DEFINING DISTURBANCE AND RECOVERY: THE INFLUENCE OF LANDSCAPE SPECIFIC ECOLOGICAL RESPONSES TO OIL AND GAS LINEAR DISTURBANCES IN NORTH YUKON

K. Simpson, M.Sc.

Yukon Government, Department of Energy Mines and Resources
P.O Box 2703, Whitehorse, Yukon Y1A2C6

ABSTRACT

Across northern Canada evidence of oil and gas seismic exploration remains from the 1950's to current day. While many of these linear features are still visible, others can no longer be seen. Research carried out by Yukon Government, Energy Mines and Resources looked at the status of historical oil and gas exploration disturbances and recovery. A key question was the definition of the words "disturbance" and "recovery". What do we use for criteria in the determination of whether a site is disturbed or not, and when do we consider that a site has recovered? What variables are important to measure? A key tool that was considered was a comparison with natural disturbance regimes in the study area. Does natural recovery depend on the disturbance conditions under which the lines were constructed or is the limiting factor, or filter, the dominant ecological process in the area in which the exploration was carried out. Our findings indicate that disturbance factors include changes to permafrost, soil structure and mycorrhizal dynamics in combination with propagule removal, community shifts to graminoid dominance and nutrient availability. The dominant ecological processes are permafrost, available nutrients and temperature.

Key Words: Seismic, Succession, Permafrost, Nutrients, Active Layer, Compaction.

DESCRIPTION OF PROJECT

A Seismic Line Disturbance and Recovery Research Study was initiated in 2006 by Yukon Government, Energy Mines and Resources (EMR). North Yukon field work was carried out in the Eagle Plains area in 2006 and 2007 and in the Peel Plateau area in 2007. Further field work was carried out in the south-east Yukon and south-west NWT in 2008. This paper focuses on the results of the north Yukon research.

A number of assumptions and questions were on the table when we started this work and we wanted to:

- Assess the current status of historical linear feature recovery in the two current Yukon planning areas (North Yukon and Peel Watershed) and SE Yukon
- Understand if we could use remote imagery to understand and monitor the status of linear disturbance or recovery
- Understand the variation and dynamics of recovery in terms of natural succession
- Understand and support cumulative effects management as it relates to exploration activities, particularly in reference to the use of a thresholds approach to land management
- Determine the appropriateness of certain mitigation measures and best practices (e.g., line width, the re-use of linear features, snow depth, etc.) to provide advice to operators about appropriate mitigation and monitoring strategies or end of project life expectations.

A barrier to answering these questions was the lack of a definition for “Disturbance” and “Recovery” in this context. For some the perception of disturbance (i.e., being able to see a line from the air) is enough to call it a disturbance. For others the presence of woody vegetation at least 1.5 m high (North Yukon Land Use Plan 2009; NYLUP) defines recovery. Without clearly defined terms we cannot “grow” disturbances on and off the landscape.

METHODOLOGY

This study considered climate, hydrology, site chemistry, soil material, biotic factors, fire history and physical factors. Sites were pre-selected from a number of years of aerial survey and detailed analysis of photos and air photos. Information on age and history of linear disturbance using a variety of sources including air photos, National Energy Board data records, topographical maps and satellite images was collected. Unmapped features found on air photos and satellite images were hand plotted and aged.

Criteria for site selection included securing information from a full range of historical seismic line ages. Selection was also made on the basis of securing data from a range of landscape positions as well as mineral soil dominant vs. peat/organic dominant landscapes. Some bias was introduced in the field where pre-selected treed study sites were not helicopter accessible.

In the field, information was collected on the presence and depth of permafrost; active layer depth; soil structure, moisture and texture; nutrient availability; depth and composition of peat; vegetation abundance and composition broken down into floristic communities; treed community, tree structure and age; presence of fire; and landscape position (aspect and orientation to sun and prevailing winds, potential for snowfall accumulation due to geography and topography, etc.).

Analysis of the vegetation data was conducted post-field using a tabular sorting method that groups study plots with similar species composition together into groups which are then used to define community types. Soil texturing and tree ring aging was also done post-field in the EMR geoscience and forestry labs.

Physical characteristics of disturbance noted included feature type (winter road, trail, seismic line, well site, airstrip, camp, staging area), width and depth of disturbance, presence and height of windrows and age of disturbance. Other observations were made on a site by site basis and included evidence of human activity such as camps and snowmobile trails. Wildlife observations were also made but were casual in nature and included presence of birds and mammals, habitat use (e.g., vole tunnels, nests), defined travel corridors, discarded antlers, evidence of predation or herbivory and scat. Scat was analyzed post-field by the Yukon Department of Environment carnivore biologist.

STUDY AREA DESCRIPTION

Our study area was in the Eagle Plains, British Mountains and Peel River Plateau ecoregions (Smith 2004). Permafrost is ubiquitous at this latitude and only high rock and gravel ridges and water bodies are permafrost free. The geophysical histories of these three ecoregions set the stage for the present vegetation communities found across the landscape and the study location offered a unique opportunity to consider linear disturbance response on both the beringian and non-beringian sides of the British Mountains.

All control sites in the study area consisted of an open black spruce-Labrador tea forest in different moisture phases. The primary community type was *Betula-Rubus* representing a richer phase of the black spruce-Labrador tea forests followed by *Betula-Polytrichum* representing a drier phase of the black Spruce-Labrador tea forests and influenced by elevation (Polster 2009).

Fire is the dominant disturbance regime in this area along with rapid landscape change resulting from permafrost slumping. The black spruce-Labrador tea forest common to this area recovers primarily through the regeneration of shrubby species such as Labrador tea, lingonberry and cloudberry from underground root systems that are not damaged (Polster 2009). Where a recent fire (2004 and 2005) overlapped our study area, fire recovery processes dominate and is reflected in the vegetation.

Active-layer thickness was very homogeneous averaging 45 cm in undisturbed (anthropogenically or naturally) sites (Table 1). Burned areas such as site 2007-09 responded to fire with increased active layer thickness. This is consistent with long term active-layer records that have been collected in the NWT and north Yukon (Mackay 1995). Mackay's data indicate that fire disturbance and subsequent ecological recovery had a dominant effect on active-layer thicknesses.

Table 1. Active layer depth

Sample ID	Feature type	Vegetation community	Depth to permafrost
07-001e/5	well	8	0.575
07-006	road/burn	8	0.8
07-007	winter road	8	0.9
07-009	seismic line/burn	8	0.6
07-009a	control/burn	8	0.6
07-010b	winter road	8	0.65
07-014	road	8	0.9
07-017	road	8	1.1
07-018	well	7	0.9
07-019	staging site	7	0.725
07-020	staging area	7	0.6
07-021	staging area/road	7	0.5
07-024	trail	3	0.8
07-026	trail	5	0.6
07-031	well	8	Refusal at 30
07-035	well	8	0.6

EVOLVING TIMES AND EVOLVING TECHNOLOGY

Exploration was conducted as early as 1944 and until the early 70's this exploration took place in the summer months. In the Eagle Plain and Peel Plateau areas surface exploration commenced in the mid-1950s, with 92% of the seismic lines shot before 1975 (Hannigan 2001). The presence of tracked and/or wheeled vehicles in this vulnerable summer landscape and the application of such methods as stripping the active layer and organic overburden down to permafrost or mineral soil to facilitate summer travel resulted in extensive damage to vegetation and permafrost.

There was little to no regulation of land use activities until 1972 when regulations under the *Territorial Lands Act* came into force and were applied to this region. Until then companies only reported to the National Energy Board in Calgary regarding the successful acquisition of seismic data but there was no requirement to report on the physical disturbance resulting from the seismic lines, access trails and camps.

Seismic survey methods of the day were based on trigonometry and triangulation methods and relied on long line-of-sight lines to delineate the seismic program. These methods were used until the development of the global navigation satellite system in the 1980s allowed for geo-spatial positioning instead.

Line-of-sight methods usually involved heavy equipment that operated with the blade down to strip down to permafrost thereby destroying the insulation on the line and leaving large windrows on either side of the disturbance. In forested areas, cutlines were traditionally cleared using a bulldozer to pull up roots, stumps and woody materials which were then pushed into windrows. The remoteness of this area necessitated "cat trains" and mobile camps to support the crews on the land – with this equipment often running parallel to the seismic programs.

Seismic lines, winter trails and winter roads were all established along with well sites, camps, staging areas and airstrips. Single-pass winter trails were used for convoys of tracked heavy-axled vehicles. Natural frost penetration in the ground and snow was relied upon to support their weight and there was no prior surface preparation. With the surface organic layer remaining intact, the active layer on winter trails was generally not affected (Kemper and Macdonald 2009a, b).

In contrast, winter roads were built for repeat winter traffic by heavy-axled wheeled vehicles, including haul trucks. All woody vegetation was cleared, and each winter, a load-bearing road bed was prepared with packed snow or ice. Winter roads caused mechanical damage to vegetation (Adam and Hernandez 1977; Bliss and Wein 1972; Felix and Raynolds 1989a), and if the depth of frozen soil was insufficient, they disturbed or compacted the surface organic layers (Bliss and Wein 1972; Felix and Raynolds 1989b) which led to increased depth of the active layer (Bliss and Wein 1972; Forbes et al. 2001; Haag and Bliss 1974; Hernandez 1973). The different kinds of disturbance are reflected in the status of these features.

Since the 1990's, evolving footprint minimization approaches have been developed and are now utilized in the seismic industry. Low Impact Survey (LIS) techniques have been introduced to minimize disturbance – in particular these techniques narrowed seismic line widths, reduced the loss of merchantable forest, and minimized disturbance of the soil and ground cover (CAGC 2011). Low impact seismic access lines are now being cut as narrow as 1.75 m, smaller "enviro" drills are capable of traversing narrow lines to drill shot holes and the use of geo-positioning technologies allows operators to establish a meandering seismic trail between shot points which reduces the line-of-sight (CAPP 2004).

All this is to say that while the understanding of the dynamics behind historical seismic disturbance and defining what we mean by disturbance and recovery is important from a land management, cumulative effects and prescriptive mitigation perspective, the severity of early disturbances should not be a reflection on current practices. However, the intensity of activity in the north Yukon, while currently low, has the potential to grow. The complex geology and anticipated high exploration risks associated with all exploration plays in the Eagle Plains area suggest that considerable amounts of new seismic data and more exploration wells may be required to properly evaluate the region's hydrocarbon potential

(Hannigan 2001). Therefore lessons learned from the past will help the industry move forward and continue to develop and implement strategies to reduce the environmental impact of their operations.

RESULTS

Disturbance Type and Response

Our findings broke disturbance down into three types as follows:

Type 1 disturbance

- No or very limited disturbance such as a meandering snowmobile track
- Hand-cut lines
- Travel over frozen wetlands
- Blade kept high with understory and ground surface protected by sufficient snow cover and frozen ground
- Disturbance dynamics mimicked natural environment (e.g., line width same width as natural tree spacing)
- Natural disturbances had re-set the successional trajectory

No recovery is required to “grow” Type 1 disturbance conditions off the landscape. No permafrost or soil response was noted and floristic communities and forest structure were the same both on and off the line. Where natural disturbance such as fire overlapped with oil and gas disturbance the natural successional processes were re-set and the seismic line disappeared. This was evidenced by identical disturbance recovery processes being observed both on and off line. In addition, as per the NYLUP these sites do not facilitate travel or access by wildlife or people.

Approximately one third of our study plots fell into this category. As a note, this finding disagrees with similar studies in the NWT (Kemper 2006). This is likely due to the very poor historical seismic data record (Smith and Groenewegen 2008) in the NWT. Without accurate map-based records of historical activity, researchers would not be able to find historical features that had either grown off the landscape or that had not actually disturbed the landscape at all thus investigating only lines that were still visible. As well, given the distinct difference in disturbance response to different kinds of oil and gas features in our study area, I suggest that there may not have been a clear differentiation between what was a road, trail and or seismic line in some studies.

Type 2 disturbance

- Removal of trees only on the line with limited disturbance to shrubs and understory
- Low level disturbance with the some surface disturbance to the duff but the organic horizon left largely intact and propagules, in particular suckering roots, unaffected
- Some crushing of vegetation and slight (<30 cm) depression along line

Under these conditions locally consistent early pioneering seral species were established and sites were moving along the appropriate successional recovery trajectory. Approximately one third of our study plots fell into this category. Disturbance recovery was compared with natural disturbance recovery and the same processes were in play as for natural disturbance recovery. Recovery timing was consistent with the level of disturbance. The NYLUP suggests that human-caused surface disturbance is considered recovered when it no longer facilitates travel or access by wildlife and people. All the historical airstrips fell into the Type 2 category as did most of the seismic lines and winter trails. Winter roads, well sites, staging areas and camps fell into Type 3 disturbance.

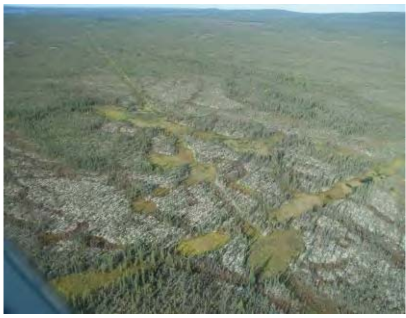
Type 3 disturbance

- Permafrost exposed
- Active layer removed or thinned
- Mineral soil stripped and exposed
- Mixed soil horizons
- Agronomic grass seeded
- Erosion and thaw failures
- Significant rutting or compaction leading to subsidence (>30 cm) of ground
- Scalping of cottongrass (*Eriophorum*) or sedge (*Carex* spp.) tussocks

Response to disturbance Type 3 was significant, outside of the range of natural disturbance recovery and often modified to a locally inconsistent successional trajectory. Stripping and compaction resulted in or contributed to cool moist conditions, elevated water table, active layer deepening and graminoid successional stagnation (primarily *Calamagrostis*). Seeded agronomic species such as Kentucky bluegrass also caused successional stagnation. Both types of graminoid succession/stagnation response were remarkably resilient to change – with some disturbances over 50 years old while less disturbed same-age sites alongside them were recovering appropriately under a natural successional recovery curve (Photo 1 and 2). Horizon mixing would also tend to shift the community into a disturbance dynamic rather than a recovery dynamic.

Photo 1 and 2. Study Plot 2007-17. Calamagrostis successional stagnation and normal successional processes alongside in windrows

Retrogressive succession or the setting back in time of disturbance occurred when peatlands (forested and non-forested) were stripped down to permafrost creating long linear fen like wetlands (Photo 3). Peatlands offer a particularly interesting response to disturbance. When disturbed, peatland becomes altered to present fresh physiographic conditions, its materials undergo change and it becomes endowed with a new set of thermal, hydrological, structural and chemical characteristics (Radforth 1977). Often these changes are irreversible. Natural disturbance (e.g., fire) overlain on Type 3 disturbance was not able to re-set the disturbance (Photo 4).



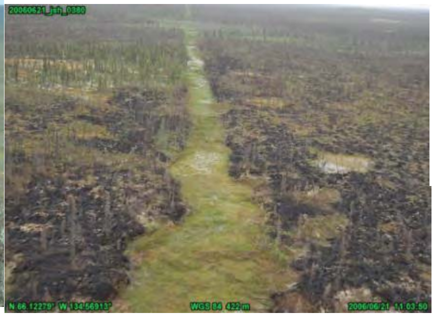


Photo 3. Retrogressive successional response.
Photo 4. Linear fen disturbance cannot be re-set by fire

The NYLUP suggests that in forested areas, a feature can be considered recovered when it contains woody vegetation (trees and shrubs) approximately 1.5 m in height. This may need to be re-considered as some Type 3 disturbed sites have recovered to this height or greater – but have done so in a modified manner presenting vegetated conditions anomalous to the region.

DISCUSSION

In this region recovery is reflective of slow rates of colonization as well as a low resource base that is associated with low temperatures, a short growing season and slow rates of decomposition and nutrient turnover (Bliss and Matveyeva 1992; Nadelhoffer et al. 1992). Dominant factors behind response to disturbance are discussed below.

Permafrost

The landscape and permafrost are very closely related and the degree of initial disturbance is an important control on the extent of permafrost thaw and thus the overall recovery of the linear disturbance. The presence of permafrost greatly increases the complexity of ecological responses to disturbance, due to feedbacks between soil topography, hydrology, and ground ice. Initial minor thaw settlement caused by disturbance can lead to water impoundment, decreased albedo, and increased heat flux, which in turn can cause more thaw settlement (Lawson 1986).

If a disturbance causes substantial changes to edaphic conditions (e.g., thermal regime, permafrost, hydrology, nutrient cycling) this will, in turn, influence community re-development (Chapin and Shaver 1981). The recovery of the pre-disturbance permafrost condition is considered a necessary pre-requisite for return of plant communities to their pre-disturbance state (Lawson 1986; Shirazi et al. 1998; Walker et al. 1987; Walker and Walker 1991). In all Type 3 disturbances in our study, permafrost degradation was implicated (Table 1).

Soil Structure and Mycorrhizal Propagules

Recovery may be impaired by the removal of propagules during soil stripping and horizon mixing. The removal of propagules, especially suckering roots, reduces a site's ability to revegetate naturally (Osko and Glasgow 2010).

Most forest plants are dependent on mycorrhizal fungi for establishment and productivity (Janos 1980) and mycorrhizal propagules are the primary mode of forest regeneration (Brundrett et al. 1996a). Sources of mycorrhizal propagules include old roots and spores (Brundrett and Kendrick 1988). Light, temperature and moisture are all factors known to influence mycorrhizal colonization and stripping and mixing soil disrupts old root systems and mycelia networks (Stottlemyer et al. 2009). Existing vegetation plays an important role as refugia for the mycorrhizal fungi and direct and indirect damage to propagules or changes in soil chemistry (Buchholz and Gallagher 1982; Klopatek et al. 1988) changes the mycorrhizal dynamics (Janos 1980).

If old roots and mycelia are the major sources by which mycorrhizal colonization is initiated, it is likely that the pre-disturbance vegetation community determines the type and amount of mycorrhizal fungi available to regenerating plants (Stottlemyer et al. 2008). Mycorrhizal fungi therefor have the potential to influence the trajectory of vegetation succession after a disturbance. On disturbance Type 3 sites where the successional trajectory has deviated to a new community type this is likely a factor.

The Roles of Graminoids in Influencing Vegetation Succession

The shift to a *Calamagrostis* community type was defined by *Calamagrostis canadensis*. This community was found in areas where clearing and grading had removed the organic surface horizons and left fine textured, moisture-retaining mineral soil that supports dense stands of *Calamagrostis*, limiting establishment of other species, hence the very low average number of species in this community type.

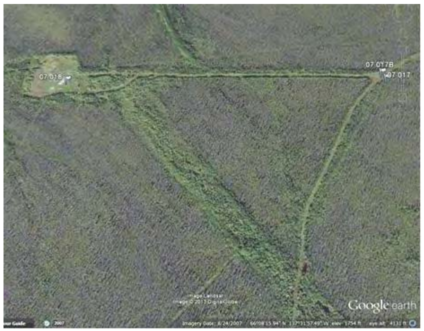
Only one of our study sites had been re-seeded (2007-34). This site was the largest overall disturbance covering a number of hectares and consisted of a well site, camp, staging site and airstrip as well as seismic lines. Kentucky bluegrass had been planted at some point in the 1970's and the site was still grass dominated. Agronomic grasses as well as natural grasses and sedges will act to prevent seedling establishment by pioneering species, thus creating a successionally stagnant environment.

This finding is supported by the work of Forbes (1999) who looked at the introduction of surrogate non-native species (graminoids) to hasten the establishment of plant cover. Osko and Glasgow (2010) found that at Alberta well sites the removal of propagules, especially suckering roots, promotes the dominance of the site by grass. Forbes and Jefferies (1999) work on revegetation of arctic sites also found that the prevalence of mineral rich soils at disturbed sites can limit the re-establishment of species which originally occurred at sites and promote the dominance of grasses.

Interestingly, grasses are the least dependent on mycorrhizal colonization of all mycorrhizal plants (Janos 1980) so able to establish much more independently than other species.

Compaction and Density

A marked difference of density (compaction) relative to undisturbed areas was observed in a number of our plots, none of which were seismic lines. Three road sites were particularly interesting. Site 2007-17 had the most intense historical activity and greatest extent of disturbance and included a well site, airstrip, seismic lines and multiple roads. This access road site was stripped to mineral soil and highly compacted. Permafrost depth was beyond the reach of our 1.1 m rod, contrasting with the average 0.45 m depths found at control plots, seismic lines and airstrips. The floristic conditions at site 2007-17 had shifted from an older mesic black spruce-Labrador tea forest to a *Calamagrostis*-based community. This road was also oriented ENE which would have contributed to the cool conditions. Combining increased soil density with increased clay content and poor soil structure (Osko and Glasgow 2010) can perpetuate cooler, moister conditions that prevent colonization by the adjacent forest and encourage colonization by grasses.



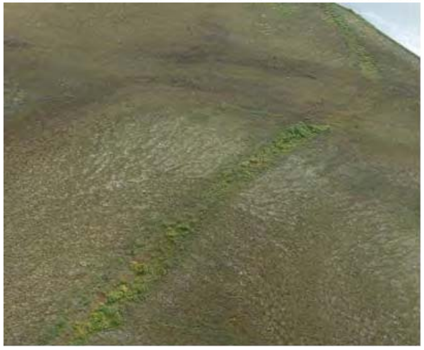


Photo 5. Site 2007-17 with normal succession on airstrip. Photo 6. Site 2007- 24 Accelerated succession due to compaction

Adjacent to the road, the windrowed disturbance, the seismic lines and the airstrip were recovered (Photo 5) floristically back to a black spruce-Labrador tea forest although structural recovery (tree height) was not yet complete.

Sites 2007-24 and 2007-26 also exhibited a response to compaction (Photo 6). These were both winter trails on the Peel Plateau side of our study area. These sites were not disturbed in the conventional sense and no stripping or other soil or direct vegetation disturbance had been carried out. The sites were however slightly depressed from the weight of equipment that had traveled over them and some crushing of vegetation had occurred. A noticeable change in soil density and compaction was observed on the lines. The result of this disturbance was an increase in permafrost depth and an accelerated willow regrowth caused, presumably, by the combination of a nutrient flush from the damaged vegetation and some warming caused by the thickening of the active layer. There was no shift in community at site 2007-26 and a small shift at site 2007-24.

Nutrient Availability

The supply of available nitrogen appears to be strongly limiting for plant growth in this region (Bliss and Wein 1971). The ecosystem has, however, evolved an efficient means of recycling nitrogen with available nitrogen values much higher in the organic horizon than in the mineral B or C horizons. Any disturbance resulting in a modification of this layer will result in the disruption of the nitrogen cycling system and have a consequent effect on plant growth and production. In an environment in which nutrients are already limited, total levels of soil phosphorous, nitrogen and potassium may be lowered substantially with the removal of the organic layer (Cargill and Chapin 1987; Mitchell and McKendric 1975).

Nutrients, already low, are also bound in the organic material. Sufficient disturbance will often cause a nutrient flush followed by an accelerated growth of shrubs and woody species such as willow, alder and birch. So called “green-belts” along winter vehicle trails are commonly reported in the literature and increases in primary productivity have been reported in several tundra disturbance studies (Chapin and Shaver 1981; Hernandez 1973; Vavrek et al. 1999). Accelerated nutrient cycling is also thought to be associated with the compression of standing dead or living plant material into contact with the soil decomposer community (Abele et al. 1984; Rickard and Brown 1974), along with increased soil temperature (Chapin and Shaver 1981). Together, these factors increase decomposition, hence improving nutrient availability. Site 2007-24 and 2007-26 are good examples of this response.

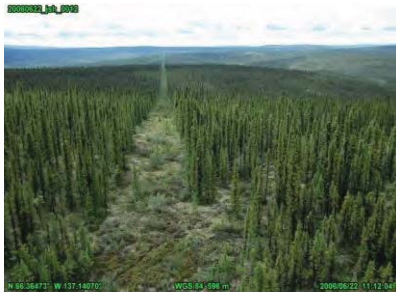


Photo 7. Delayed recovery of spruce trees on a circa 1970 line due to insufficient disturbance to initiate a recovery response

Kemper (2006) found that vegetation composition and structure on seismic lines differs from control sites despite no persistent differences in organic layer depth or depth to permafrost. He proposed that this could reflect successional re-development following changes in soil conditions and nutrient availability arising from the disturbance. While this was true of structure and abundance in our study it was not true of composition on seismic lines, though it clearly was on areas of higher disturbance such as winter roads, well sites and staging areas.

Interestingly there were a number of sites in which there was a delayed recovery (photo 7), perhaps because, in this nutrient limited community, there was insufficient disturbance to kick start a recovery process and therefor an insufficient release of nutrients to allow successional processes to initiate.

Winter Roads, Trails and Well Sites

Winter roads are used to access remote communities and resource development camps in the north, yet little is known of their ability to recover after abandonment. Campbell and Bergeron (2012) evaluated the natural recovery of winter roads abandoned within 7 years on peatlands in the Hudson Bay Lowland and found a significantly thinner active layer, lower species richness and changes in species composition. Kemper suggested that although the visual signature of seismic lines was still apparent 18 to 33 years post disturbance, some may have been ice roads associated with exploration activity, which though not well studied, typically have more severe impacts than seismic lines (National Research Council 2003). Our study found an almost 100% correlation between Type 3 disturbance and these types of features (Table 1). The only exception to this was when severe fire had burned through the area (plot 2007-09).

Photo 8 and 9. Fire has re-set the successional processes on these seismic lines

Fire versus Seismic Line

An indication that underlying disturbance factors were not at play in the recovery of some seismic line disturbance were sites where fire had re-set the successional processes on the line to match that of the adjacent burned forest. In one case (plot 2007-09, Photo 8) severe fire damaged the site to the extent that the resulting vegetation both on the line and in the surrounding environment reflected the same early pioneering species. Permafrost depth was equally affected on and off the line. A significant number of other fire- affected sites that were observed from the air exhibited characteristics that indicating that underlying disturbance had been re-set (Photo 9). Not all of these sites could be visited due to burned tree snags preventing helicopter access and so permafrost depth at these sites is unknown.

In these cases clearing of the seismic line would have been done in such a way that the surface soil and vegetation was protected. With the exception of spruce trees either removed or burned there was little difference between the burned seismic line and the adjacent burned forest.

CONCLUSIONS

It is difficult to identify any one factor as responsible for the impairment of growth on these disturbances. Both the nature of the disturbance and the physical and environmental factors at play are very complex and it can be difficult to nail down a single limiting factor or filter to the recovery of these disturbances.

The two factors that appear most significant in terms of measuring disturbance are floristic community type and depth of permafrost or thickness of active layer and each is strongly correlated to the other. Our study, though focused on seismic disturbance, looked at a variety of oil and gas disturbances – well sites, staging areas, airstrips, roads, trails and seismic lines. There was a 100% correlation between type of disturbance and intensity of disturbance with winter roads, well sites and staging areas consistently shifting the floristic community into a disturbance community (not a successional community) and creating significant deepening of the active layer and depth to permafrost.

Our study found limited effects of seismic lines and airstrips on the soil organic layer and density or depth of permafrost 30 to 60 years after disturbance. However we found that historical seismic exploration has led to an increased cover of deciduous shrubs and reduced cover of mosses and lichens. The greater cover of deciduous shrubs on seismic lines can be attributed to their ability to take advantage of short-term increases in nutrient availability; however such effects are likely long-lasting given the high inertia of tundra plant communities. Overall, our results agree with those of Forbes et al. (2001) in that seismic lines had fairly similar floristics to the reference tundra, but the appearance of the vegetation was often quite different because of increases in cover of taller shrubs and pioneering trees such as willow, alder and birch. Comparing the disturbance response to natural disturbance response in the region we can assume that the timing of recovery will be the same. As such we fully expect to see a completion of this successional recovery response back to normal site characteristics as already found at a number of our sites (Photo 10).

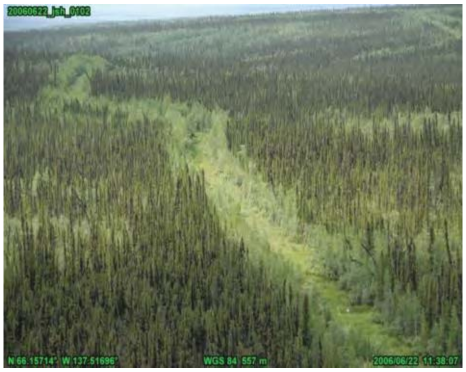


Photo 10. Site 2007-1 1970 Airstrip with almost complete recovery
Photo 11. Winter road type 3 disturbance

This is not the case for the highly disturbed winter roads (Photo 11), well sites, camps and staging areas where we found an overall significant difference in vascular plant community composition, soil density, permafrost depth and active layer thickness.

We know that pre-disturbance environmental information is valuable for post-disturbance comparative purposes. The baseline for defining recovery or restoration of disturbance is the surrounding or control conditions – including natural disturbance regimes. These baseline or pre-disturbance conditions however can be even more valuable for prescriptive purposes. For example, knowing the depth of the active layer and water table in combination with soil texture could help predict how susceptible a site might be to post-disturbance domination by *Calamagrostis*, thereby enabling the prescription of preventative measures such as minimization of stripping. Presence, extent and volume of ground ice are important determinants of disturbance response (Lawson 1986; Walker and Walker 1991) and therefore prescriptive mitigation.

Walker et al. (1987) related the magnitude (and reversibility) of impacts on substrates to alternate states of post-disturbance recovery including: (1) complete recovery with succession, where substrates are not permanently changed and the pre-disturbance plant community returns; (2) positive functional recovery, where substrates are either moderately or severely changed and post-disturbance vegetation is dissimilar to the undisturbed condition but is more productive; and (3) negative functional recovery, where the post-disturbance community is dissimilar to, and less productive than, the pre-disturbance type. Our study findings of three types of disturbance and recovery agree with this.

The findings illustrate that the greater the intensity of disturbance the greater the deviation from the natural successional pathway to recovery. Highly disturbed Type 3 sites have a modified response that includes pioneering species such as grasses and sedges. This is significantly different than sites responding to lower level disturbance. Type 2 disturbance can recover via the same processes as do natural disturbances such as fires and rapid landscape change. Given the high inertia of recovering northern plant communities this becomes something of a societal or land management decision. Do we want to permit disturbance that requires the same timescale as a natural disturbance to fully recover? Are we willing to push the perceptual norms by calling a visible site that is appropriately recovering but not quite there yet a recovered site? Structural recovery may require many decades as the growth of trees is very slow in this region. This may mean that the line remains visible for as much as 50 to 70 years even though the site has recovered ecologically and it is called recovered.

The NYLUP has established a disturbance threshold approach for land management in the planning region. In so doing they have recommended that, as human-caused surface disturbances, including linear features, recover through natural re-vegetation or active reclamation, they are subtracted from the total amount of disturbed area. We propose that Type 1 disturbances can be removed from our accounting of disturbance in this region and that Type 2 disturbances can be "grown" off the landscape as appropriate to their age and stage of successional response. Type 3 disturbance will require intervention in order to recover and will otherwise remain on the landscape indeterminately.

REFERENCES - an extensive list of reference is available on request.

Overcoming Northern Challenges

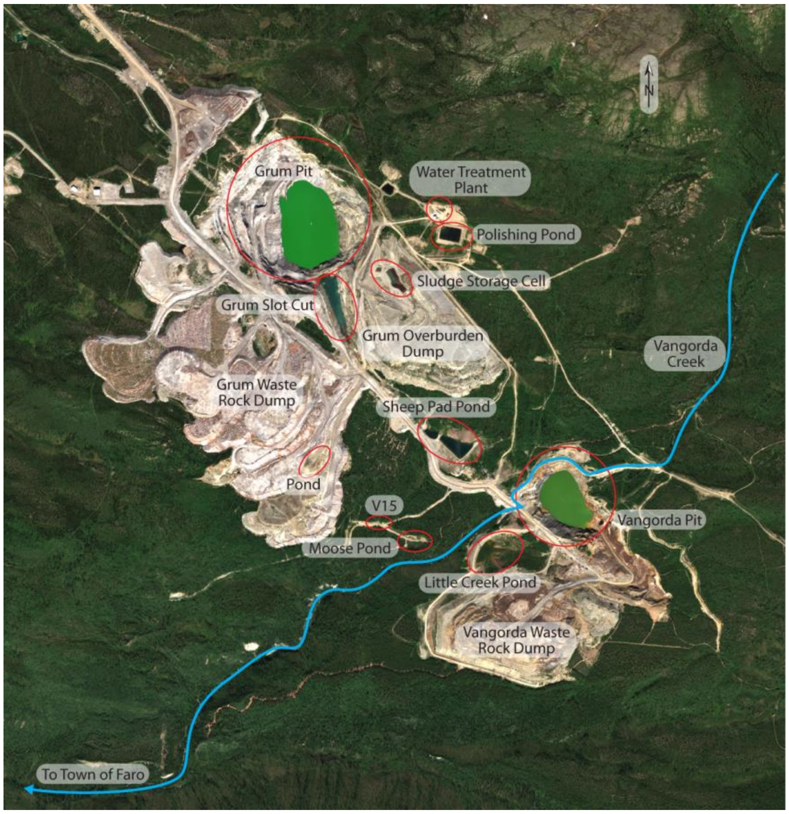
Proceedings of the 2013 Northern Latitudes Mining Reclamation Workshop and

38th Annual Meeting of the Canadian Land Reclamation Association

Whitehorse, Yukon September 9 – 12, 2013

CLRA | ACRSD
Canadian Land Reclamation Association
Association canadienne de réhabilitation des sites dégradés

Northern
Latitudes
Mining
Reclamation
Workshop



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Wednesday:

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Eary, Russell, Johnson, Davidson and Harrington	Water Quality Modelling and Development of Receiving Environment Water Quality Objectives for the Closure Planning in the Keno Hill Silver District (paper not attached)
Knight	Galena Hill, Yukon, Ecosystem Mapping Project
Polster	Natural Processes: An Effective Model For Mine Reclamation
Dustin	Implementation of contaminated water management system upgrades to allow for dewatering of two open pits at the Vangorda Plateau, Faro Mine Complex, Yukon
Kempenaar, Marques and McClure	Tools for Arctic Revegetation: What's in Your Toolbox?
Smreciu, Gould, and Wood	Establishment of Native Boearl Plant Species On Reclaimed Oil Sands Mining Disturbances
Keefer	Twin Sisters Native Plant Nursery
Pedlar-Hobbs, Ludgate and Luchinski	Key Factors in Developing and Implementing a Successful Reclamation Plan
Chang, et.al	Effects of Soil Aggregates Sizes (paper not attached)
Heck	Phytoremediation of petroleum hydrocarbon impacted soils at a remote abandoned exploration wellsite in the Sahtu Region, Northwest Territories
Janin	Passive treatment of drainage waters: Promoting metals sorption to enhance metal removal efficiency
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Simpson	Defining Disturbance and Recovery - the influence of landscape specific ecological responses to oil and gas linear disturbances in Yukon

NORTHERN LATITUDES MINING RECLAMATION WORKSHOP

The Northern Latitudes Mining Reclamation Workshop is an international workshop on mining, land and urban reclamation and restoration methods. The objective of the workshop is to share information and experiences among governments, industry, consultants, Alaska Natives, northern First Nations and Inuit groups which undertake reclamation and restoration projects, or are involved in land management in the north or in comparable environments.

The first Workshop was held in Whitehorse, Yukon Territory, Canada in 2001 and it has been held every two years since, alternating between Canada and Alaska. The primary sponsors of the Workshop include the Yukon Geological Survey, Indian and Northern Affairs Canada, Natural Resources Canada, US Department of the Interior Bureau of Land Management, and the State of Alaska Department of Natural Resources.

CANADIAN LAND RECLAMATION ASSOCIATION

The CLRA/ACRSD is a non-profit organization incorporated in Canada with corresponding members throughout North America and other countries. The main objectives of CLRA/ACRSD are:

- To further knowledge and encourage investigation of problems and solutions in land reclamation.
- To provide opportunities for those interested in and concerned with land reclamation to meet and exchange information, ideas and experience.
- To incorporate the advances from research and practical experience into land reclamation planning and practice.
- To collect information relating to land reclamation and publish periodicals, books and leaflets which the Association may think desirable.
- To encourage education in the field of land reclamation.
- To provide awards for noteworthy achievements in the field of land reclamation.

ACKNOWLEDGEMENTS

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- The Conference Organizing Committee: Alissa Sampson, Andrea Granger, Bill Price, David Polster, Diane Lister, Justin Ireys, Linda Jones, Mike Muller, Neil Salvin and Samantha Hudson.
- The Conference Papers and Posters Committee: Andy Etmanski, Bill Price, Chris Powter, David Polster, Diane Lister and Scott Davidson
- The Conference Sponsors (see next page)
- The Conference paper and poster presenters
- Dustin Rainey, Jocelyn Douheret and Brian Geddes for permission to use their photos on the Cover, Papers and Posters pages, respectively

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