural forest vegetation on OSE sites is improved when a specific outcome is envisioned for the site and construction and reclamation practices are carefully planned to achieve that outcome. Such planning requires site knowledge, an idea of the potential range of site responses, and knowledge of the tools that can be used to direct the desired outcome.

**Natural Disturbances as a Baseline**
Alberta's boreal forests have developed under the influence of frequent disturbances, primarily fire. The adaptation of Alberta's forests to this frequent disturbance has resulted in natural resilience, meaning forests recover and regenerate naturally after disturbance. For example, a fire may burn a mixedwood forest, but aspen roots that remain in the soil can quickly sprout new trees. Similarly, forest fires that do not fully consume the litter layer, leave seed banks intact, allowing various understory plant and tree species to quickly regrow soon after. These same principles apply to development of OSE sites. If operators can carefully preserve the integrity of roots and seed banks they can aid in the successful recovery of a site.

**Low Disturbance Principles**
Low disturbance techniques have been widely adopted in many OSE programs because of the recognition of the improved efficiencies and effectiveness that this approach introduces. By minimizing disturbance of the soil surface when constructing OSE sites, construction staff can retain as much of the natural regenerating ability of a site as possible. This has direct implications for reducing reclamation costs and timelines for achieving reclamation certification.

**Peatland Operations**
Current OSE sites constructed on peatlands or muskeg are almost exclusively constructed under frozen conditions. The general process is to progressively increase traffic loads on the peatland surface, causing incremental frost penetration, until a stable frozen platform for supporting the drilling rig and associated equipment is established. No soil excavation is completed and, other than clearing trees, surface vegetation is minimally disturbed.

Despite these efforts, the natural variation of small mounds and potholes (also known as hummocks and hollows) on the peatland surface are commonly flattened when compressed by equipment and/or have inadvertent scraping of the natural moss hummocks. Where hummocks and hollows were flattened during construction, surface roughness will need to be re-introduced mechanically during reclamation. There are generally two options to achieve this. The first is by creating furrows and windrows by tilting a dozer blade and making passes over the site at the time of reclamation. Another option is to use an excavator to lift large chunks of frozen peat out of the peat surface and laying them beside the hole from which they were extracted.

**Upland Operations**
In cases where minimal disturbance techniques are not possible, salvage depths within upland soils should strive to collect the entire rooting zone in the first soil layer to preserve the root integrity and enable regeneration following reclamation. Surface variability should be introduced when replacing soils using excavators to replace topsoils, and woody materials should be carefully managed and replaced on sites to provide maximum opportunities for the recovery of the reclaimed sites.

**Effective Well Centre Management**
A standard procedure following well completion and OSE abandonment is to cut and cap the well. Experience has shown that merely leveling this area to match the adjacent contours after the well has been capped often leads to soil sinking or slumping and water ponding at the well centre. To avoid sunken well centres, a mound of fill material is placed at the well centre. This excess fill material will settle over time to be roughly level with the remainder of the site. Specific heights of this fill material will depend on the site type (upland versus peatland) and the amount of snow and ice within the fill material.

Many of the practices listed here are not revolutionary, and in many cases may already be used by some operators. However, by using the practices highlighted in this guide more consistently, oil sands operators are likely to see improved efficiency and effectiveness of their OSE reclamation programs.

## Field Tour

A field tour was implemented in 2018 with participation from industry, regulators and academics. As with previous years, the attendance was capped at 25 people to ensure discussions routinely involved the entire group and were as candid as possible.

Field tours to visit Oil Sands Exploration reclamation sites started in the autumn of 2011 as an initiative of the Oil Sands Leadership Initiative Land Stewardship Working Group (OSLI-LSWG) to share information in an informal and open manner with each other and the Province of Alberta. As a result of these tours, all participants found great value in sharing ideas, collaborating for innovative solutions and growing relationships.

Participants recognize that fostering a culture of openness creates opportunities to challenge the status quo and the freedom to explore and develop innovative solutions to accelerate environmental performance.

The purpose of the Faster Forests (FF) field tour is to display the 'fruits of the program's labour' and provide a forum for people to collaborate, advance research and development, and promote the use of the best new practices. In 2018 the Field Tour was attended by a mix of construction personnel, environmental advisors, reclamation managers, regulatory representatives from both AER and AEP, and reclamation consultants.

The theme for 2018 was 'Investigating the Effect of Different Construction Practices on Reclamation Success'. As with previous years, non OSE-sites (Oil Sands Exploration) that use the same construction and reclamation practices that were developed by the Faster Forests program were also visited.

### Efficacy Assessment

A pilot study that measured productivity on a small number of Faster Forests planted OSE sites and unplanted (natural recovery) OSE sites was initiated in 2018. Preliminary results suggest that planting significantly increases the amount of vegetation on the planted sites as compared to unplanted sites, as measured with multispectral satellite imagery. A more robust investigation of site productivity commenced in 2018 and is planned to report quantitative results in 2019 (over 450 sites).

## LESSONS LEARNED

While developing *A Visual Guide to improved construction and reclamation practices on oil sands exploration sites*, it became apparent that site construction and reclamation practices are not consistent across the industry. There is an opportunity to align the industry along multiple best management practices for OSE construction.

## PRESENTATIONS AND PUBLICATIONS

### Reports & Other Publications

Improving OSE reclamation performance through enhanced construction and reclamation practices (Prepared by: Terry Osko Ph.D., P.Ag., Circle T Consulting Ltd. & Matthew Pyper M.Sc., Fuse Consulting Ltd. Report Date: November 13, 2018)

A Visual Guide to improved construction and reclamation practices on oil sands exploration sites. (Prepared by: Terry Osko Ph.D., P.Ag., Circle T Consulting Ltd., Matthew Pyper M.Sc., and Sonya Odsen M.Sc., Fuse Consulting Ltd. Report Date: November 13, 2018)

## RESEARCH TEAM AND COLLABORATORS

Principal Investigator: Jon Hornung

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
|---|---|---|---|---|
| Dr. Terry Osko | Circle T Consulting Ltd. | Principal | | |
| Matthew Pyper | Fuse Consulting Ltd. | M.Sc. | | |

Research Collaborators: Amanda Schoonmaker, Northern Alberta Institute of Technology, Centre for Boreal Research; Simon Landhäusser, University of Alberta; Katalijn McAfee, Natural Resources Canada; Kevin Ball, Alberta Energy Regulator

# Oil Sands Vegetation Cooperative

**COSIA Project Number:** LE0014

**Research Provider:** Wild Rose Consulting, Inc.

**Industry Champion:** Canadian Natural Resources Limited

**Industry Collaborators:** Cenovus Energy Inc., ConocoPhillips Canada Resources Corp., Devon Canada Corporation, Imperial Oil Resources Limited, Nexen Energy ULC, Suncor Energy Inc., Syncrude Canada Ltd., Teck Resources Limited

**Status:** Ongoing

## PROJECT SUMMARY

The Oil Sands Vegetation Cooperative (OSVC) was established in 2009 to enable collaborative harvesting and banking of native boreal forest seed for use in revegetation and research. In 2014, the OSVC became a project under Canada's Oil Sands Innovation Alliance (COSIA) Land group. The OSVC is providing support for seed collection initiatives in the Northern Athabasca Oil Sands (NAOS), Southern Athabasca Oil Sands (SAOS) and Cold Lake (COLK) regions, and the identification and development of research projects relevant to revegetation of reclaimed oils sands lands.

The scope of work for this project includes preparation of seed harvest needs, coordination of the annual seed harvest program, management of records for the OSVC seed inventories in the provincial seed bank, provision of technical expertise on identification, collection, storage and deployment of native seed, technical guidance to the OSVC regarding research needs, coordination and record keeping for ongoing discussions related to research project development, preparation of support documents such as literature reviews and data summaries, and preparation of a bi-annual newsletter.

## PROGRESS AND ACHIEVEMENTS

In 2018, the OSVC continued its efforts to direct research applicable to the efficient use of seed and alternative propagules as well as successful native plant community establishment.

Additional activities supporting OSVC initiatives included:

1. Annual reporting on OSVC seed collection and banking activities.
2. Preparing and maintaining research needs documents and tracking current research initiatives.
3. Completing a literature review regarding vegetative propagation of boreal shrub species.
4. Continuing to pursue the establishment of stooling beds for beaked hazelnut (*Corylus cornuta*), and seed orchards for red-osier dogwood (*Cornus sericea*).
5. Initiating a pilot study for vegetative propagation of beaked hazelnut (*Corylus cornuta*) and lowbush cranberry (*Viburnum edule*).

6. Providing seeds for the Alberta Government to further their research on shrub seed viability, germination, and longevity.
7. Liaising with the Alberta Government to improve seed collection methods on public lands.
8. Entering into discussions regarding seed banking and collection to support related projects such as provincial caribou conservation, and revegetation of conventional oil and gas sites provincially.

In 2018, the OSVC harvested 2665 litres (L) of seed from five seed zones in northeastern Alberta. The following were extracted and registered:

COLK – 900 L of tamarack seed from a single lot in seed zone CM 3.1.
SAOS – 1330 L of tamarack seed from 4 seed lots from seed zones CM 2.1, CM 2.4, CM 3.1 and LBH 1.5.
NAOS – 435 L of seed from 33 seed lots representing 21 species from seed zones CM2.1 and CM 2.2.

**Table 1. Species harvested**

| NAOS | |
|---|---|
| *Alnus viridis* (green alder) | *Larix laricina* (tamarack) |
| *Amelanchier alnifolia* (Saskatoon) | *Linnaea borealis* (twinflower) |
| *Arctostaphylos uva-ursi* (bearberry) | *Populus balsamifera* (balsam poplar) |
| *Betula papyrifera* (paper birch) | *Populus tremuloides* (trembling aspen) |
| *Caltha palustris* (marsh marigold) | *Prunus pensylvanica* (pin cherry) |
| *Chamerion angustifoilum* (fireweed) | *Prunus virginiana* (chokecherry) |
| *Cornus canadensis* (bunchberry) | *Rhododendron groenlandicum* (Labrador tea) |
| *Cornus sericea (*red-osier dogwood) | *Shepherdia canadensis* (buffaloberry) |
| *Corylus cornuta* (beaked hazelnut) | *Vaccinium myrtilloides* (blueberry) |
| *Dasiphora fruticosa* (shrubby cinquefoil) | *Viburnum edule* (lowbush cranberry) |
| *Empetrum nigrum* (crowberry) | |

## LESSONS LEARNED

The OSVC, continues to explore research opportunities that were identified in the earlier knowledge gap analysis. There has been a particular focus on shrub establishment on oil sands reclamation sites, including shrub mortality monitoring and plant material quality, vegetative propagation of boreal shrubs, and increasing the efficiency of seed harvest for key species such as aspen (*Populus tremuloides*). The long-term goal of establishing production units (stooling beds and/or seed orchards) for characteristic shrub species is ongoing and requires collaboration among several stakeholders – industry, nursery producers and the Government of Alberta.

## PRESENTATIONS AND PUBLICATIONS

### Newsletters

Wild Rose Consulting, Inc. 2018. Oil Sands Vegetation Cooperative Newsletter. May 3(1). 3 pages. https://www.cosia.ca/sites/default/files/attachments/OSVC%20Newsletter%20-%20May%202018.pdf

Wild Rose Consulting, Inc. 2018. Oil Sands Vegetation Cooperative Newsletter. December 3(2). 3 pages. https://www.cosia.ca/sites/default/files/attachments/OSVC%20Newsletter%203%282%29.pdf

### Reports

Wild Rose Consulting, Inc. 2018. Vegetative Propagation of Native Shrubs: A Literature Review. 50 pages

## RESEARCH TEAM AND COLLABORATORS

Institution: Wild Rose Consulting, Inc.

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
|---|---|---|---|---|
| Ann Smreciu | Wild Rose Consulting, Inc. | Principal/ Ecologist | | |
| Kimberly Gould | Wild Rose Consulting, Inc | Field Ecologist | | |

Research Collaborators: Dr. Jean-Marie Sobze, NAIT Centre for Boreal Research; Lindsay Robb, Alberta Tree Improvement and Seed Centre (Government of Alberta)

# Bioengineering and Conventional Erosion and Sediment Control

**COSIA Project Number:** LE0041

**Research Provider:** Associated Environmental Consultants Inc.

**Industry Champion:** ConocoPhillips Canada Resources Corp.

**Industry Collaborators:** Canadian Natural Resources Limited, Cenovus Energy Inc., Devon Canada Corporation, Imperial Oil Resources Limited, Nexen Energy ULC, Suncor Energy Inc., Syncrude Canada Ltd., Teck Resources Limited

**Status:** Year 1 of 1

## PROJECT SUMMARY

A key component of the, Bioengineering and Conventional Erosion and Sediment Control Solutions for Oil Sands Operations Study, was to document erosion and sediment control (ESC) approaches currently used by in situ and mining companies in northern Alberta. The study also included some coal and forestry companies where their ESC experiences would be relevant to the geographic and ecological conditions encountered by oil sands companies.

Information was collected through, interviews with eleven companies, and documents acquired from operational personnel. Successes, and lessons learned from failures, of bioengineering ESC and of conventional engineered ESC were evaluated. In this study, conventional approaches are defined as techniques to control ESC using concrete, riprap, aggregate, nylon, geotextiles (commonly polypropylene or polyester), and gabion baskets (i.e., wire baskets and/or cages filled with riprap). Bioengineering, is the use of living plant materials to perform some engineering function of ESC (e.g., live pole drains, wattle fences, live staking etc.).

Bioengineering may improve environmental performance at oil sands operations and help meet the COSIA Land EPA goals of reducing footprint, more rapid reclamation, and optimizing biodiversity. These ESC techniques may:

- Reduce footprint intensity, in some cases, as vegetation can be re-established more rapidly and permanently during either operations or phased closure;
- Provide biodiversity benefits, as the bioengineered structures will lead to early successional ecosystems that will succeed to more mature ecosystems and provide a diversity of habitats, especially with phased reclamation;
- Support reclamation objectives for closure by helping create self-maintaining, self-healing ecosystems that mimic natural creeks, wetlands, and other landforms; and
- Result in cost savings during operations, due to lower cost materials and lower maintenance needs, with no requirement to remove synthetic materials/structures at closure.

## PROGRESS AND ACHIEVEMENTS

A final report documenting the benefits and limitations of bioengineering and conventional ESC approaches, as identified by operations personnel, was prepared and published in 2018.

## LESSONS LEARNED

The final report was published in 2018. Some of the key findings are summarized below:

- Bioengineering techniques have been implemented in field operations for at least the past 10-15 years at a variety of mining and in situ facilities.
- Bioengineering techniques can be used successfully alone and in combination with conventional erosion and sediment control in a variety of settings.
- The use of rough and loose soil management with coarse woody material and the planting of shrub and tree seedlings, is being used more commonly at some of the oil sands and coal mines for rapid, natural revegetation. The use of the rough and loose technique will allow oil sand operators to move away from the practice of hydroseeding. Grasses and legumes reduce the survival of tree and shrub seedlings, and reduce the potential for ingress of native plant species from surrounding areas.
- Bioengineering techniques to establish vegetation are discouraged at higher-risk operational sites where: encroaching wildlife could increase human-wildlife conflicts; or where rapid or certain ESC is required to manage safety risks; or where vegetation would obscure visual integrity inspections.
- Bioengineering techniques using live plants are considered permanent ESC methods that require little maintenance once established. They are particularly successful along streambanks, drainways, and near groundwater seeps. The vegetation helps manage the water sources that can cause erosion and helps to stabilize the slopes with its root masses. These techniques are particularly useful for operational projects away from high ESC risk areas, such as, at well pads, soil stock piles, bridges, roads and for the closure landscape.
- Bioengineering techniques may be challenging to implement for larger scale, landscape-level projects, due to the intense labour required for installation, and due to the limited availability of live cuttings. Live plant cuttings could be grown in stooling beds (cultivated in fields) or rooted in nurseries.
- Although erosion and control matting is used at several oil sands and coal operations, it can be challenging to install, maintain and remove at final reclamation, and can inhibit plant species diversity.

Ten factors to be considered when determining the suitability of specific erosion control practices for a project were identified:

1. Risks or consequences of failure,
2. Need for immediacy,
3. Water flow and velocity,
4. Topography/slopes,
5. Soil characteristics and moisture,
6. Accessibility,
7. Weather and season,
8. Permanency of techniques,
9. Availability of materials, and
10. Cost.

Three recommendations are proposed to encourage the use of bioengineering as a more common ESC practice in the oil sands region:

1. Increase training on bioengineering techniques and installation
2. Coordinate live plant production for bioengineering installations
3. Coordinate and expand research on bioengineering techniques

## PRESENTATIONS AND PUBLICATIONS

### Reports & Other Publications

INTEGRATED REPORT Canada's Oil Sands Innovation Alliance (COSIA). Bioengineering and Conventional Erosion and Sediment Control Solutions for Oil Sands Operations. Associated Environmental Consultants Inc. May 2018. Available at: https://www.cosia.ca/sites/default/files/attachments/Bioengineering%20and%20Conventional%20Erosion%20and%20Sediment%20Control%20Solutions%20for%20Oil%20Sands%20Operations.pdf

## RESEARCH TEAM AND COLLABORATORS

Institution: Associated Environmental Consultants Inc.

Principal Investigator: Judy Smith

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
|---|---|---|---|---|
| Stephanie Findlay | Associated Environmental Consultants Inc. | Environmental Scientist | | |
| Kristin Andersen | Associated Environmental Consultants Inc. | Senior Environmental Scientist | | |
| Dave Polster | Polster Environmental Services Ltd. | Plant Ecologist | | |

# WILDLIFE RESEARCH AND MONITORING

# South LiDea Restoration Area Project

**COSIA Project Number:** LJ0182 and LJ0307

**Research Provider:** Cenovus Energy Inc.

**Industry Champion:** Cenovus Energy Inc.

**Industry Collaborators:** Imperial Oil Resources Limited, Canadian Natural Resources Limited, Devon Canada Corporation

**Status:** Year 2 of 2

## PROJECT SUMMARY

Caribou decline is one of the most serious environmental challenges facing in-situ oilsands. In fact, the issue has been described as an existential threat. A substantial body of research has found the ultimate cause of herd declines is related to habitat disturbance. Linear features, especially legacy seismic lines, contribute disproportionately to the apparent disturbance as it is calculated in the Federal recovery strategy for woodland caribou prepared by Environment Canada (Environment Canada 2012). Legacy linear features are distributed widely on the landscape in NE Alberta and are very slow to return to tree cover which exacerbates their habitat impact.

Over the last decade, COSIA member companies have conducted a series of applied investigations into the use of silvicultural restoration techniques with the objective of making the return to tree cover more rapid and predictable. Following the successful testing and refinement of restoration techniques, treatments have been deployed at landscape scale within the Cenovus Caribou Habitat Restoration Project (Cenovus 2016). This approach to restoration has the following biophysical objectives:

- To increase the growth and abundance of conifer trees on legacy seismic lines
- To reduce the preferential use of lines as travel corridors by large mammals
- To restore plant and animal species distribution at various spatial scales.

In a continuation of this landscape scale restoration work, Cenovus Energy Inc. completed the South LiDea Restoration Project in 2017. The South LiDea project is distinguished from previous efforts because it involved the collaboration of four COSIA member companies including Cenovus Energy Inc. In addition, the implementation of learnings and efficiencies led to the mechanical treatment of nearly all features within a four-township area within one year, including the completion of a portion of the project under non-frozen conditions using equipment capable of amphibious operations.

## PROGRESS AND ACHIEVEMENTS

The South LiDea restoration project resulted in 17,343 hectares of disturbed habitat being treated for restoration, including the planting of approximately 360,000 tree seedlings. Related investigations on these restoration techniques in the Cenovus LiDea projects revealed that:

- Large mammals, especially wolves, move more slowly through lines that are treated for restoration
- Wolves preferences changed once lines were treated intensively with restoration techniques
- Conifer seedling growth and survival is improved
- Natural ingress of conifers is improved

## LESSONS LEARNED

In-situ oil sands are faced with the challenge of a significant backlog of legacy linear disturbances in NE Alberta, many of which are not returning to forest cover passively. Active restoration treatment has resulted in positive plant and animal response, which will in time help to address the issue of caribou decline.

Responding to the backlog of legacy features requires attention to a number of needs including the:

- Prioritization of large contiguous areas for treatment;
- Restoration of forest cover outside of individual oilsands lease or project boundaries; and
- Collaboration of COSIA members in execution of large scale restoration projects on the NE Alberta landscape.

## PRESENTATIONS AND PUBLICATIONS

No presentations or publications in 2018.

## LITERATURE CITED

Cenovus 2016. Caribou Habitat Restoration Project. Online: https://www.cenovus.com/responsibility/environment/caribou-habitat-restoration-project.html. Cenovus Energy Inc.

Environment Canada 2012. Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal population, in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada. Xi+ 138 pp.

## RESEARCH TEAM AND COLLABORATORS

Institution: Cenovus Energy Inc.

Principal Investigator: Michael Cody

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
|---|---|---|---|---|
| Ted Johnson | Cenovus Energy Inc. | Group Lead | | |
| Lori Neufeld | Imperial Oil Resources Limited | Lead – Biodiversity | | |
| Amit Saxena | Devon Canada Corporation | Lead – Biodiversity | | |
| Jon Gareau | Canadian Natural Resources Limited | Environmental Coordinator | | |
| Kristen Foxcroft | Cenovus Energy Inc. | Specialist - Biodiversity | | |

# Regional Industry Caribou Collaboration (RICC)

**COSIA Project Number:** LJ0155

**Research Provider:** Alberta Biodiversity Monitoring Institute (ABMI)

**Industry Champion:** Devon Canada Corporation

**Industry Collaborators:** Cenovus Energy Inc., Imperial Oil Resources Limited, Canadian Natural Resources Limited, Suncor Energy Inc., Nexen Energy ULC, Athabasca, MEG, Alberta-Pacific Forest Industries

**Status:** Year 3 of 5

## PROJECT SUMMARY

The main cause of caribou declines across most of their ranges is excessive predation, mostly by wolves. The current high predation levels are a result of many complex and interacting factors, including landscape level habitat changes (both natural and human-caused). For any caribou recovery program to be successful, it has to address the full range of habitat and population factors impacting caribou, and it must be implemented at the broad-range scale to ultimately spur caribou population growth over time.

The Regional Industry Caribou Collaboration (RICC) is a group of energy companies and a forestry company in the oil sands region of northeast Alberta that are working together across their project boundaries to:

- Restore caribou habitat on legacy seismic lines
- Conduct research on caribou ecology and their relationships with other parts of the landscape
- Lead trials on restoration methods, effectiveness and how wildlife respond to restoration

Reversing the decline of caribou requires a focused, science-based strategy that involves multiple partners at many levels. RICC brings together energy and forestry companies, government agencies, academia, and third party consultants to contribute to the recovery of boreal woodland caribou and their habitat.

## PROGRESS AND ACHIEVEMENTS

**Large-Scale Habitat Restoration** Since 2012, the year RICC was formed, member companies have led or collaborated on large-scale habitat restoration projects spanning multiple townships. RICC members have initiated restoration of over 1,000 linear km of legacy seismic lines.

**Wildlife Monitoring:** Monitoring wolf movements to understand how these predators use seismic lines to hunt caribou. Wolf radio telemetry revealed that wolves select for conventional seismic lines and avoid low impact seismic lines. Furthermore, wolves moved up to 2.5 times faster on those conventional seismic lines than in the undisturbed forest. In addition, vegetation growth of 50 cm on these lines slowed wolf travel speeds considerably.

**Wildlife-Landscape Research:** Conducting research on deer, moose, caribou, wolf, black bear, and landscape patterns to better understand how these inter-relationships affect caribou populations. In 2018, work focussed on (i) deployment of camera arrays to gauge biodiversity responses to caribou management tools in different caribou ranges in northeastern Alberta and (ii) two research projects on various aspects of fire ecology as it pertains to caribou recovery.

**Camera Arrays:**

Camera array results are intended to be collected over multiple years so as to amass a sufficient sample size to draw conclusions. 2018 was Year 1 of data collection, so results are not yet available.

**Caribou Use of Burns:**

To examine the effects of forest fires on woodland caribou, we collected GPS location data on five caribou ranges in northeastern Alberta. We used high-resolution imagery to map wild fires that have burned in the past 40 years. Using caribou locations and updated mapping we assessed fine-scale habitat selection to examine whether caribou were selecting or avoiding burned areas within their home range. Our updated fire mapping shows that previously delineated fire boundaries contain a large percentage of unburned residual patches within the burn complex, which may be suitable habitat for caribou. Preliminary habitat selection results suggest that caribou are avoiding burned landscapes, including both the burn complex and these residual patches. This avoidance can persist for up to 30 years post-fire, presumably until the forest is old enough to support lichen.

**Caribou, Moose and Fire:**

A recent analysis tested this assumption using GPS radio-collar data from 112 individual moose distributed among three study areas situated in northeastern Alberta, northwestern Saskatchewan and northeastern British Columbia. All three study areas encompassed portions of recognized woodland caribou ranges. The analysis specifically focused on moose response to fires (or burned areas) and responses were evaluated at multiple spatial scales. Moose showed low use of burns at all scales of analysis and during all seasons, regardless of time since fire. For example, out of 98 moose monitored during the summer season (July – November), 86 had burned areas (= 25 years post-fire) within their summer home ranges, yet 71 of these individuals had no GPS locations within burns. Burned peatlands were particularly avoided by moose. At a larger scale, moose did not situate their seasonal home ranges to take advantage of burned areas. To determine if these behavioural findings scaled up to population changes, the analysis further evaluated whether the extent of burned areas influenced moose densities within 24 moose survey units in Alberta and 17 in northeast British Columbia (n = 17). When considering all burns = 40 years old – a threshold used by the federal recovery strategy for quantifying burns in caribou range, results suggest no effect of burns on estimated moose densities, even after accounting for the effects of other land cover types within survey units.

## LESSONS LEARNED

**Wolf Use of Seismic Lines:**

Based on the results of our wolf use of seismic lines study, lines with vegetation already exceeding 50 cm would be considered "restored," providing an immediate bump in undisturbed habitat. For example, in one study area within the Cold Lake caribou range, 13% of lines had already reached the 50 cm height threshold, reducing restoration cost and timelines required for caribou ranges to meet federal disturbance targets by decades. Conversely, lines with vegetation below 50 cm can be prioritized for restoration activity. While more research is needed to determine exactly when wolves begin to treat seismic lines the same as natural forest, Dickie's work suggests an intriguing new paradigm for seismic line restoration, at least with respect to woodland caribou.

**Caribou Use of Burns:**

Currently, both the burn complex and unburned residuals are considered disturbed habitat, and cannot be included in the federal recovery strategy's 65% undisturbed habitat threshold. This understanding originates from only a few studies, which lack focus on woodland caribou and mostly overlook residuals. This research will further explore these relationships to fully understand the effects of fire on the behaviour and survival of caribou, and inform habitat management goals.

**Caribou, Moose and Fire:**

Our research findings suggest that forest fires have minimal impact on moose populations within western boreal forests, which calls into question the prevailing hypothesis linking fires to caribou population declines. Further research is necessary to understand the mechanisms by which fires affect caribou populations and the relative importance of fire effects. By refining our understanding of how disturbance affects caribou populations, such research will inform assessments of caribou habitat quality, which in turn should guide the collaborative management actions required for mitigating disturbances within caribou range.

## PRESENTATIONS AND PUBLICATIONS

Dickie, M., R. Serrouya, S. McNay, and S. Boutin. 2017. Faster and Farther: wolf movement on linear features and implications for hunting behaviour. J. Appl. Ecol. 54: 253-263.

Dickie, M., R. Serrouya, C. DeMars, J.Cranston, and S. Boutin. 2017. Evaluating functional recovery of habitat for threatened woodland caribou. Ecosphere. Vol 8 (9).

More information about RICC can be found at: [www.cosia.ca/initiatives/land/regional-industry-caribou-collaboration](www.cosia.ca/initiatives/land/regional-industry-caribou-collaboration)

## RESEARCH TEAM AND COLLABORATORS

Institution: Alberta Biodiversity Monitoring Institute

Principal Investigator: Rob Serrouya

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
|---|---|---|---|---|
| Melanie Dickie | Alberta Biodiversity Monitoring Institute | Research Analyst | | |
| Craig DeMars | Alberta Biodiversity Monitoring Institute | Research Analyst | | |
| Sean Koncolics | University of Alberta | M.Sc. | 2017 | 2019 |
| Stan Boutin | University of Alberta | Professor | | |

Research Collaborators: Alberta Biodiversity Monitoring Institute, Caribou Monitoring Unit; University of Alberta; Government of Alberta; Alberta Environment and Parks

# Assessing Wildfire Risks to Caribou Recovery Projects in Northeast Alberta

**COSIA Project Number:** LE0035

**Research Provider:** Natural Resources Canada (NRCan), Canadian Forest Service

**Industry Champion:** Devon Canada Corporation

**Industry Collaborators:** Canadian Natural Resources Limited, Cenovus Energy Inc., ConocoPhillips Canada Resources Corp., Imperial Oil Resources Limited, Nexen Energy ULC, Suncor Energy Inc., Syncrude Canada Ltd., Teck Resources Limited

**Status:** Year 1 of 1

## PROJECT SUMMARY

The boreal forests of Alberta have extensive networks of legacy seismic lines that have been linked to the decline of boreal woodland caribou *(Rangifer tarandus caribou)* populations throughout Alberta. This is due to the effects these disturbances have on increasing predation pressure on caribou. In order to contribute to caribou recovery, energy companies are investing significant resources in the restoration of these seismic lines, as well as planning for population augmentation projects, in key areas. However, frequent large and intense wildfires may undermine the effectiveness of these conservation measures. To minimize the wildfire risk, managers need to know the likelihood of wildfire and the effectiveness of mitigation measures.

In this study, a wildfire risk assessment was conducted across two spatial scales: (i) a large study area encompassing the entire COSIA study area, and (ii) a more detailed assessment within the Cold Lake caribou range. The Canadian Forest Services' Burn-P3 model was used to determine burn probability, wildfire risk to restored seismic line areas, and the effectiveness of mitigation measures. Specifically, this project's objectives were to:

- Assess the current wildfire risk to restored seismic line areas within the Cold Lake Caribou Range;
- Determine the best places on the landscape to invest in caribou conservation efforts with respect to minimizing susceptibility to wildfire risk;
- Determine which mitigation measures may reduce wildfire risk; and
- Determine burn probability under future climate change scenarios.

## PROGRESS AND ACHIEVEMENTS

Through this project, the burn probability of the landscape was found to be highly heterogeneous. In the larger COSIA study area, the highest burn probability was found to occur in the western half of the study area. Within the Cold Lake caribou range itself, the highest burn probabilities are found on the northern and western portions of the range. To date, most of the largest tracts of seismic line restoration have been conducted within the easternmost portions of the Cold Lake caribou range, and these areas generally have a low burn probability.

Recent large burns and waterbodies were found to provide "shields" that reduced burn probability on their leeward sides (to the east). Nine mitigation scenarios were tested based on ignition management, fuel conversion and combinations of these two tools. These mitigation scenarios were designed to mimic the shielding effect of waterbodies and large recent burns. It was found that these intensive management actions reduced the burn probability and wildfire hazard in the restored habitat zones, but that this effect was minimal as the effectiveness of these treatments declined rapidly as distance from the treatment zones increased.

Incorporation of future climate scenarios impacted the burn probability significantly. Within a total study area of 19,715,000 ha, the mean annual modeled area burned is 179,000 ha for the baseline period, 442,000 ha for the 2050s, and 690,000 ha for the 2080s. Overall, the wildfire predictions for the COSIA oil sands region saw increases in area burned, increases in large fires greater than 100,000 ha, and decreased fire return intervals (i.e., fires more often).

## LESSONS LEARNED

The report will be shared with caribou range planners and recovery managers to help inform restoration activities.

By mapping the probability and mitigating the risk posed by wildfire to ongoing and future caribou recovery projects, the potential success of these projects can be improved. For example, if land managers want to minimize the risk of losing their investments in caribou conservation to wildfire, it would be wise to have mitigation measures spatially targeted closer to the conservation areas. Furthermore, it would be advisable to have redundancy in any conservation measures and wildfire-risk mitigations to ensure that losses due to wildfire on one area do not jeopardize all measures within the landscape. The results of this project (i.e., burn probability) can also be used as a data input to guide the location selection for other caribou recovery tools such as predator exclosure fencing or maternity pens.

## PRESENTATIONS AND PUBLICATIONS

### Journal Publications

Stockdale, C., Q. Barber, A. Saxena, M.A.Parisien. 2018. Examining management scenarios to mitigate wildfire hazard to caribou conservation projects using burn probability modeling. Journal of Environmental Management.

### Reports & Other Publications

Stockdale, C., Q. Barber, M.A. Parisien. 2018. Assessing Wildfire Risk to Caribou Conservation Projects in Northeast Alberta. Final Report. Prepared by Natural Resources Canada (Canadian Forest Service) for Canada's Oil Sands Innovation Association (COSIA).

## RESEARCH TEAM AND COLLABORATORS

Institution: Natural Resources Canada (NRCan), Canadian Forest Service

Principal Investigator: Chris Stockdale, Post-Doctoral Research Scientist

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
|---|---|---|---|---|
| Marc-Andre Parisien | Canadian Forest Service | Research Scientist | | |
| Quinn Barber | Canadian Forest Service | Spatial Analyst | | |
| David Price | Canadian Forest Service | Research Scientist | | |

Research Collaborators: Government of Alberta

# Migratory Connectivity Project

**COSIA Project Number:** LJ0276 Migratory Connectivity Project

**Research Provider:** Migratory Bird Center, Smithsonian's National Zoo and Conservation Biology Institute

**Industry Champion:** ConocoPhillips Canada Resources Corp.

**Status:** 2014 – Present (annual participation)

## PROJECT SUMMARY

Migration is one of the most engaging phenomena of the animal world and is epitomized by birds. Understanding and tracking animal movements are crucial components for conserving the habitats that are essential to species survival. And yet, our knowledge about why, how, when and where most of Earth's bird species migrate during their lifecycle is rudimentary, at best. Migratory connectivity is the geographic linking of individuals and populations between one life cycle stage and another, such as between breeding and wintering locations for a migratory bird. Without an understanding of migratory connectivity, conservation investments can be ineffective because they are implemented at the wrong place or time, or for the wrong purpose.

Support from ConocoPhillips Global Signature Program for the Smithsonian Migratory Bird Center's Migratory Connectivity Project (MCP, http://www.migratoryconnectivityproject.org) is enabling critical work on the conservation of birds. Considerable overlap exists between MCP and ConocoPhillips Canada Resources Corp.'s (ConocoPhillips) biodiversity stewardship strategies, including conserving critical habitats where ConocoPhillips does business; strengthening the ability of multiple public and private stakeholders to address and manage biodiversity needs collaboratively; and improving the depth and quality of scientific research of key environmental challenges that will inform more effective solutions for biodiversity conservation.

Primary objectives include:

1. Signature Electronic Tracking Projects to track the migrations of birds throughout their annual cycles, discover unknown migrations, discover important breeding, stopover, and wintering habitats, and make this information available to managers;
2. Testing and advancing new technologies; and
3. Catalyzing research and scientific collaborations around the migratory connectivity of birds throughout North America and across the Western Hemisphere.

## PROGRESS AND ACHIEVEMENTS

### Signature Tracking Projects

In the last 50 years, Common Nighthawk populations have declined by 80% across North America for reasons still unknown. In order to begin solving this puzzle, we partnered with the University of Alberta to track the migrating bird across two hemispheres. We needed to track the nighthawk to understand what risks it might encounter during the eight months it spends outside of Canada each year.

In 2018, we revealed the migration routes and overwintering areas of a threatened boreal bird species, the Common Nighthawk (Ng et al. 2018, see publications). By tracking 10 individuals with small satellite tags, our new research discovered the 20,000 km annual journey of nighthawks from their breeding areas north of Fort McMurray, Alberta to the Amazon rainforest in Brazil.

We were surprised to find that all individuals spent their winters in Brazil, because most observations of them are from further south in Argentina. We also learned that nighthawks return to almost exactly the same place they nested in the previous summer.

### Testing and Advancing New Technologies

Our work with Common Nighthawks also resulted in the first successful (full-year) deployment of a tiny GPS-Argos satellite tag small enough to use on songbirds and shorebirds. In 2014-2015, we served as beta testers for this new tag for Lotek Wireless, the tag manufacturer. We tested the first two generations of this tag and published our results (Scarpignato et al. 2016). Our work with Common Nighthawks using an improved model of this tag provided the first successful results. By helping groundtruth the use of this tag, we contributed to a new and accurate way for biologists to track the migrations of birds that weigh as little as 120 grams.

### Catalyzing Research and Scientific Collaborations

The success of this program, both from a logistical, but also conservation perspective, hinges on successful collaboration with many local and regional partners. Our partners, who have provided local expertise and field personnel have increased our capacity to execute expeditions, conduct scientific research, and disseminate our results.

Our work in 2018 included collaborations with at least 25 individuals and 14 organizations. In addition to generous support we received from ConocoPhillips, our collaborators contributed additional funds and in-kind support for tracking devices, equipment, field time and expenses, and graduate student assistantships. The Migratory Connectivity Project is enabling research at a large scale by catalyzing partnerships across organizations and places.

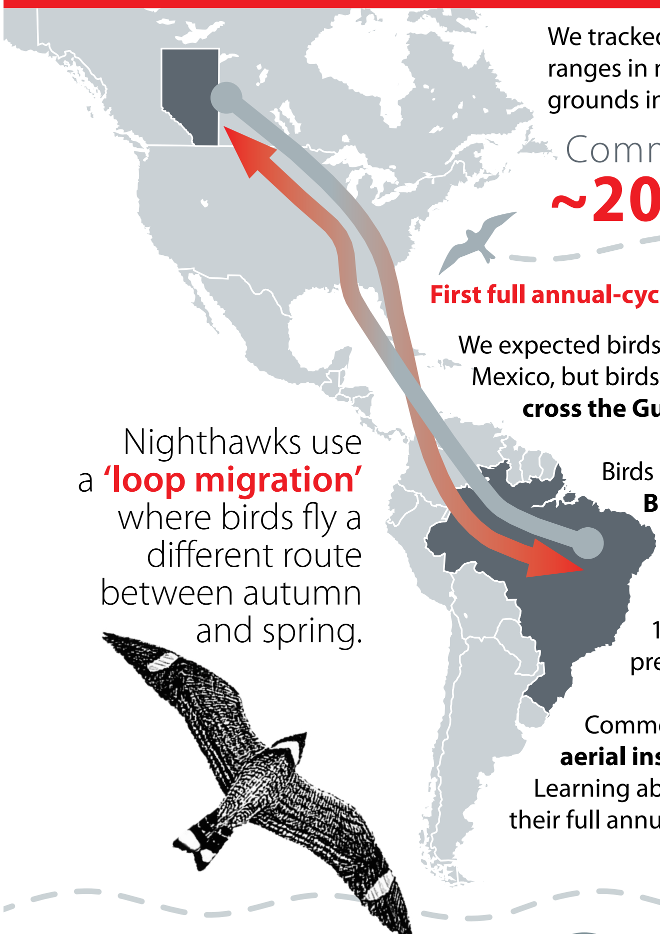
## LESSONS LEARNED

We provided the first insights into links between breeding habitats in the boreal forest of northern Alberta and Amazonian rainforests in Brazil, for a species of conservation concern, the Common Nighthawk (see infographic). Understanding when and where birds migrate is a key first step in learning how to manage them effectively (and *where* to implement management actions) to reverse declines. Also, Alberta nighthawks demonstrated relatively high site fidelity to breeding locations during the study; nighthawks returned from their migration to almost exactly the same place (~1 km) to nest as they did the previous summer. In 2017-2018 we expanded our Common Nighthawk project across North America to compare the risks that different threatened bird populations face, a critical first step for developing effective and relevant conservation strategies.

# Brazil and Back

## Satellite Tracking Reveals Common Nighthawk Migration Across Two Hemispheres

ConocoPhillips



We tracked six nighthawks from breeding home ranges in northern Alberta to their wintering grounds in central Brazil.

Common Nighthawks migrate **~20,000 KM/YEAR**

**First full annual-cycle tracking of Common Nighthawks**

We expected birds to migrate overland down through Mexico, but birds migrated through Florida and Cuba to **cross the Gulf of Mexico.**

Birds nesting in the boreal forest wintered in **Brazil's tropical savannas and rainforest.**

Birds **returned next spring near their original home range,** often within 1 km of where they were captured the previous year.

Nighthawks use a **'loop migration'** where birds fly a different route between autumn and spring.

Common Nighthawks are **one of many aerial insectivores that are declining rapidly.** Learning about risks they might encounter during their full annual-cycle helps shape conservation.

**80%**

Common Nighthawks are a **species at risk** in Canada. Their populations have declined by ~80% since 1968

We tracked birds with tiny satellite transmitters that weighed just over a penny, **~3.5 grams**

**Future research** will connect Common Nighthawks breeding across North America to their wintering grounds

University of Alberta · Smithsonian Conservation Biology Institute Migratory Bird Center · The Migratory Connectivity Project

Ng, J., Knight, E., Scarpignato, A., Harrison, A. L., Bayne, E. M., & Marra, P. P. 2018. First full annual cycle tracking of a declining aerial insectivorous bird, the Common Nighthawk (Chordeiles minor), identifies migration routes, non breeding habitat, and breeding site fidelity. Canadian Journal of Zoology 97 (8): xx. This research was supported by ConocoPhillips Charitable Investments Global Signature Program

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## PRESENTATIONS AND PUBLICATIONS

### Journal Publications

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Public access: http://www.nrcresearchpress.com/doi/full/10.1139/cjz-2017-0098#.XDyuA89KjAI

### Conference Presentations/Posters

Knight, E.C. 2018. Strength in numbers: Collaboration and new technology reveal secrets of the Common Nighthawk. Prairie Conservation Action Plan. Edmonton, AB. Webinar Presentation.

Available at: https://www.youtube.com/watch?v=tU_QW6R9Bvs&feature=youtu.be

## RESEARCH TEAM AND COLLABORATORS

Institution: Migratory Bird Center, Smithsonian's National Zoo and Conservation Biology Institute

Principal Investigator: Peter Marra, Ph.D

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
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| Amy Scarpignato | Migratory Bird Center, Smithsonian's National Zoo and Conservation Biology Institute | GIS Specialist | | |

Research Collaborators:

| Organizations | Collaborators |
| --- | --- |
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| Northern Arizona University | Jeff Foster |
| Smithsonian Migratory Bird Center | Mike Hallworth (Postdoctoral Research Associate |
| The Ohio State University | Jay Wright |
| University of Alberta | Elly Knight, Student (Ph.D. 2021) |
| University of Alberta | Janet Ng, Student (Ph.D. 2019) |
| University of South Dakota | Gretchen Newberry |
| USFWS, Alaska | Jim Johnson |
| USFWS, Nevada | Chris Nicolai |

# Monitoring Avian Productivity and Survivorship in the Oil Sands Region (Boreal MAPS)

**COSIA Project Number:** LJ0214

**Research Provider:** Owl Moon Environmental Inc.

**Industry Champion:** Syncrude Canada Ltd.

**Industry Collaborators:** ConocoPhillips Canada Resources Corp., Hammerstone Corporation, Husky Oil Operations Ltd., Suncor Energy Inc., Devon Canada Corporation, Nexen Energy ULC

**Status:** 2011 – Present (annual participation)

## PROJECT SUMMARY

Monitoring Avian Productivity and Survivorship (MAPS) is a continent-wide mark-recapture (bird-banding) program dedicated to understanding population demographics and vital rates of landbirds (passerines and woodpeckers), most of which are Neotropical migrant species. Indices of avian vital rates provide a strong indication of habitat quality and structural complexity in consideration of the various life history requirements of each species. Data collected using captured and banded birds are useful in evaluating many aspects of landbird dynamics, including effects from industrial activities. In northeastern Alberta, there is significant interest in boreal forest ecology in response to industrial operations, habitat disturbances, and reclamation efforts. The overall value from this program is the understanding of what is driving changes in avian population dynamics and diversity for bird species nesting in the boreal forest near the oil sands region.

Vital-rate data are lacking for landbird species that rely on the boreal forest (Thompson 2006; Wells 2011), limiting our ability to address underlying causes of population changes for those species that are experiencing population declines (Rosenberg et al. 2016). Measurement of vital rates within reclaimed, fragmented or otherwise disturbed, and natural habitats over time provides an assessment of local scale effects, including habitat performance, and identifies regional effects resulting from pressures or stress experienced during migration or on the wintering grounds (Newton 2004, Albert et al. 2016). Low or declining productivity would indicate that effects are occurring on the breeding grounds, while low or declining adult and/or juvenile survivorship would suggest that the effects are caused on the wintering grounds or during migration (Newton 2004; Wilson et al. 2018). Understanding factors within the annual cycle leading to population declines is critical to the effective management and recovery of bird populations, including decisions on whether to devote resources to management on breeding or wintering grounds.

The industry-specific value from this program is twofold:

1. It advances the understanding of local effects and those encountered during migration or on the wintering grounds; and
2. It provides the opportunity for industry to potentially optimize reclamation, mitigation, and habitat restoration best practices considering the habitat requirements of select species that are experiencing population declines as a result of low productivity on the breeding grounds.

The Monitoring Avian Productivity and Survivorship in Oil Sands Region Program (Boreal MAPS Program) has been established to address two objectives:

1. To advance the understanding of avian population dynamics and diversity in reclaimed habitats and in habitats subject to disturbances associated with industrial and human activities, as compared to natural, unaffected areas; and
2. To acquire data for use in estimating population vital rates for bird species nesting in the boreal forest.

A third goal, although not a formal program objective, is to provide a platform for use by other researchers undertaking complementary programs. This results in opportunities for the leveraging of data and collaboration.

In 2011, six MAPS stations were established in the oil sands region and the program was expanded to include 38 stations by 2015, although not all stations were operated in each year due to safety concerns related to the Horse River wildfire in 2016, and due to funding constraints. A total of 35 stations have operated over enough years to be included in the analytical dataset. These include 15 natural or reference stations (>90% of habitat unaffected by disturbance), five reclaimed stations (>55% of habitat reclaimed), and 15 disturbance-affected stations (<90% natural, <55% reclaimed; e.g., cutlines, exploration well pads, roads). Since 2011, six stations have been affected by natural disturbance; one station was flooded in 2013, and five stations burned in 2016.

Each MAPS station consists of eight to fourteen, 12-m mist nets operated for six hours per day on six days between June 10 and August 8 each year, in accordance with the standardized protocol developed by The Institute for Bird Populations (DeSante et al. 2018).

For captures of unbanded birds, a uniquely numbered, aluminium leg band issued by the Canadian Wildlife Service was applied to the leg. Data on species, age, sex, breeding characteristics, moult status, and other physical characteristics were recorded, along with biometrics such as wing length and weight. Age classes were assigned as HY (hatched during the monitoring year) or AHY (hatched before the monitoring year) and most AHY birds were separated into SY (hatched in the previous year) or ASY (hatched before the previous year) (Pyle 1997). Where birds are difficult to age, photographs are taken for later evaluation and confirmation of bird age.

Computer entry, data proofing, and verification of banding, mist-net effort, and breeding status data were completed using specially designed data entry, verification, and editing programs. For analyses, the number of adult birds captured per 600 net-hours was used as an index of adult population size, and post-fledging productivity was estimated by the ratio of individual young to adult birds captured. A minimum of 2.5 adult captures per 600 net-hours is required to derive adult population size and productivity index estimates. Survival estimates require an average adult capture rate of ≥2.5 adults per year and at least two between-year recaptures over a minimum of four, and preferably five consecutive years of collected data. More years of data improves the precision of the survival estimate, and up to 10 years may be required to collect sufficient data for some species. For species with sufficient capture and recapture data, survivorship was estimated using Modified Cormack-Jolly-Seber capture-mark-recapture models (Pollock et al. 1990; Lebreton et al. 1992). Recruitment is being evaluated as an additional vital rate metric. As estimate of recruitment of breeding birds into the adult population is obtained from the number of young (HY) that survive and reproduce, as determined by the capture rate of second-year (SY) birds or through capture-mark-recapture analyses. Recruitment may include birds that immigrate into the area.

## PROGRESS AND ACHIEVEMENTS

Quality assurance review and analyses of the 2018 data are ongoing, and the numbers presented here are preliminary and may change as the data are validated. In 2018, field work comprised 11,648 net-hours of operation at 33 stations, resulting in 3,789 birds newly banded, 55 released unbanded, and 1,339 recaptures of previously banded birds, for a total of 5,183 captures (267 total captures per 600 net-hours). Captures were higher than those recorded in 2017 (4,701; 246 total captures per 600 net-hours), and similar to those recorded in 2016 (5,087; 279 total captures per 600 net-hours), and much lower than in 2015 (8,315; 393 total captures per 600 net-hours). A statistically-significant (p=0.001) downward trend of -4.4% in adult population size (all species pooled) is apparent from 2011 to 2018 (Figure 1). Preliminary analyses estimate 123.4 adults per 600 net-hours in 2018, compared to 115.9 adults capture per 600 net-hours in 2017. Productivity (the number of young relative to adult captures for all species, normalized for effort) has also decreased significantly (p=0.001) with a slope of -0.070 since 2011 (Figure 1). The preliminary productivity estimate for 2018 appears to be 0.71, compared to 0.68 in 2017.

With the data collected under the MAPS program, we are able to examine possible explanations for these trends on per species basis, such as effects of the forest fire in 2016, natural cycles in local populations, regional resource development, a reflection of the general decline in landbird populations continent-wide, or a combination of factors. The population trends we are observing are consistent with continental findings and the general decline in bird populations.

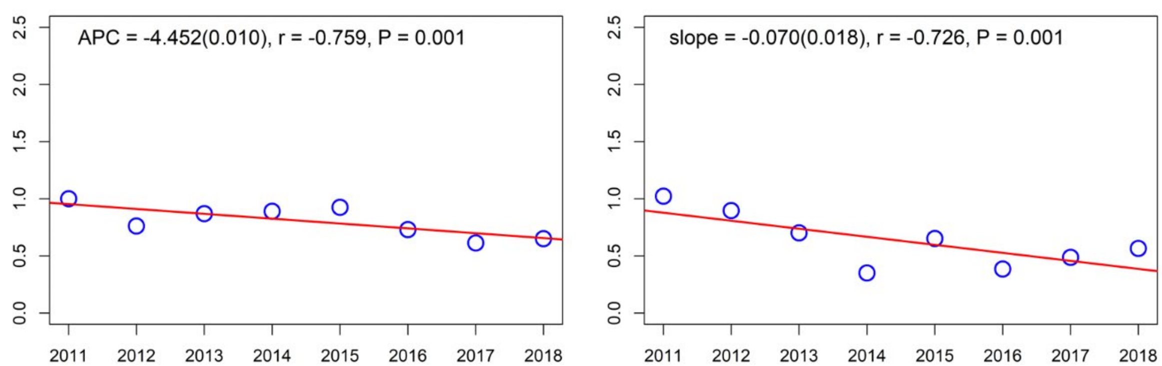


**Figure 1**. Regional landbird adult population size (left panel; APC is annual percent change [±SE of the slope]) and productivity (right panel; slope of the regression line is the annual change in productivity index [±SE of the slope]), from 2011 to 2018, with the correlation coefficient (r) and significance of the correlation coefficient (P) shown in each graph. The index of population size was arbitrarily defined as 1.0 in 2011, while productivity was defined as the actual productivity index value. A correlation coefficient close to 1.0 indicates a close fit of the data to the regression line.

### Objective 1: To advance the understanding of avian population dynamics and diversity in reclaimed habitats and in habitats subject to disturbances associated with industrial and human activities, as compared to natural, unaffected areas

Across all stations and over all eight years, 42,642 bird captures of 96 species have been recorded, of which 32,042 were newly banded, 658 were released unbanded, and 9,942 were recaptures of birds banded earlier in the same season or in previous seasons. As reclaimed habitats reach 30 years old, species richness approaches that of predominantly undisturbed habitat (Figure 2), as measured by species presence determined by point counts (10-minute), species captured during MAPS banding, and species observed at the station during the banding process, including those captured (MAPS breeding status). Point counts represent the total number of territorial males detected calling as compared to both males and females captured and their breeding condition, and males and females exhibiting auditory or visual breeding behaviour (breeding status) during the MAPS banding program. Species richness varies by method, with richness as measured by the MAPS breeding status procedure resulting in the highest level of observed species richness, consistent across all MAPS stations. The MAPS procedures show a substantial difference in the number of species detected compared to point counts from newly reclaimed through to older (e.g., mature forest) habitats, allowing greater understanding of changes in performance over time as station habitats mature.

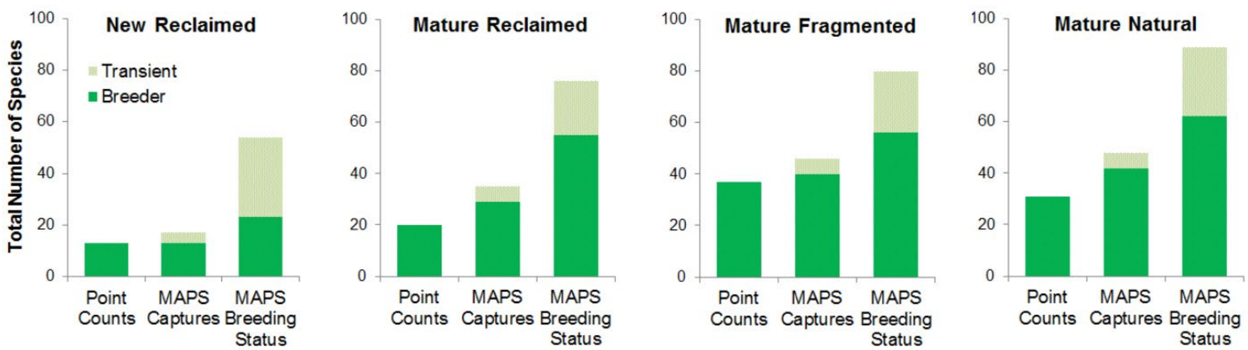


**Figure 2.** Cumulative species richness (across all years) at representative Boreal MAPS stations as measured using 10-minute point count, MAPS capture, and MAPS breeding status procedures.

Monitoring at the five stations at which the habitat burned in the 2016 Horse River wildfire provides an opportunity to track avian community recovery in a natural disturbance area and compare it to that observed in habitats recovering from anthropogenic disturbances. In 2018 (two-years post-fire), early colonizing sparrow species continued to predominate in the recovering burn habitats. A few species present before the fire, including a Canada warbler, were recaptured in 2018. It is expected that as the burned habitats grow and mature, a broader range of species will occur, although the timing of colonization is not known.

A habitat structure assessment was completed in 2018 at all operating MAPS stations. This represents the second assessment conducted to-date, with the first habitat structure assessments completed in 2012 and 2013. With these data we will be able to compare the habitat changes among undisturbed natural habitats, natural habitats recovering from the 2016 wildfire, disturbed (anthropogenic) habitats, and reclaimed habitats.

The potential use of the age-class structure of breeding landbirds in the evaluation of habitat quality, in reclaimed, disturbed and natural areas is being examined. Preliminary analyses indicate that lower quality habitats support an overall younger bird age-class structure (higher proportion of first-time breeding individuals) relative to higher quality habitats, which tend to be occupied by a proportionately higher number of older, experienced birds. This effect appears to be habitat and species-specific, potentially making it an indicator of habitat quality, adding to the indicators represented by adult population size, productivity, survivorship, and species richness.

With each yearly increment of data to the database, the demographic analyses become more robust (greater statistical precision for more species), allowing us to differentiate long-term, naturally cyclic population patterns from changes due to anthropogenic habitat disturbance. Our data are also used to determine which species are experiencing declines as a result of breeding grounds stresses (productivity; which may be mitigatable in the oil sands region), or by stresses in migratory and/or winter habitats (survivorship) for which fewer options for mitigation may be available.

### Objective 2: To acquire data for use in estimating population vital rates for bird species nesting in the boreal forest

Data from 2018 are currently being integrated into the trend analyses and updating of population size, productivity, and survivorship estimates. Data from MAPS banding programs outside of the oil sands region have been acquired (through data-sharing and use agreements), allowing derivation of vital rate estimates for these same species nesting elsewhere in the boreal forest. These analyses will provide insight into the contribution of regional stresses on the population trends for these species, and identify the species that may benefit from regional efforts (e.g., productivity effects indicate breeding ground stresses) and those that would not (e.g., survivorship effects indicate stresses outside the breeding grounds). This analysis is core to the question of whether or not changes in bird populations in the region reflect relatively local stresses or are an expression of changes in these populations at a continental level.

This Boreal MAPS dataset now contains more than half of the Canada warbler continent-wide MAPS data upon which vital rate estimates may be obtained. Using this integrated database, we have published an account of the complex relationships among habitat quality (breeding, wintering, migratory), human footprints, and Canada warbler populations (Wilson et al. 2018). Breeding density declines were greater in the eastern than in the western and central portions of the breeding range, productivity did not significantly decline in any of these three regions, recruitment declined in all regions, and both juvenile and adult survival appeared low in the east and west and was declining in the east. Abundance also declined in relation to increasing habitat disturbance, most of which was occurring on wintering grounds, where the human footprint index increased by 14% between 1993 and 2009, compared with an increase of only 0.1% within the breeding range. These demographic trends and correlations suggest that habitat disturbance on the wintering grounds are negatively affecting survival (particularly that of juvenile birds), and is the primary driver of Canada warbler declines. The population of Canada warbler in the oil sands region is declining at a lower rate than in populations to the east. The western population wintering grounds have been affected to a lesser extent. Canada warbler adults showed significant correlations with habitat-specific covariates responding to mature forested habitats (Foster et al. 2016), and recently Krikun et al. (2018) presented the results of a study of vegetation species preferred by Canada warbler, suggesting that measures can be taken to identify and protect Canada warbler habitat on the breeding grounds.

We have conducted preliminary vital rates analyses for least flycatcher and yellow warbler, for comparison to the vital rates derived for Canada warbler. Adult population and productivity analyses are presented in Figure 3. The declining population of least flycatcher coupled with increasing productivity and a low adult survivorship (0.27) indicates that effects outside of the breeding grounds are likely driving the population trend. For yellow warbler, decreasing productivity and a reasonably high survivorship (0.48) suggests that effects on the breeding grounds are driving the declining population of this species. For Canada warbler, declining populations and a non-significant productivity trend and a reasonably high adult survivorship rate (0.53) suggests the absence of a breeding ground effect, and that adult survivorship is not affected. Although not analysed solely using Boreal MAPS data, inclusion of our data in the continental analyses (Wilson et al. 2018) resulted in the identification of juvenile survivorship as the primary driver for declining populations, including those in northeastern Alberta.

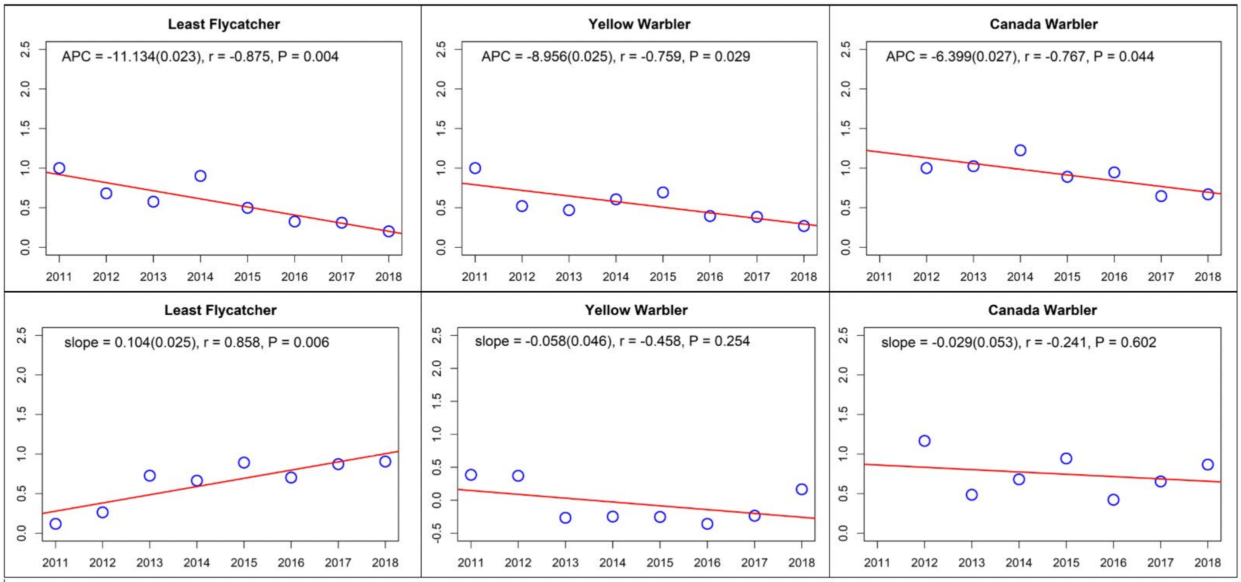


**Figure 3.** Adult population size (top panels; APC is annual percent change [±SE of the slope]) and productivity (bottom panels; slope of the regression line is the annual change in productivity index [±SE of the slope]) for least flycatcher (left), yellow warbler (centre) and Canada warbler (right), from 2011 to 2018, with the correlation coefficient (r) and significance of the correlation coefficient (P) shown in each graph.

These analyses, on a species by species basis, are supportive of reclamation and disturbance recovery planning, as species experiencing breeding ground stresses are those that would benefit from habitat improvements. Investment into efforts to reverse the decline of Canada warbler (6.4% per year as of 2018 data) would be generally limited to protection of Canada warbler breeding habitats (as required under SARA), although inclusion of preferred vegetation species (e.g., choke cherry, Canada buffaloberry, green alder) in planting prescriptions in habitats with suitable canopy species (aspen was not preferred by Canada warbler) would benefit this (Krikun et al. 2018) and potentially other species. Since the primary driver of declining (at 11.1% per year) least flycatcher (Sensitive in Alberta) populations appears to be outside of the breeding grounds, specific reclamation or disturbance restoration practices focused on this species are unlikely to have a measurable population-level effect. Yellow warbler, on the other hand, has a reasonably high adult survivorship value with a significantly declining productivity, indicating that effects primarily on the breeding grounds are driving yellow warbler population decline (currently 8.9% per year) in the region. Inclusion of yellow warbler habitat in reclamation and disturbance recovery programs is likely to have a direct benefit on yellow warbler populations.

Although not an objective of this program, collaboration with other researchers is actively being sought. Our collaborations in 2018 included publication of the Canada warbler paper containing our data to-date (Wilson et al. 2018), and with researchers from the University of California, Los Angeles, on the *Bird Genoscape Project, Mapping the Flyways of the Americas* project. The Boreal MAPS program has provided blood and feather samples for genetic analyses (Canada warbler, American robin, American redstart); these data will be integrated with data from samples provided by researchers across North America. The goal of the Bird Genoscape Project is to use genomic sequencing to map the migratory connections between breeding, wintering and migratory stop-over areas linking critical bird habitats across geographic boundaries. For migratory birds, knowledge of these connections is essential for the development of effective conservation strategies.

Owl Moon Environmental Inc. is also collaborating with other MAPS operators through database integration and analyses to provide a broad perspective on the reasons for landbird population changes and the potential contribution of oil sands regional resource development to these changes.

## LESSONS LEARNED

Understanding regional landbird population trends and their underlying vital rates provides necessary context for the interpretation of population trends of species in reclaimed habitats, in areas recovering from anthropogenic disturbance, and in areas subjected to natural disturbances. The MAPS protocol is a robust protocol that can be applied across a large range of species and habitats and is capable of providing evidence of avian habitat use and the proximal causes of population change for individual species. Data collected using other methods such as bird point counts and automated recording units can be put into context by comparing against MAPS vital rate data. Demographic data are more robust than presence/absence data, and although data from point counts and automated recording units can identify increasing or decreasing trends, MAPS vital rate data can suggest why populations are changing.

- Work is continuing to determine which of the species showing a consistent, regional population decline are driven by low productivity on the breeding grounds, and which species appear to be driven by low adult survivorship during migration or on the winter grounds:
    - Low or declining productivity would indicate that effects are occurring on the breeding grounds.
    - Low or declining adult and/or juvenile survivorship would indicate that the effects are occurring on the wintering grounds or during migration, as demonstrated for Canada warbler (Wilson et al. 2018). Canada warbler recruitment declined in western, central and eastern regions, and both juvenile and adult survival appeared low. Demographic trends were correlated with habitat disturbance on the wintering grounds, which is negatively affecting juvenile Canada warbler survival, and is the primary driver of Canada warbler declines.
- Species-by-species demographic analyses, correlated with habitat structure data, can directly inform reclamation planning by targeting species that are at risk for which effects are occurring on the breeding grounds:
    - Our data show that regional Canada warbler populations are declining by 6.7%/year, but productivity is relatively stable. Survival of juvenile and adult birds is affected by wintering habitat disturbance. Canada warblers are semi-colonial, and avoiding disturbing known Canada warbler habitat on the breeding grounds would mitigate declines, but is likely to have limited effectiveness in enhancing population growth.
    - Regional least flycatcher (Sensitive in Alberta) populations are decreasing by 11.1%/year, while productivity is increasing. Low survival on the wintering grounds is suggested, providing limited local opportunities to reverse this trend.
    - Regional yellow warbler populations are declining by 8.7%/year, and productivity is decreasing in the oil sands region. Stress on the breeding grounds is suggested, and habitat requirements for this species are understood and are likely to be easily incorporated into reclamation and restoration plans.
- This program is measuring the substantial short-term (annual) variability, superimposed on population cycles that operate on long term (i.e., decadal) time scales. Long-term monitoring is important in understanding the

contribution of resource development and human activity in the region to avian population changes, in the context of natural variability and population cycles.

- Understanding vital rates for species of conservation concern (e.g., Canada warbler, yellow warbler) is a critical requirement in being able to prepare and implement effective recovery strategies and will help to focus efforts on reducing the more substantial stresses in the life cycle for these species.
- The SY:ASY (age class ratio) appears to be an indicator of habitat quality, with lower ratios in more highly structured habitats suggesting the potential presence of source habitat (analyses in progress)
- Species richness increases with stand age, and this is directly related to increasing habitat structure complexity.
- Species diversity indices (preliminary analysis only, data not shown) based on point counts appears to be more variable than diversity based on MAPS captures, and point counts appear to overestimate diversity in young habitats.

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## PRESENTATIONS AND PUBLICATIONS

Wilson S, Saracco JS, Krikun R, Flockhart DTT, Godwin CM, Foster KR (2018) Drivers of demographic decline across the annual cycle of a threatened migratory bird. Scientific Reports, 8:7316 | DOI:10.1038/s41598-018-25633-z

## RESEARCH TEAM AND COLLABORATORS

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Principal Investigator: Kenneth R. Foster

| Name | Institution or Company | Degree or Job Title | Degree Start Date (Students Only) | Degree Completion Date (Students Only) |
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| Peter Pyle | The Institute for Bird Populations | Staff Biologist | | |
| Ron Taylor | The Institute for Bird Populations | Staff Biologist | | |
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| James Saracco | The Institute for Bird Populations | Research Ecologist | | |
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Research Collaborators:

*Drivers of demographic decline across the annual cycle of a threatened migratory bird* (Canada Warbler vital rates relative to habitat conditions on the breeding and wintering grounds)
Collaborators: Dr. Scott Wilson, Canadian Wildlife Service, Ottawa; Dr. Tyler Flockhart, University of Maryland & Lesser Slave Lake Bird Observatory; Richard Krikun, Lesser Slave Lake Bird Observatory

*The Bird Genoscape Project – Mapping the Flyways of the Americas*
Collaborators: Ms. Jasmine Rajbhandary and Dr. Thomas B. Smith, Department of Ecology & Evolutionary Biology, University of California, Los Angeles

# ENVIRONMENTAL RESEARCH AND MONITORING

# Approaching Zero Footprint Seismic – Pinpoint Pilot

**COSIA Project Number:** LJ0320

**Research Provider:** Explor

**Industry Champion:** Suncor Energy Inc.

**Industry Collaborators:** Alberta Innovates

**Status:** Year 2 of 4

## PROJECT SUMMARY

The COSIA Land Challenge[1] includes the evolution of the oil sands industry towards smaller clearings, with an ultimate goal of eliminating exploration footprint and assisting with the reduction of forest fragmentation. It is looking for other exploration solutions beyond today's known and regulatory-approved exploration approaches. Suncor Energy Inc. (Suncor) and Explor conducted two pilot tests using a new technology, called Explor PinPoint, which gathers seismic data with zero/near zero surface disturbance and has the potential to meet the COSIA Land Challenge.

Successful resource recovery requires detailed information about the location and quality of the oil resource under the ground. Industry practice and the Alberta regulatory minimum is to drill at least 8 wells per section and shoot 3-Dimensional (3-D) low impact seismic (LIS) (or to drill 16 wells per section) during winter (January to March) to delineate the geological formation, including oil reservoir, underlying a lease. Suncor's current seismic exploration approach uses LIS lines that are approximately 30 m apart, up to 3 m wide and span kilometers.

The Explor PinPoint lines are virtually "invisible" since this approach eliminates tree cutting for equipment access and data may be collectable year-round. With this new technology, future in situ project footprints can be up to 50% smaller than today's projects. This supports the conservation of the boreal forest ecosystem and specifically boreal woodland caribou (*Rangifer tarandus caribou*), a species at risk of localized extinction within the oil sands region.

Explor developed and advanced the Explor PinPoint technology to the small-scale pilot test stage between 2015 and 2016. Explor and Suncor partnered to further evaluate the technology through the following pilot tests:

- **2-D Seismic Pilot Test** – Explor PinPoint 2-D seismic data was acquired along 2.35 km within a forest area in fall 2017, at a Suncor lease. Data was compared to historical 2-D LIS data collected in the same geographic location during 2003 using conventional dynamite.
- **3-D Seismic Pilot Test** – In Q1 2018, Suncor acquired a conventional production 3-D using LIS cleared lines in a 30 m x 30 m grid over 0.79 $km^2$ of forest. Shortly after, in April-May 2018, Explor PinPoint 3-D seismic data was collected in a 10 m x 10 m grid over the same geographic region, which included newly LIS-fragmented and undisturbed areas.

The objectives of the 2-D and 3-D seismic pilot tests were to:

- Evaluate if the Explor PinPoint technology can significantly reduce or avoid boreal forest disturbance, while safely obtaining subsurface imaging from surface (0 m) to basement (500 m) and to compare it directly to standard LIS gathered in the same geographic location to understand the petroleum resource.
- Evaluate year round seismic acquisition.

## PROGRESS AND ACHIEVEMENTS

### 2-D Seismic Pilot Test:

- Seismic data was acquired in fall 2017 and data processing and evaluation were completed by January 2018.
- Suncor conducted a multidisciplinary review (geology, operations, regulatory, environment and reclamation, technology development) on safety, footprint, and seismic data quality. The technical results were sufficiently promising and, consequently, approved advancing to a larger scale pilot at the same Suncor lease, the 3-D pilot test.

### 3-D Seismic Pilot Test:

- The first 3-D seismic test of the Explor PinPoint technology commenced in 2018.
- Seismic data was acquired in April and May 2018, and data processing and preliminary data evaluation occurred throughout 2018.
- A detailed assessment of safe work practices was completed by Suncor Environment, Health and Safety (EH&S) personnel post-3D data acquisition.
- Development of a technology summary report and review of final results is planned to be completed by spring 2019.

Zero trees were cut down during PinPoint data acquisition for the 2-D and 3-D Seismic Pilot Test, further demonstrating that this technology achieved at least one of the three COSIA Land Challenge[1] performance metrics (i.e., ≥ 50% footprint reduction relative to LIS footprint). This is similar to the results achieved in the 2-D Seismic Pilot Test conducted during fall 2017. However, due to logistical challenges, the 3-D LIS program was completed in March 2018, just ahead of the Explor PinPoint data acquisition. Consequently, existing mulched lines made it significantly easier to access the region.

Both pilots revealed that Explor PinPoint data acquisition can occur in other seasons besides winter. However, spring acquisition became significantly more challenging when a very rapid spring melt started partway through the 3-D pilot test, which reduced productivity levels, increased project costs and prevented data acquisition in deep water areas.

## LESSONS LEARNED

- The 2-D pilot test validated the Explor PinPoint technology as a “proof-of-concept”.
- Zero trees were cut down during PinPoint data acquisition, demonstrating the conservation potential for this new exploration approach.

- A draft recommendation is to avoid Explor PinPoint data acquisition during spring melt to prevent increased costs due to slower acquisition in flooded areas. However, results suggest acquisition can occur in summer, fall and winter (data from previous tests not provided).

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## PRESENTATIONS AND PUBLICATIONS

### Conference Presentations/Posters

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## RESEARCH TEAM AND COLLABORATORS

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Principal Investigator: Allan Châtenay

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# A Multiple Lines of Evidence Approach for the Ecological Risk Assessment of an Accidental Bitumen Release from a Steam Assisted Gravity Drainage (SAGD) Well in the Athabasca Oil Sands Region

**COSIA Project Number:** LJ0267

**Research Provider:** Omnia Ecological Services

**Industry Champion:** Devon Canada Corporation

**Status:** Year 5 of 5

## PROJECT SUMMARY

In July 2010 an accidental steam release occurred at the Jackfish 1 Well Pad B (Site 1), which resulted in the deposition of approximately 259 $m^3$ of bitumen and 761 $m^3$ of water over an approximately 636 ha area. Following the release, remediation was immediately initiated to minimize environmental impact. This included the removal of highly covered vegetation and ground lichen, hand clearing of vegetation surrounding a nearby creek, and the use of oil socks to minimize the impact of runoff. In addition, woody browse species were removed by hand from the high exposure zone. Chemical concentrations in surface water, sediment, soil, moss and herbaceous plants and shrubs were assessed and extensive surveys of wildlife utilization of the area were conducted.

In 2012 Intrinsik Environmental Services Inc. (Intrinsik) completed an ecological risk assessment (ERA) subsequent to the Jackfish 1 Well Pad B incident. The purpose of this ERA was to evaluate the potential that ecological receptors living in or frequenting the area of the release may experience toxicologically induced changes in health. Three lines of evidence (LOE) were used: hazard quotient calculations, statistical representation of data and biological assessment.

The ERA was informed in part by site-specific data and includes the following:

1. AMEC Environment & Infrastructure (2012). Impacts of The Pad B Release Incident on Vegetation and Soil 3 Year Summary;
2. HAB-TECH (2011). Jackfish B3P Steam Release Spring 2011 Vegetation Clearing Summary and Winter 2010/11 Ungulate Monitoring;
3. HAB-TECH (2010). Jackfish B3P Well Release Wildlife Assessment;
4. Matrix Solutions Inc. (2011). Bitumen Release, Devon Canada Corporation (Devon) Jackfish Well Pad B – Summary of Water and Sediment Sampling Conducted in 2011;
5. Matrix Solutions Inc. (2010). Bitumen Release – Devon Jackfish Well Pad B Interim Report on Water and Sediment Monitoring Results; and
6. Personal communications between the Intrinsik ERA team and HAB-TECH project managers and biologists.

The ERA concluded that the likelihood of long-term adverse health effects to ecological receptors was negligible.

A second accidental steam release occurred in 2013, adjacent to Site 1 at the Jackfish 1 Well Pad C (Site 2) affecting an approximately 63 ha area. The results of the Site 1 ERA were reviewed after the release at Site 2 and it was determined that the results of the Site 1 ERA would apply to Site 2 as well, that is to say long-term adverse health effects to receptors at Site 2 were not expected.

A fourth LOE was implemented in 2014 to investigate the conclusions of the Site 1 ERA. In 2014 and 2017 a small mammal trapping program targeting southern red-backed voles *(Myodes gapperi)* was completed in the high, medium, low exposure/impact zones and a reference zone. Metal body burden and ethoxyresorufin-o-deethylase (EROD) analyses were completed on the captured red-backed voles to assess the potential impacts of the steam releases and success subsequent remediation on this bio-indicator species.

The key objectives of this study were to:

1. Assess the success of selective vegetation removal as a means of remediation, in the event of an accidental steam and bitumen release.
2. Assess the accuracy of the conclusions in the ERA.
3. Assess the potential effects of the release after remediation on a bio-indicator species (southern red-backed voles).

## PROGRESS AND ACHIEVEMENTS

### 2014 Sampling and Study

In 2014 a total of 51 southern red-backed voles and one deer mouse (*Peromyscus maniculatus*) were captured at

Site 1 and 2. Forty red-backed vole specimens were kept and processed for analysis; all others were live-released at the trap site. All animals were found to have good overall body condition based on the professional judgment of the biologists conducting the assessment. Overall, body condition was based on visual assessment, condition of pelt (e.g., no bare patches, sores, cysts, cuts), musculoskeletal structure (e.g., no broken bones or apparent sprains) and healthy mass and vigor (e.g., ribs showing and appropriate level of activity). In addition, any potential visual signs of illness were to be noted (e.g., cloudy eyes).

Mean capture rates of red-backed voles in both the impacted and reference areas were, 11 red-backed voles per 100 trap nights (Table 1). These results suggest the red-backed vole population was probably not affected by the releases.

**Table 1. Southern red-backed vole capture rates at impacted and reference sites.**

| Capture Site | 2014 Captures per 100 trap nights | 2017 Captures per 100 trap nights |
|---|---|---|
| Pad B High Impact | 12.5 | 5.8 |
| Pad C High Impact | 15.8 | 6.5 |
| Total High Impact | 15.4 | 6.1 |
| Pad B Med Impact | 5.6 | 2.3 |
| Pad C Med Impact | 25.8 | 5.1 |
| Total Med Impact | 10.7 | 3.0 |
| Pad B Low Impact | 10.0 | 11.7 |
| Pad C Low Impact | 8.1 | 2.7 |
| Total Low Impact | 8.8 | 4.6 |
| **Overall Impacted** | **10.8** | **4.1** |
| **Overall Reference** | **10.6** | **3.4** |

The metal body burden analysis found a significant difference between nickel (Ni) and chromium (Cr) concentrations in exposure and reference zones. However, the increased Ni and Cr concentrations did not correspond with increasing bitumen coverage within the exposure zones (i.e., Cr concentrations were highest in specimens from the low exposure zone and Ni concentrations were lowest in the medium exposure zone). These results suggest that the increased Cr and Ni concentrations are not correlated to the release.

The EROD analysis found a significant difference between the high exposure zone and reference zone. The observed increase in EROD activity indicates a natural upregulation of this enzyme system in response to chemical exposure, suggesting that though there are strong indications of recovery in the affected areas, this recovery is ongoing. In other words, animals in the high impact areas of Site 1 and 2 were exposed to bitumen-related contaminants of potential concern (COPC) that their conspecifics in the low, medium and reference areas were not. Regardless, biological and chemical markers of exposure did not provide any observable adverse effects that correspond with the observed increase in EROD activity.

## 2017 Sampling and Study

In 2017, a total of 55 southern red-backed voles, nine deer mice, and three shrew spp. (Sorex spp.) were captured from the same exposure/impact and reference zones. Again, 40 red-backed voles were tested for body burden of metals and EROD, while an additional seven red-backed voles were analyzed exclusively for metal residues and eight live released. All animals were found to have good overall body condition during field assessments. In addition, scaled mass index (SMI) was used to assess body condition based on morphometric measurements. The SMI was assessed for both 2014 and 2017 (this assessment was not done in the original 2014 study) and no significant difference was found between exposure/impacted sites versus reference sites.

The overall capture rate was lower in 2017 than in 2014. However, both exposure/impact and reference zones had reduced capture rates, suggesting these results were unrelated to the releases (Table 1).

The metal body burden analysis completed in 2017 found that lead (Pb) concentrations were significantly higher in medium and high exposure/impact zones relative to the reference zone in both 2014 and 2017 (Pb was not part of the original 2014 study analysis). Further, Pb residues negatively affected body condition, a correlation that differed between years. In 2014, Pb was negatively correlated with body condition considering all animals, a correlation which was stronger when only looking at exposure/impact sites. By 2017, Pb was no longer correlated with SMI.

The EROD analysis completed in 2017 found that significant differences between exposure/impact zones and reference zones no longer existed.

## LESSONS LEARNED

The results of this work indicate that the choice of selective vegetation removal as a means of remediating an accidental steam and bitumen release is effective. Where determined to be statistically significant, negative impacts to southern red-backed voles, based on capture rates, body condition, metal body burden and EROD were negligible or decreased over time. However, significant differences (Pb levels) did remain seven (Site 1) and four (Site 2) years post release.

The conclusion of the ERA, that no unacceptable risk was presented to ecological receptors, was further supported by the southern red-backed vole trapping program.

The remediation strategy of selective vegetation removal leaves much of the release site intact and potentially allows for a more rapid ecosystem recovery than the removal of all vegetation in the release site.

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## PRESENTATIONS AND PUBLICATIONS

### Journal Publications

Smits J., G. Sanders, M. Charlebois. 2019. Response of a small mammal population post-remediation for an in-situ oil pipeline blow out on the Athabasca Oil Sands. Environmental Toxicology and Chemistry. *In Submission*

## RESEARCH TEAM AND COLLABORATORS

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# Boreal Ecosystem Recovery and Assessment (formerly known as Geospatial Technologies for Monitoring Vegetation Recovery on Human Disturbance Features in Alberta's Boreal Forest)

**COSIA Project Number:** LJ0220

**Research Provider:** University of Calgary

**Industry Champion:** ConocoPhillips Canada Resources Corp.

**Industry Collaborators:** Cenovus Energy Inc., Devon Canada Corporation, Alberta Pacific Forest Industries Ltd.

**Status:** Year 4 of 5

## PROJECT SUMMARY

The boreal forest regions of Alberta are under increasing pressure from human development related to natural-resource extraction. Roads, seismic lines, well sites, cut blocks, mines, pipelines, and other elements of human footprint exert cumulative environmental effects that can harm biodiversity, water quality, and the habitat of threatened species such as woodland caribou. In order to mitigate these effects, resource extraction companies and provincial regulators are working to develop monitoring initiatives that track the amount of human footprint present in a given area and measure the rate at which forests on previously disturbed areas are being restored.

The Natural Sciences and Engineering Research Council of Canada (NSERC) Collaborative Research and Development (CRD) Boreal Ecological Recovery and Assessment project (BERA, http://www.bera-project.org) brings researchers, government, stakeholders, and industry together to mitigate the effects of non-permanent industrial activities, such as the construction of seismic lines, access roads, and well pads, on the boreal forest. The team, led by research experts from the University of Calgary, University of Alberta, Trent University, and Natural Resources Canada, aims to develop cutting-edge technologies and techniques that can help to measure, monitor, and predict the recovery of vegetation and some animal uses after temporary human disturbance by industrial activity.

### The Technology

The research program employs advanced geospatial technologies and modelling techniques to aid in the process of measuring, monitoring, and predicting vegetation recovery on non-permanent (i.e., to be reclaimed) human footprint features (i.e., seismic lines, roads, etc.).

BERA works across three research areas: remote sensing, sensor networks, and ecology.

### Objectives

The research project will address five specific research objectives to:

1. Map human footprint features with advanced remote-sensing devices;
2. Assign descriptive attributes to human-footprint features that can be tracked through time in a monitoring program;
3. Develop low-cost ground-sensor networks that can track the physical condition and human or animal use of human-footprint features;
4. Develop statistical models that can predict the rate of vegetation recovery in human-footprint features across the boreal forest; and
5. Deliver a rapid verification protocol designed to assess the reclamation status of areas disturbed by humans.

### Potential/Actual Environmental Benefits

By discovering new ways to monitor and measure how humans impact the boreal forest and predict how vegetation can return to areas of temporary disturbance, the oil sands and forest industry can improve how they manage reclamation efforts across their areas of operation.

### Outcomes

Innovative approaches to mapping the extent and condition of temporary footprint, monitoring vegetation recovery, and the efficacy of habitat restoration activities in the boreal forest are key to effective land reclamation.

Remote sensing technologies offer a credible and defensible way to map and monitor recovery of vegetation on disturbed sites. To address cumulative effects of resource development in Alberta's boreal forest region, regulators are moving toward threshold-based management policies, which may place limits on the amount of activity in a given region, depending on the amount of industrial disturbance and the timing of successful reclamation. BERA's research will go toward industry efforts to develop timely land-reclamation practices designed to ensure that prescribed thresholds are not exceeded. Novel geosensor technology can aid in better understanding the use of recovering temporary disturbances, by both humans and boreal forest dwellers, which is an important factor determining future recovery success.

Arriving at a set of unambiguous scientifically defensible criteria determining vegetation recovery success and future success trajectories will aid in prioritizing areas for treatment as well as inform regulatory requirements for effective boreal forest reclamation.

## PROGRESS AND ACHIEVEMENTS

### Objective 1: Map human footprint features with advanced remote-sensing devices

Silvia Losada (University of Calgary, MSc) worked in collaboration with Alberta Biodiversity Monitoring Institute (ABMI) to develop the Seismic Line Mapper, which is a semi-automated ArcGIS tool for mapping seismic lines with remote sensing data. Two sets of inputs are required: (i) a raster-based canopy height model; and (ii) key-point locations defining major nodes within a seismic-line network. The tool uses the canopy height model to develop a cost surface then delineates least-cost pathways between major key point locations. There are presently two outputs for the tool: (i) least-cost-path centrelines that follow the mid-point of each detected seismic line, and (ii) polygons defining the extent of each detected seismic line.

### Objective 2: Assign descriptive attributes to human-footprint features that can be tracked through time in a monitoring program

Several BERA researchers are collaborating on the use of remote-sensing data sets and workflows to perform conifer seedling detection and stocking assessment in line with the Provincial Restoration and Establishment Framework for Legacy Seismic Lines. Softcopy (manual) photointerpretation of piloted-aircraft imagery (5-cm, 4-band imagery) detected just 44% of field-surveyed conifer seedlings, but 72% of those with a height larger than 100 cm. This suggests that while survivability assessments are likely not feasible at this resolution, establishment surveys should be possible under the correct conditions. Man Fai Wu (University of Calgary, MSc) and Michael Fromm (Ludwig-Maximilian University Munich, MSc), documented similar error patterns with automated-detection techniques.

Annette Dietmaier (Ludwig-Maximilian University Munich, MSc), tested the capacity of LiDAR and photogrammetric datasets for detecting forest-canopy openings. Three canopy height models (CHMs) were derived and two methods of delineating structural openings in the canopy cover were applied to each CHM. Photogrammetric data were most negatively affected by large errors of omission (15% – 46%) associated with small openings, revealing the optical method's vulnerability to occlusions, shadows and tree sway.

Gustavo Lopes-Queiroz (University of Calgary, MSc), developed a novel approach to mapping coarse woody debris (CWD), both on seismic lines, and in the surrounding forest. Gustavo's preliminary results show that remote sensing can be very effective in this task, producing high measures of accuracy (>90%), even when applying models to geographically detached study areas.

Dr. Steven Franklin (Trent University), showed that UAV (Unmanned Aerial Vehicle) multispectral remote sensing object-based image analysis can outperform pixel-based image analysis for classification of commercial deciduous and conifer species identification. Up to 85% accuracy was possible in five test areas in mixedwood forests. The most accurate identification was of conifers (up to 90%) based on their distinct tree crown shapes and spectral characteristics. New methods based on convolution neural networks (deep learning algorithms) are an obvious way to increase accuracy to levels comparable to those generated by trained colour, large-scale and specialized aerial photography forest species interpreters.

Cassondra Stevenson (University of Alberta, BSc), used a high-precision altimeter to demonstrate that seismic lines on average lose ~20% of their microtopographic variation 8 cm in their elevation (depressed) compared to adjacent undisturbed forests. Microtopography was related to tree regeneration rates but varied among ecosites with its effects in fens being most pronounced. Wildfires further alter microtopographic variation and depressions depth, but not in consistent manner.

### Objective 3: Develop low-cost ground-sensor networks that can track the physical condition and human or animal use of human-footprint features

To date, most research on acoustic animals have used relatively coarse measures of abundance to evaluate the success of recovery and restoration. We have shown that such approaches do not have the resolution to accurately represent how animals react to energy sector disturbances. As such, we have developed a variety of new techniques using sound triangulation that allow us to precisely locate where animals are spending their time and exactly what elements influence whether an animal will or will not use an energy sector footprint. Combining this with the new imagery and remote sensing tools we have developed an unprecedented ability to track the impact and recovery of small-scale energy disturbances that was not possible in the past. At the same time, we have developed a number of new tools for including covariates like industrial noise, traffic, and most recently hunting to better document the relative importance of the foot versus the footprint.

Kan Luo (University of Calgary, PhD), developed and deployed a 20-node wireless sensor network in the field, and transmitted data over a Low Power Wide Area Network (LPWAN). The sensor node was able to collect and transmit data through LPWAN continuously with a battery and a solar panel. Kan also tested the range of the LPWAN and demonstrated that the LPWAN gateway can cover an approximately 1 km to 2 km radius. Based on the data collected from the field sensor network, Sara Saeedi (University of Calgary, PDF) and Soroush Ojagh (University of Calgary, PhD) developed spatiotemporal data mining algorithms to automatically extract micro-climate patterns. The goal is to have an end-to-end workflow that processes real-time data streams and detects micro-climate movement patterns.

### Objective 4: Develop statistical models that can predict the rate of vegetation recovery in human-footprint features across the boreal forest

We examined conifer recruitment post-fire, in reclaimed exploratory well pads within jack pine forests, to investigate natural versus planted establishment and recovery dynamics. Overall, well pads had higher natural regeneration than in-forest plots at moderate to higher fire severity, with highest fire-severity sites containing approximately twice the natural regeneration of conifers on well pads than adjacent forests. These results demonstrate that areas burned by wildfire promote natural forest recovery of well pads. Likewise, we also examined natural and planted recovery of trees in Cenovus Energy Inc.'s Linear Deactivation restoration site (see https://www.cosia.ca/initiatives/land/projects/caribou-habitat-restoration) in the Cold Lake Air Weapons Range, finding that silvicultural treatments of mounding increased tree density of natural regeneration compared to untreated lines, despite averaging 3.8-yrs. since treatment (vs. 22 yrs. since disturbance for untreated). Specifically, treated lines averaged 12,290 regenerating tree stems/ha, which was 1.6-times more than untreated lines (7,680 stems/ha) and 1.5-times more than the adjacent undisturbed forest (8,240 stems/ha). Treated seismic lines consistently have more regenerating trees across all ecosites, although the higher amounts of stems observed on treated poor fens were not significantly different to untreated or adjacent undisturbed reference stands.

### Objective 5: Deliver a rapid verification protocol designed to assess the reclamation status areas disturbed by humans

Out of the over 3,000 conifer seedlings inventoried by BERA in Kirby South, we used 400 that were located in four seismic lines for which we had drone imagery acquired at different flight altitudes (5 m to 120 m, pixel size from 0.35 cm to 3 cm). We estimated the height of those seedlings based on photogrammetric point cloud data around the seedling locations. The best results were obtained with the finest spatial resolution (0.35 cm) in leaf-off conditions (RMSE= 0.17 m), and the worst with the coarsest resolution in leaf-on (3 cm, RMSE= 0.47 m).

## LESSONS LEARNED

### Remote Sensing

- Remote sensing is an effective and authoritative source of information for canopy structure, coarse woody debris, and - under the correct conditions - conifer seedling detection and stocking. It is unlikely that survival surveys (two to five years after treatment) can be done from the air if they must include seedling height. However, establishment surveys (done eight to 10 years after treatment) could be feasible given the larger size of seedlings at that age. Further testing is required.
- Enhanced forest inventory (EFI) using UAV multispectral remote sensing for small areas is possible and desirable with light-weight, low-cost roto-blade or fixed-wing systems such as the eBEE or Responder. Operational requirements include trained personnel, appropriate image acquisition (i.e., mission) planning, advanced sensor radiometric and geometric calibration (i.e., in-flight incident light sensor or insolation observations), and detailed image analysis based on tree crown size, shape, colour, texture and associations.

### Sensor Networks

- Our initial deployment demonstrated that Low-power Wide Area Network (LPWAN) is a promising technology connecting low-cost wireless sensor networks over a wide area (1+ km radius), and the devices can continuously collect and transmit data with a solar panel and a battery. Our cloud-based sensor data management Application Programming Interface (API) was also able to aggregate, analyze, and visualize real-time data from multiple sensors. We also demonstrated that our Lambda architecture-based implementation is able to handle queries against a very large amount of sensor data (700+ million rows) with a very short response time (sub second). In addition, our initial investigation on spatiotemporal data mining techniques demonstrated the potential to automatically detect and extract micro-climate patterns.

### Ecology

- Seismic lines and well pads do impact the abundance of birds and how they use space. However, over time as vegetation regrows, birds are starting to reuse these locations. The trajectory of change is similar to that of forest harvesting, but not identical. There tends to be a delay in recovery relative to forest harvesting (i.e., we can't predict bird use based on time since reclamation).
- Although wildfires cannot be directly used as a restoration tool on seismic lines and well pads, we found that wildfire effectively resets forest conditions to be similar among disturbed and forest sites, with in some cases, greater tree regeneration on footprints than adjacent forests. Likewise, we found that current silvicultural treatments of seismic lines involving mounding in peatland forests were effective in natural regeneration for all peatland sites except for poor fens suggesting that allocation of restoration treatments should focus on other peatland ecosites.

## PRESENTATIONS AND PUBLICATIONS

### Published Theses

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## RESEARCH TEAM AND COLLABORATORS

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