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Seismic Line Recovery in the Southeast Yukon: Patterns and Processes

By

David Polster

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SEISMIC LINE RECOVERY IN THE SOUTHEAST YUKON: PATTERNS AND PROCESSES

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RECOVERING SEISMIC LINE SE YUKON (PHOTO BY D. POLSTER)

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EXECUTIVE SUMMARY

Increased interest in oil and gas exploration in the Yukon is leading to an increase in the use of seismic exploration as a tool for identifying potential drill sites. Although there are a number of techniques that have been developed over the years to minimize disturbances associated with seismic exploration, in some cases the information that needs to be gathered dictates that a less than environmentally optimal treatment be employed. Seismic line cuts can cause a number of outcomes from significant environmental degradation to lines that are barely a whisper on the landscape. Studies conducted in the Eagle Plains and Peel Plateau areas in 2006 and 2007 have provided significant information on the ecology of recovery of seismic lines in these areas. The results of these studies were presented at the 2007 Oil and Gas Best Management Practices Symposium in Inuvik in October, 2007. The South Eastern region is different ecologically from the Eagle Plains and Peel Plateau region. The lower elevation sites in the South Eastern region are vegetated by substantial forests of white spruce, poplars and birch while the Eagle Plains area is tundra at higher elevation and black spruce / Labrador tea scrub forests at lower elevations. The relation to recovery processes in the North Yukon bears consideration as the general processes of recovery illustrate elements that should be considered when seismic lines are cut. This study builds on the studies completed in 2006 and 2007 and provides information that illustrates the ecological characteristics of seismic line recovery as a tool for the continued development of best management practices and standard operating procedures for oil and gas exploration.

A total of 193 species and 64 relevés (plots) have been used to define 11 community types on the basis of 6 species-relevé groups. This information has been used to assess the relative levels of recovery and to illuminate those factors that either limit or assist recovery of the seismic lines. Vegetation patterns on seismic lines can provide an excellent indication of the level of recovery of the line in question. Floristic similarities between the vegetation on the line and the vegetation in the adjacent, undisturbed area suggest that vegetation recovery is progressing, although structural recovery may take many decades where vegetation is slow growing. The preponderance of early successional forests in many areas of the SE Yukon and adjacent NWT create conditions that foster recovery of seismic lines. Sites where mineral soils have been seeded with non-native grasses and legumes recover much more slowly and carry floristic dissimilarity with adjacent vegetation over many years. Vegetation information provides an effective measure of recovery progress.

The forests of the project area were assessed on the basis of the ecoregion in which the plots were located. The sample area includes examples of four ecoregions:

Northern Alberta Uplands Ecoregion
Sibbeston Lake Plain Ecoregion
Muskwa Plateau Ecoregion

Hyland Highland Ecoregion

Forest recovery on the seismic lines depends on the ecological conditions of the area where the line was cut, the severity of disturbance associated with the line and the successional status of the line in question. At lower elevations recovery of trees on seismic lines can be relatively rapid if the line clearing has created suitable seed beds. Where soil disturbance is limited, such as on wider hand cut lines, limited tree recruitment was noted. Where pioneering species such as willows, alder and poplar dominate the line, conifers can be found invading under the deciduous species suggesting a shift back to a conifer forest over time. At higher elevations, tree regeneration can be very limited as the harsh climatic conditions restrict seed production as well as establishment and growth.

Soils information was collected at the sampling locations to compliment the vegetation and forest information. Soil conditions reflected the manner in which the line was cleared. On machine cleared lines at lower elevations, the organic matter was usually windrowed on the side of the line, producing a nutrient rich area for vegetation development. On the lines, however, the lack of organic soil horizons often resulted in a distinct shift in the vegetation that re-established away from conifers towards deciduous dominated stands. At higher elevations, the general lack of significant soil development, due to the harsh conditions, limited the differences found on and off the lines.

Assessments and inspections of SE Yukon seismic lines and well sites were undertaken in the summer of 2008 by the Oil and Gas Resources Branch of the Department of Energy Mines and Resources. Logistical support for this study was coordinated with the Oil and Gas Resources Branch. The information collected in this study built on information gained during the 2006 and 2007 studies. Information gained during this study provides a greater understanding of the ecological and physical elements that enhance recovery rates. This report presents the methods employed for the collection and analysis of ecological and physical information to help elucidate the recovery dynamics of seismic lines in SE Yukon.

1.0 INTRODUCTION

The objectives of this study are to collect and analyse data on the vegetation, forest and soil conditions on seismic lines in the SE Yukon with the aim of defining ecological and physical parameters that will assist in determining recovery and best management practices. Understanding the natural processes involved in recovery of seismic lines provides a foundation for development of best management practices to minimize the impacts of seismic activities. Since many of the recovery processes that operate on seismic disturbances are common to other types of disturbance, understanding the ecology of recovery processes allows other disturbances to be developed in such a way that recovery is enhanced.

Natural processes such as vegetation succession can serve as models for restoration treatments (Polster 1991). Understanding how natural processes such as succession address the filters or limitations that prevent vegetation establishment allows treatments to be applied that reduce the impediments to recovery (Walker and del Moral 2003). Traditional concepts of vegetation succession, with an orderly progression from bare soil through pioneering vegetation to climax communities, are changing as we recognize the complex overlay of ecological processes that go to make up vegetation succession (Walker et al 2007). Features such as nutrient cycling processes are complex and often involve an ever-changing suite of organisms. Although it is interesting to understand this complexity, recognition of limits or constraints to natural recovery can permit the design of restoration systems that lead to successful recovery without knowledge of the detailed processes that occur to make this happen (Polster 1989).

Construction features that maintain woody debris in large pieces will assist in recovery of nutrient cycling processes (Miller and Seastedt 2009). Incorporation of woody debris and litter in the completed seismic line and leaving the ground rough and loose will assist in preventing erosion and create micro-sites for seeds to lodge in and germinate and seedlings to grow (Polster 2009). Evidence of these processes can be observed on seismic lines where appropriate actions were taken during construction even inadvertently. By planning for these processes through a few simple best management processes, recovery of seismic lines will be greatly enhanced.

There are two primary phases of recovery that need to be considered in the design of recovery systems; floristic or species recovery; and structural recovery. Where vegetation grows slowly, floristic recovery may occur many decades or even centuries before the seismic line disappears from the land. However, even though a line is still clearly visible on the land, if floristic recovery has occurred, then all that is needed is time for full recovery to occur. Understanding the ecological elements that make up recovery allows regulators to define appropriate restoration end points and cumulative effects.

2.0 METHODS

The field work for this study was conducted in the area of the Kotaneelee Gas Plant in SE Yukon and adjacent areas of the North West Territories. Field work for all study components was conducted from August 25th to September 1st, 2008. Sampling sites were selected to show the range of seismic line conditions in the area where the site was located. In addition, sites that were accessed by helicopter were selected based on the ability to land a helicopter near the sampling location while sites that were sampled from the truck were located near a serviceable road. In some cases sample sites were accessed on foot from a helicopter landing location some distance away. In many cases, landing location in wetlands allowed sampling to be completed in the wetland as well as in the adjacent upland areas. Very few of the seismic lines were wide enough to land a helicopter in, although well sites and old camp locations provided convenient landing locations.

Sampling sites were selected to represent a uniform location in terms of vegetation, forestry and soils if possible. In some cases, streams or wetlands that developed as a result of erosion on the seismic line created heterogeneity in the sampling area on the line. Plots were paired where possible to give one plot on the seismic line (or other disturbance) and one plot in the undisturbed natural vegetation adjacent to the seismic line. Data collected at each site is described below under the different disciplines. Sample sites are numbered so that the numerical plot number without the alphabetic modifier denotes the plot on the line while the alphabetic modifier indicates that the plot was in an adjacent undisturbed area, although in the case of plot 8013B, the plot was located in a cleared area that may have been used by a shot truck recording the seismic data and plot 8009A is at a well site.

2.1 VEGETATION ASSESSMENTS

Vegetation information was collected at each sampling location and consisted of a list of all of the vascular plant species and the dominant bryophytes (mosses, liverworts and lichens) present. An estimate of the combined cover and abundance of each species was recorded. The floristic data that was collected at each relevé (plot) was analysed using standard phytosociological methods (Mueller-Dombois and Ellenberg 1974). These methods have been used for defining the Biogeoclimatic Ecosystem Classification Zones in British Columbia. Detailed photographic documentation was made at each site and a GPS record of the sites visited and the travel tracks taken was compiled. Taxonomy follows Cody (2000). Voucher specimens were collected as needed for identification in the camp or office.

Floristic analysis of vegetation data consists of a simultaneous sorting of the rows and columns in a table composed of all of the plants found and the relevés (plots) in which they were found. The sorting is aimed at grouping the species that occur together and the relevés with similar species occurrences together so that species-relevé groups are formed. Species-relevé groups are named by the dominant species in the group. Vegetation types are defined by the presence or absence of the species-relevé groups. Community types, indicative of the underlying processes that caused the vegetation to establish in the manner it has, are defined by the presence or absence of the species-relevé groups. In addition, the relative strength of the species-relevé group within the community type can provide indications of the trends that are occurring in the vegetation. The accompanying species also show patterns that can be indicative of the direction the community type is going in. These aspects of the floristics of recovering seismic lines are discussed in the results and discussion section below.

2.2 FORESTRY ASSESSMENTS

Forest data was collected at paired plots in the same location as the vegetation plots. These were established on disturbed sites and adjacent undisturbed control areas. Where appropriate, tree data from the plots were subsequently analysed using Yukon formulae and volumes generated. Stems per hectare were calculated for fixed area plots to give an indication of regeneration of forest trees. In neither case were the data broken down by species.

Due to the nature of the seismic line disturbances fixed area fifty square metre ($50m^2$) plots were used to record data. Plots were line width (m) times appropriate depth (m) to equal fifty square metres. Control plots in adjacent undisturbed forest were either measured using prism sweeps or fifty square metre fixed plots depending on the nature (size and density of the trees) of the forest. Computed volumes are totals and not by species as are the densities of stems per hectare. Densities were only computed for fixed area plots on disturbed sites (Table A: Forest Data, NWT Plots Recorded 27, and 28 August 2008).

2.3 SOILS ASSESSMENTS

Soils assessments were conducted in the same locations as the vegetation and forestry plots. Soil pits were excavated both on and off the line. At each site, the depth of the organic duff or peat was recorded. Soil texture and moisture information was collected at the depth of sample collection. In most cases the depth to permafrost was not collected although the depth to resistance where this was met at less than 1 m was collected. Information on windrows caused by clearing the lines, if present, was also collected at the seismic line sites. In addition, any subsidence that was present was noted. The collected soils information was compiled into a large spreadsheet. An analysis conducted by Dryas Ecological Research & Consulting (Morrison 2010) provides some insights into the information collected.

3.0 RESULTS AND DISCUSSION

3.1 VEGETATION RECOVERY PATTERNS

A total of 193 species and 64 plots were used to define 11 community types on the basis of 6 species-relevé groups. Table 1 presents the differential portion of the vegetation table. Table 2 lists the species-relevé groups that were used to define the community types (named by number in Table 1). The full vegetation table is provided as an Excel® spreadsheet. All of the species found in the relevés are listed in this full vegetation table.

TABLE 1
VEGETATION TABLE, SE YUKON SEISMIC LINE STUDY

	Total Vegetation Cover	95	99	85	85	95	95	95	90	95	85	99	75	99	95	90	80	95	65	90	90	90	95	85	99	99	95	99	95	80	99	99	95	99	90	65	95	95	99	95	90	85	80	85	90	80	99	75	75	40	99	80	25	80	95	85	80	85	99	95	70	15	99	80	95
	Tree	0	30	60	35	50	35	30	65	1	60	10	20	35	65	30	50	65	35	45	50	25	30	1	35	40	15	25	40	20	40	25	30	20	20	R	1	5	5	15	1	5	5	5	1	20	25	5	10	20	50	70	1	5	1	0	5	15	R	0	5	1	0	0	35
	Shrub	40	1	50	25	50	20	50	25	40	15	60	25	15	45	35	15	30	20	30	40	60	50	65	20	10	60	25	20	35	5	35	50	60	50	25	1	40	30	60	25	40	40	15	30	40	5	30	50	10	35	15	5	5	50	5	5	5	0	0	10	5	&	10	1
	Herb	40	5	30	10	30	50	40	15	30	70	30	20	25	35	20	30	40	15	50	15	35	25	30	15	10	20	25	5	10	1	10	30	25	25	15	15	10	30	5	10	20	0	25	5	10	5	5	20	10	5	5	15	75	50	80	75	70	25	5	10	10	50	90	5
	Moss	75	90	10	10	60	80	0	40	30	10	60	25	90	25	15	5	0	25	10	&	60	85	60	95	95	70	90	95	60	95	95	70	90	70	25	80	50	70	95	80	40	80	50	80	50	85	75	20	25	40	R	5	0	0	0	0	0	90	95	50	0	90	40	90
	Number of Species	15	14	16	15	18	17	18	20	31	17	23	27	28	23	20	27	18	19	24	22	19	20	21	20	20	22	15	16	22	14	17	24	21	18	21	10	14	18	15	17	20	13	27	17	24	9	20	22	22	10	12	35	15	22	19	19	15	12	13	11	16	8	8	14
	64	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
	Community Type	**1**			**2**								**3**									**4**			**5**				**6**										**7**									**8**			**9**				**10**				**11**						
Constancy	193	8013	8021A	8004A	8001	8012A	8018A	8014	8014A	8010	8015	8010A	8018	8033A	8017	8021	8022	8023	8033	8019	8002	8022A	8017A	8012	8034	8034A	8029	8019A	8025A	8024	8029A	8015A	8016	8016A	8013A	8009B	8008	8008C	8013B	8024A	8027A	8028	8028A	8032	8027	8025	8008A	8031	8007	8030	8001A	8002A	8009	8006	8011	8004	8005	8020	8003A	8031A	8008B	8009A Well	8003	8026	8032A
40	**Cornus** canadensis		5	10	10	1	35	5	5	5		15	10	15	10	5	10	10			5	15	5	10	5	5		10	5	1	1	1	5	1			5	5		5	1	1		1		5	5		5		1										5				1
40	Pleurozium schreberi	75	40	10		60	80		40	25	10	60	15	50	25	15	5		25	10		60	80	60	90	5	60	90	60	10	95	10	25	40	70		80	20	65	60						15	80	15			40										30				85
35	Picea glauca		10	20			1	&	25		10		&	30	5	1	1	5	10		5	15	25		25	35	1	5	10	5	5					&					R		1	R	1			1	1	1		40	1					1				&			
27	Equisetum arvense	30		1	&	1		20	1	1	40	5	1	1	5		1	R		10	&		5	1							R	1	10	5	10																			1		1	1		1						
27	Rosa acicularis	&	&	10	1	5	5		1	5		5	5	1	10	1	5			1	1	10	10	1	5		1					R			&				5													1		R	5										
31	**Vaccinium** vites-idaea	1	1			1			1	1		5									1		1	1	1	1		5	5	5	1	1	1	15	1	&	1	1	1	5	1	1	1	1				1	5											1					
25	Ledum groenlandicum	10				15				15	R	30		R									30	15	1	1		15		5	1	35	40	50	10	R			10	10	1	1			R	1					1														
27	Betula glandulosa																										1		1	5	5			5	5	15	1	25	20	10	15	5	10	1	5	25	1	20	25	R			1		5				10	20	1				1
26	Abies lasiocarpa						30						1		&			R		&							15	5	30	15	35					R	1	5		15	R	&	1	1	1	15	25	1	10	5											1				35
24	Empetrum nigrum																								1	5	5		10	15	1	1	1	1		&	1	5		10	10	25	30	10	30	10	1	10	5	5			1												
26	**Epilobium** angustifolium		&		1	1		1			35	1	1	&			1		1	1	&	1			1	1	1						1			&								1		1		1	1	1			R	&	5										
25	Linnaea boreale	5		5		1	5	1	1	1				5	1	1		1	1			5	5	1	5		1	5			1				1			1	1										1		1	1													
21	Populus balsamifera							15			40		1	R	10	15	15	10	15	30	30	10			5	5																						&		10				5	1	1	5	10							
22	Alnus crispa				20	5	10	10	10	1		5	5							5			15	15	5	1		5																					5	5	30	10	&	R	5				1						
19	**Betula** papyrifera		R	10	35	5	1	10		R		1	10		25	10	20	10			&				1								15													R					1				1										
18	Viburnum edule	&		40		5		R	5	5		10		5		1	10	1			10	15	5	20	1	1																							5																
16	Populus tremuloides			35	1	5	1	5	40		10			R		5	5	40	10	15	10																													1		35													
15	Rubus idaeus			5			5	1	1	1	1	1	5	10	5	5	1		10	10	10																																												
6	**Trifolium** hybridum							R			1																																												1	20	20	15							
4	Festuca rubra																																																						10	30	30	20							
4	Hieraceum gracile																																									R				1										&	R								
4	Phleum pratense																																																						10	20	10	15							
11	**Calamagrostis** canadensis												5		1		1			1			1											1																				60	5	30	25							15	
11	Mertensia paniculata			1										1	&	5	1	5	1		&	1					1																											1											
10	Cornus stolonifera					1								1			15	5	5			1	R																															R	5			R							
10	Salix scouleriana				R								5			25		5		15	15																															1		5		&	5								
16	Cladonia stellaris puffs		5							5																5				5				1	5	10	1	15	5	30	65		30		25	5														65					
16	Peltigera aphthosa	1	5					1							1								5		5	5	1	1	1		1	5	1	5																		R								1					

The vegetation table (Table 1 above) lists the total vegetation cover as well as the cover provided by trees, shrubs, herbs and mosses. In addition, the constancy (left hand side of Table 1) provides the number of times the species occurs out of a total of 64 possible times. A total of 193 species were found during this study. Community type names are based on the occurrence of the species-relevé groups listed in Table 2. So for instance, community type 1 is the Cornus Community Type and 2 is the Cornus-Epilobium-Betula Community Type and so on. Discussions of the ecological relevance of the species-relevé groups and community types are provided below.

TABLE 2
SPECIES-RELEVÉ GROUPS DEFINED IN THIS STUDY

Cornus canadensis
Pleurozium schreberi
Picea glauca
Equisetum arvense
Rosa acicularis

Vaccinium vites-idaea
Ledum groenlandicum
Betula glandulosa
Abies lasiocarpa
Empetrum nigrum

Epilobium angustifolium
Linnaea boreale
Populus balsamifera
Alnus crispa

Betula papyrifera
Viburnum edule
Populus tremuloides
Rubus idaeus

Trifolium hybridum
Festuca rubra
Hieraceum gracile
Phleum pratense

Calamagrostis canadensis
Mertensia paniculata
Cornus stolonifera
Salix scouleriana

3.1.1 Species-Relevé Groups

The **Cornus** species-relevé group is composed of *Cornus canadensis* (Bunchberry), *Pleurozium schreberi* (Big Red Stem (moss)), *Picea glauca* (White Spruce), *Equisetum arvense* (Common Horsetail) and *Rosa acicularis* (Prickly Rose). This group represents mesic, relatively low elevation boreal forests. Many of the relevés (18) that are included with this group (total 34) are of disturbed sites suggesting that floristic recovery on these sites is relatively complete, although structural recovery may be lagging. In addition, where the plots associated with this group are in undisturbed areas, the species composition suggests that natural disturbance events (probably wildfires) maintains a stock of early seral species in the ecosystem to colonize new disturbances.

The **Vaccinium** species-relevé group is composed of *Vaccinium vites-idaea* (Lingonberry), *Ledum groenlandicum* (Labrador Tea), *Betula glandulosa* (Dwarf Birch), *Abies lasiocarpa* (Subalpine Fir) and *Empetrum nigrum* (Black Crowberry). This group is indicative of moister, higher elevation forests that are tending towards Black Spruce / Sphagnum bogs. These sites can be very moist and relatively nutrient poor (oligotrophic). As with the **Cornus** group, many (13) of the plots (total 26) were of disturbed areas, suggesting floristic recovery.

The **Epilobium** species-relevé group is composed of *Epilobium angustifolium* (Fireweed), *Linnaea boreale* (Twinflower), *Populus balsamifera* (Balsam Poplar) and *Alnus crispa* (Green Alder). This group represents a mesic to moist recovery path with 21 out of 32 plots being on the seismic lines (disturbed). This group splits with three quarters of the plots in the right split being representative of disturbed sites. The split in this group occurs because the Vaccinium group species which is indicative of less severely disturbed sites shows connections to both the more mature mesic site vegetation of the Cornus group and the more disturbed conditions associated with the Trifolium group (described below).

The **Betula** species-relevé group is composed of *Betula papyrifera* (Paper Birch), *Viburnum edule* (High-bush Cranberry), *Populus tremuloides* (Aspen) and *Rubus idaeus* (Red Raspberry). If the Epilobium group represents a slightly wetter phase of seral vegetation, the Betula group is the drier counterpart. Two thirds of the plots in this species-relevé group are located in disturbed areas, reinforcing the suggestion that disturbance communities whether from natural wildfires or seismic lines follow similar successional trajectories (Hobbs and Suding 2009).

The **Trifolium** species-relevé group is composed of the seeded agronomic species *Trifolium hybridum* (Alsike Clover), *Festuca rubra* (Creeping Red Fescue) and *Phleum pratense* (Timothy) as well as the weak occurrence of the weedy species, *Hieraceum gracile* (Slender Hawkweed). This group is composed entirely of disturbance site plots (5 out of 5) which is not surprising given that it is composed primarily of agronomic species.

The **Calamagrostis** species-relevé group is a weak group of wetter site pioneering species. It should also include plots 8022A and 8017A, but that would cause the break at the right side of the Betula group to be less distinct. This group is composed of *Calamagrostis canadensis* (Bluejoint Reedgrass), *Mertensia paniculata* (Tall Bluebells), *Cornus stolonifera* (Red-osier Dogwood) and *Salix scouleriana* (Scouler's Willow). Not surprisingly, this group is associated with the Cornus, Epilobium and Betula groups on the left side of the table and the Trifolium group on the right side of the table, suggesting an affinity for disturbances. Twelve of the 13 relevés that make up this group are located in disturbance areas. In addition, the plots that were not included, 8022A and 8017A are not disturbance plots and therefore probably do not fully belong with this group.

3.1.2 VEGETATION TYPES

Eleven vegetation types have been defined by presence or absence of the 6 species-relevé groups described above. Community types are named by the species-relevé groups that define them so community type 1 shown in Table 1 would be called the Cornus Community Type while type 2 would be known as the Cornus-Epilobium-Betula Community Type and so on. Care must be taken not to confuse the names of the species-relevé groups with the names of the community types. The following paragraphs provide details of the 11 community types, the relationships between them and the recovery patterns that are illuminated by these relationships.

The **Cornus Community Type (1)** is defined by the presence of the Cornus species-relevé group and the occurrence of one plot that was grouped with the Betula species-relevé group. Two of the three plots that characterize this community are undisturbed forests of White Spruce (*Picea glauca*), Aspen (*Populus tremuloides*) and Black Spruce (*Picea mariana*). The mix of disturbed and undisturbed plots included in this community suggest that the floristic relationship between the recovering line sampled as 8013 and the two undisturbed plots, 8021A and 8004A is close, although the disturbed plot (8013) lacks the White Spruce that is present in the undisturbed plots. The presence of one plot that has been grouped with the Betula species-relevé group suggests a relationship with the Cornus-Epilobium-Betula Community Type (2).

The **Cornus-Epilobium-Betula Community Type (2)** is defined by the occurrence of the Cornus, Epilobium and Betula species-relevé groups. Of the 8 plots that have been used to define this community type, half have been disturbed (8001, 8014, 8010 and 8015) while half represent undisturbed sites (8012A, 8018A, 8014A and 8010A). Two sets of plots 8010 and 8010A, and 8014 and 8014A represent adjacent plot sets suggesting that a high degree of floristic recovery is illustrated by this community type.

The **Cornus-Epilobium-Betula-Calamagrostis Community Type (3)** is defined by the Cornus, Epilobium, Betula and Calamagrostis species-relevé groups. With one exception, plot 8033A, all of the plots represented by this community type have been disturbed. The Calamagrostis species-relevé group, as discussed above, is a split disturbance related group that shows affinities to the less disturbed left side of the vegetation table as well as the more disturbed right side of the table. This community type is representative of less well recovered sites.

The **Cornus-Epilobium Community Type (4)** is defined by the Cornus and Epilobium species-relevé groups. Two of the three plots, 8022A and 8017A, that have been included in this type are undisturbed while plot 8012 is disturbed suggesting that this community illustrates sites that have recovered well or were not disturbed initially. The undisturbed forests included in this community are relatively open mature White Spruce forests while the disturbed site has recovered well and is analogous to the openings in the mature forests although with a linear arrangement.

The presence of the Cornus, Vaccinium and Epilobium species-relevé groups has been used to define the **Cornus-Vaccinium-Epilobium Community Type (5).** This community type illustrates the relationship between older forests of White Spruce and older forests dominated by Subalpine Fir. Half of the plots in this type have been disturbed (8029 and 8034) while half sample undisturbed sites (8019A and 8034A). The floristic similarity between the disturbed and undisturbed plots in this type suggests a reasonably high degree of floristic recovery. Two of the plots are a plot pair, 8034 and 8034A suggesting a high level of recovery at least in this specific location.

The **Cornus-Vaccinium Community Type (6)** is defined by the presence of the Cornus and Vaccinium species-relevé groups. Five of the seven relevés that have been included in this type are undisturbed (8013A, 8015A, 8016A, 8025A and 8029A) while the disturbed sites (8016 and 8024) have recovered well and are floristically similar to the undisturbed areas, although structurally these sites show the open linear conditions associated with recovering seismic lines.

The **Vaccinium Community Type (7)** is defined by the presence of the Vaccinium species-relevé group and the absence of other groups. Half of the relevés that have been used to define this type are undisturbed cool mid to upper elevation open subalpine fir forests. The gaps in these natural forests are similar to the gap created by the seismic line and it is not surprising that there is a floristic similarity between the disturbed and the undisturbed conditions. By mimicking the open structure of the natural forests, the vegetation of the disturbed seismic lines is responding to the general conditions of the area in which these plots are located rather than the specific conditions of the cut line. Maintaining gap sizes that reflect the natural conditions can expedite the floristic recovery processes although with the slow growth rate of the dominant species; seismic lines in this area will be evident on the landscape for many decades.

The three plots that represent the **Vaccinium-Epilobium Community Type (8)** have been disturbed. The very weak presence of pioneering species, Balsam Poplar (*Populus balsamifera*) and Alder (*Alnus crispa*) reflect this history of disturbance while the occurrence of Subalpine Fir (*Abies lasiocarpa*) suggest a level of recovery as this is a species of more mature forests. As with the Vaccinium Community Type, the gaps in this upper elevation community allow the seismic line to mimic natural conditions in the adjacent communities.

The **Epilobium Community Type (9)** is composed of a mix of disturbed and undisturbed plots. Plot 8006 is on a seismic line that is covered with Bluejoint Reedgrass (*Calamagrostis canadensis*) and is related to the disturbance community, the Trifolium-Calamagrostis Community Type. The undisturbed plots in this community have a relatively high cover of Alder (*Alnus crispa*) reflecting the fire-disturbance history associated with the forests in this region. The other disturbed site, plot 8009, is an open well site high in the mountains with no tree cover, but lots of species; 35 species vs. 10, 12 and 15 for the other plots. It may be that the occurrence of a broad number of species in plot 8009 reflects both the disturbed conditions of the well site and the open nature of the high elevation adjacent vegetation.

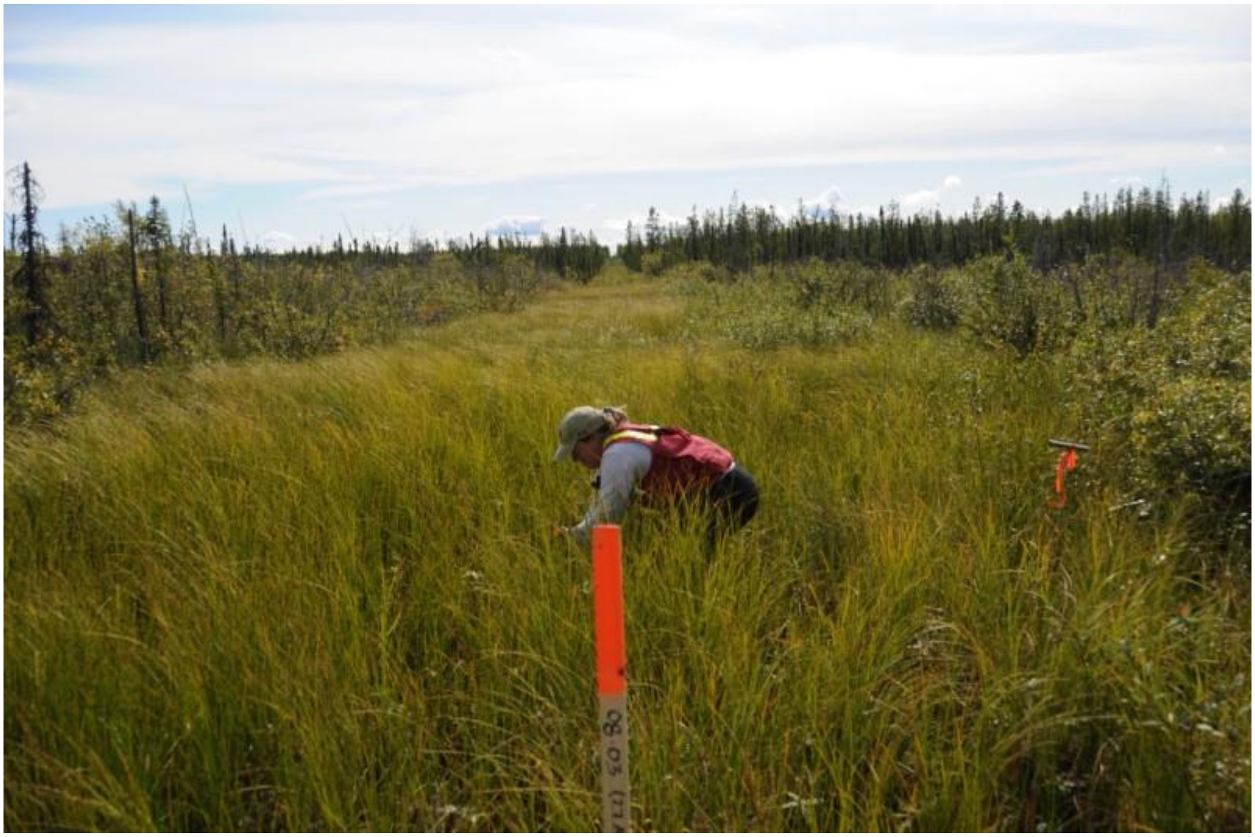
The **Trifolium-Calamagrostis Community Type (10)** is a disturbance community. The continued strong presence of the agronomic species, Alsike Clover (*Trifolium hybridum*), Creeping Red Fescue (*Festuca rubra*) and Timothy (*Phleum pratense*) as well as the weak presence of the weedy species, Slender Hawkweed (*Hieraceum gracile*) reflect the reclamation efforts on old well sites and camp areas. Seeding these sites has restricted the floristic recovery of these locations over that which would have occurred if the surface soils on these sites had been left in a rough and loose condition and the native pioneering species had been allowed to seed in naturally. It is instructive to recognize the recovery problems that are associated with this community and the agronomic species that inhabit it.

The ungrouped **Community Type (11)** is not associated with any species-relevé groups. Four of the seven plots that comprise this type are on undisturbed sites while two of the others are on seismic lines in species poor Water Sedge (*Carex aquatilis*) meadows (8003 and 8026) and the third (8009A well) is at a high elevation well site. The undisturbed plots are located at relatively high elevations with restricted species compositions.

3.2 FOREST RECOVERY PATTERNS

Recovery of forest ecosystems on seismic lines and other disturbances depends on the location of the disturbance relative to adjacent ecosystems and the severity of the disturbance. In forested ecosystems, seismic lines that have been cut to the mineral soil are colonized by pioneering species such as members of the Epilobium species-relevé group. The **Cornus-Epilobium-Betula Community Type (2)** shows a dominance of alder (*Alnus crispa*) while the **Cornus-Epilobium-Betula-Calamagrostis Community Type (3)** has the pioneering balsam poplar (*Populus balsamifera*) as a dominant species. In both cases on disturbed areas, conifers are coming in underneath suggesting that recovery of the forests is only a matter of time. The floristic similarity between the disturbed seismic lines and the undisturbed forest plots is confirmed in the forest plots. The undisturbed adjacent plots show a variety of different forest types, including some productive forests at lower elevations on the river floodplains.

Forest recovery at upper elevations and in areas of organic soils is slower and may, in some cases be derailed due to the disturbance associated with the seismic line such as those found in the **Vaccinium Community Type (7)**. Seismic lines tend to move successional progression back so that in situations where lines have been cut across peatland areas, removal of the surface materials tends to set succession back to a stage before trees could establish. Plot 08-03 and 08-03A are excellent cases in point. In Plot 08-03 (Photograph 3.2-1) the organic surface materials were removed (a 2 m wide berm was noted beside this line) and the line can no longer support tree growth while in Plot 08-03A, although flooding caused by a beaver dam has killed the larger trees, new seedlings are establishing on the mossy hummocks indicating that the site conditions are appropriate for tree growth. When the mossy hummocks are removed as is the case with the 08-03 line, this opportunity for tree growth is lost. It will be many decades if not centuries before the organic matter builds to the point where the seismic line can again support trees.



Photograph 3.2-1. Plot 08-03 is classed as belonging to Community Type 11 as it is a species poor sedge meadow. Flooding caused by a beaver dam has killed the mature black spruce in the surrounding undisturbed area. Seismic line construction removed organic surface materials setting succession back to a watery sedge meadow stage.

At higher elevations such as in the **Vaccinium Community Type (7)** the open nature of the natural undisturbed forests is similar to the open nature of the seismic line. Where soils have not been drastically disturbed, recovery of the open forest is contingent on the slow growth rate of the trees. Although the seismic lines through these areas show up distinctly in the distance as they pass through forests of larger trees, where the forests consist of younger, open stands (Photograph 3.2-2) the cut lines are difficult to identify on the ground. Floristically these sites are similar to the surrounding undisturbed areas as shown by the classification of Plots 08-08 and 08-08A, 08-27 and 08-27A as well as 08-28 and 08-28A within the same community type (7). In some cases (Plot 08-08), minor scuffs of the bryophyte layer during seismic operations may contribute to the successful establishment of forest seedlings.

Photograph 3.2-2. The open nature of upper elevation forests allow seismic lines in these areas to recover with limited traces on the ground. The line through the forests in the distance is clearly evident while in the upper elevation area of Plot 08-28 shown here the line is hard to find.

Recovery of forests on seismic lines is constrained by the slow growth of forest trees. However, where the lines cross areas of reasonable forest growth, re-establishment of trees is relatively rapid. Visually, the lines remain evident on the landscape for many years although as discussed above the floristic recovery is relatively rapid. Where pioneering species such as balsam poplar and alder have established on seismic lines that have been cut at lower elevations into the mineral soil, conifers move in and soon re-establish a conifer forest (Photograph 3.2-3).

Photograph 3.2-3. This stand of aspen and balsam poplar (Plot 08-23) has developed on an old airstrip (see inset) next to the La Biche River. Spruce trees are moving in under the deciduous cover and will eventually replace the deciduous species.

3.3 SOILS RECOVERY PATTERNS

The recovery of soil systems that have been disturbed through seismic and other activities is very slow. The soils at the site (Plot 08-23) shown in Photograph 3.2-3 consist of a 7 to 8 cm layer of organic leaf litter over a 10 cm layer of silty clay which is over a 10 cm layer of compacted silty clay. The compacted silty clay remains from the use of the area as an airstrip while the organic matter and upper 10 cm of mineral soil represent the soil development since the airstrip was abandoned more than 40 years ago. This site is classed as belonging to the **Cornus-Epilobium-Betula-Calamagrostis Community Type (3)**, a disturbance related community. The soils in other plots classified in this community show a similar pattern. Where the soils have been significantly disturbed during construction of the seismic line or other disturbance, the vegetation reflects these disturbances. Establishment of pioneering vegetation covers on these sites helps to restore the soils of the area but soil forming processes are slow.

Areas where the soils have not been significantly disturbed such as on the seismic lines in the **Cornus-Epilobium-Betula Community Type (2)** show very similar soils to the controls that have not been disturbed. In these cases the soils may show little evidence of disturbance while the vegetation may be floristically recovered, but the forest structure has yet to re-establish. Photograph 3.3-1 shows that the Plot 08-10 line is still clearly visible after at least 58 years (age from counting rings on a tree disk) although the soils show little evidence of any disturbance. The similarity in size, not shape of forest gaps in the undisturbed forests to the gap provided by the seismic line is probably responsible for the similarity in the floristics.

Photograph 3.3-1. The soils along this seismic line (Plot 08-10) were not significantly disturbed and although the line is still clearly visible, the floristics and soils show no difference compared to the undisturbed plot (08-10A inset).

Upper elevation sites where soils have not been disturbed significantly can be very difficult to see (Photograph 3.2-2) on the ground although these sites may be visible from the air (Photograph 3.3-2). In some cases the soils on the lines have been compressed compared to the control located off the line while in other cases, the organic matter does not appear to have been compressed. Where little or no floristic differences have been noted such as in the **Vaccinium Community Type (7)** the soils tend to be similar both on and off the lines. However where the floristic composition has changed dramatically from the pre-disturbance vegetation cover as represented by the control plots such as in the **Cornus-Epilobium-Betula-Calamagrostis Community Type (3)** the soils are drastically different on and off the line. It is not surprising that the sites with drastically different soils also show substantially different vegetation covers. Vegetation reflects the conditions of the site in which it grows so the sites where the soils are altered will also have changed vegetation. Over time as the soils recover, the vegetation will recover. Similarly, as the vegetation recovers, the vegetation will create appropriate soils.

Photograph 3.3-2. The soils at the seismic line shown in this photograph (Plot 08-27) do not differ substantially from those found at the control site adjacent to this line (Plot 08-27A) although the duff layer on the line was compressed compared to the control.

3.4 ECOSYSTEM RECOVERY PATTERNS

Recovery of seismic lines in the South East Yukon is enhanced by the routine disturbances associated with fires in the natural forests. Even some of the older White Spruce stands in this area have a component of Aspen or Balsam Poplar reflecting this history of repeated disturbances. Where seismic lines are located in these frequently disturbed natural forests, floristic recovery is enhanced. At higher elevations, where the size of the seismic line mimics the opening sizes in the surrounding forests, floristic recovery can proceed although the trees will take many years to fill in the linear gap created by the seismic line. Sites that have been seeded with agronomic species continue to reflect this legacy of past reclamation practices. In the future, seeding with agronomic grasses and legumes, even on large well sites, should be avoided in favour of creating a rough and loose ground surface and covering with the coarse woody debris generated from the vegetation that was cleared to build the site initially. This will encourage recovery of these sites while seeding them, even with native species if such were available, would slow the recovery process.

4.0 CONCLUSIONS

The study of seismic line recovery provides an understanding of how recovery processes proceed and the conditions that foster floristic recovery. Since structural recovery requires time for forests to re-grow, this is not a good measure of ability of a site to recover. Floristic similarity between disturbed and undisturbed sites indicates a level of recovery that establishes the appropriate successional trajectory for full site recovery. Conditions that would expedite recovery and might be included as best management practices are:

1. Avoid seeding sites with grasses and legumes as these will reduce the recovery of the disturbed site; and

2. Avoiding disturbance of the upper soil layers by only cutting lines in the winter when the soil is solidly frozen;

3. Leave roots and stumps in place if possible as many of the pioneering species (willows, poplar and aspen) will re-sprout readily from cut stumps;

4. Maintain seismic line widths that are similar to the size of openings in the natural forests adjacent to the line if at all possible;

5. Where sites are large such as drill sites and camp areas and creation of a large flat platform requires significant soil disturbance, leave the soil surface in a rough and loose condition, break up compaction and scatter woody debris that had been removed in site construction.

Seismic lines in the South East Yukon and adjacent NWT have not reacted to the severe disturbance in the same way as North Yukon seismic lines. Where a severe disturbance on the North Yukon lines could significantly change the successional trajectory from for instance a black spruce bog to a linear open water channel, severe disturbances in the South East Yukon were quickly colonized by the many pioneering species that make up the general vegetation in this area. It is believed that this is because of the regular natural burning of these ecosystems and the generally less hostile environment for plant growth. In the North Yukon, minimizing disturbance or fire is the key to recovery while in the South East Yukon, even significantly disturbed sites recover quickly, at least from a floristic perspective. With the abundance of pioneering species in the natural ecosystems of the region, seeding with agronomic grasses and legumes slows the recovery process and as noted above, should be avoided.

Forest recovery patterns follow the vegetation patterns. However, because trees tend to take many years to re-grow, the visual impacts of seismic lines will remain on the landscape for many years. Where seismic lines and other sites have been disturbed to the point that pioneering species of willows, poplars and alder establish on the line, conifers can often be found growing under the canopy of the pioneers. As this is the natural successional pattern that operates in the region and because there are a heterogeneity of successional stages in the vegetation due to the fire history of the region, the recovery of forests on seismic lines follows a ecologically familiar pattern.

Soils show the greatest sensitivity to impacts and one that will probably last for the longest time on the landscape. Where soils have been drastically disturbed such as on old airstrips, well sites or camp areas, the impact will be evident in the soils for many years. Although the vegetation may re-establish relatively quickly, the soils will remain in a non-natural state for a long time.
In the case of areas where seismic lines and the surrounding vegetation have burned, the seismic line may disappear from the landscape from a vegetation and forest perspective while the soils may continue to show the signs of the former line for many years. However, where soils have not been significantly disturbed such as on winter lines where there was no scraping of the soil, the recovery of the soils is very rapid and there may be no signs from a soils perspective that the line ever existed. The rate of recovery of seismic lines and other industrial disturbances is dependent on the level of disturbance that was created in the first place.

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