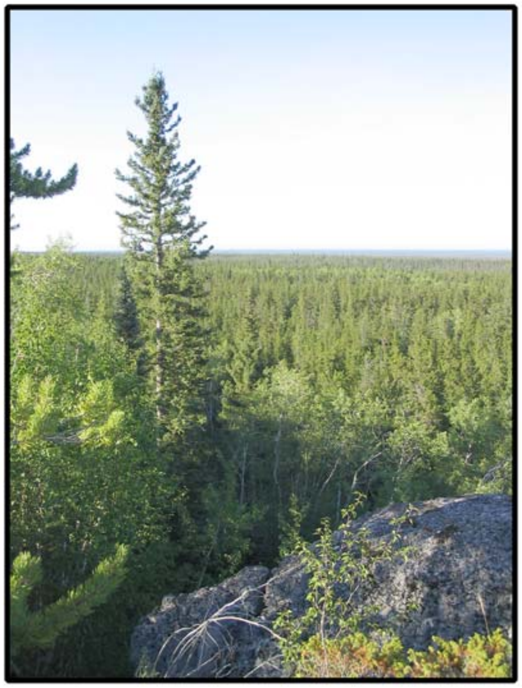
2004 Northwest Territories Forest Ecosystem Classification Pilot Project

Final Report





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EcoDynamics Consulting Group International Inc.

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1.0 INTRODUCTION

1.1 Project Background and Scope

The Department of Resources, Wildlife and Economic Development (RWED), of the Government of the Northwest Territories, has recently embarked on the development of a *Forest Ecosystem Classification* (FEC) system and field guide for use in sustainable forest management and environmental assessment. The FEC system will be based on the analysis of site, soil, and vegetation data from detailed ecological plots distributed across the Taiga Plain Ecozone of the Northwest Territories, together with existing data from ecologically equivalent areas in neighboring jurisdictions (i.e., British Columbia, Alberta, Yukon and Saskatchewan).

The purpose of FEC is to:

- Further the understanding of NWT forest ecosystem processes;
- Provide a consistent ecological framework for making forest management decisions and predicting impacts on forest ecosystems; and
- Provide a common ecological language for communication among forest users and managers.

In the summer of 2004, EcoDynamics Consulting Group International Inc. was contracted by RWED to establish fifty detailed ecological plots in the Hay River Lowland Ecoregion as a pilot project for the FEC program.

The scope of the pilot project was to:

1. Establish fifty (50) 10m x 10m ($100m^2$) ecological plots at predetermined locations in the Hay River Lowlands Ecoregion of the Taiga Plain Ecozone;
2. Collect site, soil, vegetation, and forest mensuration data at each plot according to the *Ecological Land Survey Site Description Manual – 2nd Edition* (Alberta Sustainable Resource Development, 2003) and the *NWT Inventory Field Sampling Manual – Version 2.0* (Forest Management Division, Resources Wildlife & Economic Development, 2004);
3. Classify each plot to Ecosite, Ecosite Phase, and Plant Community level using the *Field Guide to the Ecosites of Northern Alberta* (Beckingham and Archibald, 1996a) to test the guide's applicability to the Northwest Territories; and
4. Prepare a project report summarizing the results of the pilot project and making recommendations for future FEC sampling.

This final report presents the results of the pilot project and recommendations for future FEC survey work.

1.2 Study Area Locations and Description

The fifty pilot project FEC plots are located in the Hay River Lowlands Ecoregion of the Taiga Plain Ecozone in the Northwest Territories (Figure 1).

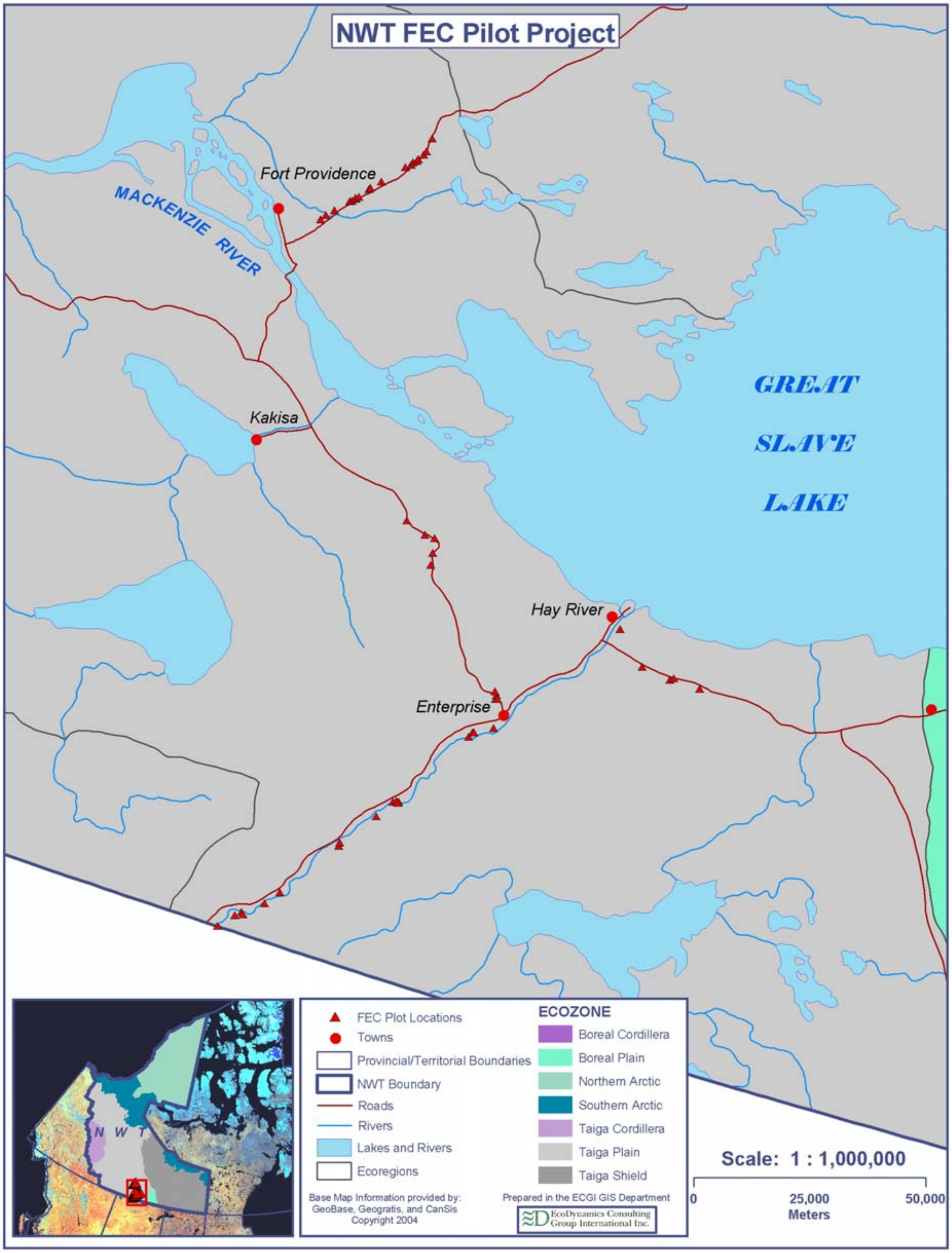
The Hay River Lowlands Ecoregion consists of a broad, level lowland plain, most of which lies within the Northwest Territories. Small portions extend into northeastern British Columbia and northwestern Alberta. Regional drainage is via the Fort Nelson, Liard, and Hay Rivers, which all ultimately flow into the Mackenzie River.

The ecoregion is classified as having a subhumid mid-boreal ecoclimate, marked by short, warm summers and long, cold winters. The mean annual temperature is approximately -2.5°C. The mean summer temperature is 13°C and the mean winter temperature is -19°C. The mean annual precipitation ranges 350-450 mm.

The area is underlain by flat-lying Palaeozoic limestones and dolomites near Great Slave Lake, and Cretaceous shale towards its western flank. The Paleozoic bedrock is spectacularly exposed as numerous waterfalls and cliffs along major rivers, and as steep, wave-cut escarpments along the south shore of Great Slave Lake. The sedimentary bedrock is in turn covered by a mixture of glacial and recent deposits. Glacial materials consist mainly of calcareous, clayey glaciolacustrine and glacial till deposits, with nearly level to gently rolling topography. In many locations the till deposits have been washed or eroded by Glacial Lake McConnel (Lemmen, 1990). This glacial lake also produced a series of gravelly raised beach ridges along the southern shores of Great Slave Lake. Glaciofluvial deposits are relatively rare. Sporadic discontinuous permafrost with low ice content is associated mainly with organic deposits. Upland soils consist largely of Gray Luvisols and Eutric Brunisols. Cumulic Regosols predominate in the silty alluvial sediments along river channels. Lowland soils are dominated by peaty phase Gleysols, Organics, and Organic Cryosols.

The well-drained upland forests of this Ecoregion are typically closed mixedwood, with various combinations of coniferous (white spruce, black spruce, jack pine, balsam fir) and deciduous (trembling aspen, balsam poplar and birch) tree species. Deciduous and mixed conifer-deciduous forests are richer is understorey shrubs and herbs, while coniferous forests tend to encourage a moss-dominated understorey. Poorly drained tamarack and black spruce peatlands cover about 30% of the ecoregion.

Figure 1. Plot location map.



2.0 Pilot Project Methodology

2.1 Field Sampling Approach

A variety of forest stand types were targeted for FEC sampling, representing a range of moisture and nutrient regimes. Each stand was pre-selected by RWED staff and was plotted on forest inventory maps and accompanying air photos. A field reconnaissance was then conducted to ensure suitability of the candidate stands (i.e., relatively undisturbed, healthy, and at least 40 years old). Most targeted stands (38) were within 100 m of major NWT highways. The remaining stands were mostly within 750m of the highway. The prior reconnaissance and focus on accessibility were designed to maximize plot the rate-of-progress and cost-effectiveness of plot establishment.

2.2 Field Data Collection and Reporting

Field sampling was conducted between August 9 and 18, 2004, by a three-person field team consisting of a botanist, a forester, and a pedologist (soil specialist). Prior to the start of the fieldwork, the team met with RWED staff in Hay River for a review of the project scope and to obtain marked copies of the inventory maps and air photos, along with geographic coordinates for each proposed plot location.

Once the field team arrived to the closest stand access point along the highway, a Garmin 12XL GPS unit was used to navigate to the pre-selected plot position. Once the team arrived at the preset location, the forest overstorey composition was compared with the targeted type. If the site was disturbed (i.e., evidence of recent harvesting or fire, extensive windthrow, severe insect, or disease damage) or did not match the targeted type the team proceeded in a cardinal compass direction at 25m intervals until out of the disturbance or an overstorey match was found. Obvious ecotones were deliberately avoided, with all plots being at least 30m from a polygon or stand boundary. This overall approach was designed to be consistent with the ecological sampling method advocated by Mueller-Dumbois and Ellenburg (1974) – 'subjective without pre-conceived bias'.

Once at the pre-selected plot position, a metal pigtail pin was placed to mark the NW corner of the plot. From this point, a 60m tape was used to establish a 10m x 10m plot along north-south and east-west axes, such that each side faced a cardinal direction. Only the NW corner and plot center pins were left in place as permanent markers.

Site, soil and vegetation data was collected at each plot using the procedures and field forms found in *Ecological Land Survey Site Description Manual – 2nd Edition* (Alberta Sustainable Resource Development, 2003). A soil pit was excavated to approximately 1m at a representative location outside of the plot for soil description and classification. Voucher specimens of unknown specimens were collected for later identification.

All forest mensuration data was collected in a manner consistent with the *NWT Inventory Field Sampling Manual – Version 2.0* (Forest Management Division, Resources Wildlife & Economic Development, 2004). Total height, dbh (diameter, breast height) and age at breast height (1.3 m) was measured on a minimum of three (3) healthy, representative trees from the co-dominant height class. In stands where more than one species made up the co-dominant crown, two sample trees of each species were measured. In stands that also had a dominant and/or intermediate crown class, an additional sample tree was measured from each of these crown classes. An inventory field call was also made describing stand structure, crown closure, and species composition.

Representative digital photographs of the overstorey and understorey vegetation, and the soil profile, were taken at each plot for future reference and for inclusion in the planned field guide. A panoramic digital video was also recorded from plot center.

Before leaving the site, the GPS coordinates of plot centre were recorded using a Trimble GeoExplorer 3 GPS Unit. Generally, these uncorrected coordinates may be considered to be accurate to within 10 m.

After data collection, each plot was given a provisional classification to the Ecosite, Ecosite Phase, and Plant Community levels using the Boreal Mixedwood and/or Boreal Highland Sections of the *Field Guide to the Ecosites of Northern Alberta* (Beckingham and Archibald, 1996a). At each level of classification (Ecosite, Ecosite Phase, and Plant Community), a rating (good, fair, poor, or no fit) was applied to indicate how well the plot fit the classification. Table 1 describes the rating criteria, which are partially based on Alberta Environmental Protection (1996).

The vascular plant scientific nomenclature used in this report follows Porsild and Cody (1980), except for the genus *Salix*, which follows Argus (2001 onwards). Lichen nomenclature follows Brodo et al. (2001), and bryophyte nomenclature follows the W3MOST database (Missouri Botanical Garden, 2004). A more detailed description of taxonomic recommendations is provided in Appendix B.

Table 1. Ecosite classification "fit" ratings.

Rating	Criteria
Good (G)	Most or all dominant/abundant species present, including most indicator species. (after Alberta Environmental Protection, 1996).
Fair (F)	Many dominant/abundant species present, including selected indicator species.
Poor (P)	Some dominant/abundant species present, with almost no indicator species present.
No Fit (N)	Few to no dominant/abundant species present, and no indicator species present.

A brief literature review was also conducted in order to place the pilot project data within a preliminary ecological context and to assist in making informed recommendations for future FEC sampling.

3.0 Results and Discussion

3.1 Provisional Ecosite Calls

Provisional classifications of each plot to the Ecosite, Ecosite Phase, and Plant Community phase using the *Field Guide to the Ecosites of Northern Alberta* (Beckingham and Archibald, 1996a) are presented in Table 2. For plots that did not fit the Boreal Mixedwood (BM) section well, a further attempt was made using the Subarctic (SB) and Canadian Shield (CS) sections of the guide. It is possible that after the pilot project data is analyzed in a database environment, the fit of the plots to the Northern Alberta guide may be refined further. Several observations were made:

- In general, provisional classification of the pilot project plot using the *Field Guide to the Ecosites of Northern Alberta* (Beckingham and Archibald, 1996a) produced generally unsatisfactory results, probably related to the steep climate gradients evident in the NWT (Dr. Rob Wright, pers. comm.). The goodness of fit became poor relatively quickly as the plots progress north. In some cases, the SB and CS sections fit better, possibly reflecting the beginning of the transition from boreal to sub-arctic climates in the study area. However, few plots fit well into the ecosites defined in the Alberta guide.

- While 177 species of plants were observed (Appendix D), several indicator species needed for keying in the Northern Alberta guide were not observed or rarely encountered in the plot data, including:
    - *Prunus virginiana*, *Aralia nudicaulis*, *Corylus cornuta* (not observed).
    - *Vaccinium myrtilloides* (uncommon, possibly due to the high base status of most soils, since it is acidophilic);
    - *Viburnum edule* (not observed north of Enterprise);
    - *Maianthemum canadense* (very rarely encountered); and
    - *Ledum groenlandicum* (found only in poorest/wettest regimes).

- Several species may have potential as indicator species:
    - *Tofieldia glutinosa* may be a good indicator of seepage. Plot #25 occurred along a beach ridge with apparently strong seepage, and a lot of short-range variability in the soils and vegetation. More transect work is needed along beach ridges and regions with shallow soils to capture this variability.
    - *Juniperus communis* may be a good indicator for gravelly or stony sites, especially in shallow soils over bedrock.
    - *Antennaria* appears to be invading wetland sites that are drying out. For example, at plot #49, it appears that *Antennaria* is moving onto the drier hummocks of this former permafrost site (has a "drunken forest" structure).

- Several plots, such as #8 and 9, possibly had poor fit due to their location in riparian areas. Ecosite guides are usually restricted in their coverage of ecotones, as such areas are usually avoided during plot sampling. Roads may also introduce 'artificial' ecotones, which have the potential to introduce noise into the data.

Table 2. Preliminary Ecosite classifications for the 2004 FEC plots.

Notes: The first letter in the three-letter goodness of fit code, in Table 1 represents the fit for the ecosite level; the second, the ecophase level; and the third, the plant community level.

Plot	Ecosite BM	Fit	Ecosite SB or CS	Fit
1	f1.1 Pb-Aw/horsetail	GGG		
2	d3.3 Sw/low-bush cranberry	FFF	SB - b4.1 Sw/feather moss	FFF
3	d2.5 Aw-Sw/rose	FFG	SB - b3.1 Aw-Sw-Sb/Canada buffalo-berry	GGG
4	d2.1 Aw-Sw/Canada buffalo-berry	GGG		
5	i1.1 Sb/Labrador tea/cloudberry/peat moss	GGG		
6	d3.5 Sw/feathermoss	PPP		
7	d1.6 Aw/rose	GGG		
8	d2.1 Aw-Sw/Canada buffalo-berry	GGF		
9	d2.1 Aw-Sw/Canada buffalo-berry	GFF	SB - b3.1 Aw-Sw-Sb/Canada buffalo-berry	FFF
10	d2.1 Aw-Sw/Canada buffalo-berry	GGG		
11	d1.1 Aw/Canada buffalo-berry	GGG		
12	d1.6 Aw/rose	GGF		
13	d2.5 Aw-Sw/rose	GGF		
14	b1.1 Pj-Aw/blueberry-bearberry	FFF		
15	j1.1 Sb-Lt/dwarf birch/sedge/peat moss	PPP	SB - 1.1 Sb-Lt/Labrador tea-dwarf birch/sedge/peat moss	PPP
16	b1.1 Pj-Aw/blueberry-bearberry	FFP		
17	d2.1 Aw-Sw/Canada buffalo-berry	GGF		
18	d2.5 Aw-Sw/rose	FFF		
19	j1.1 Sb-Lt/dwarf birch/sedge/peat moss	PNN	SB - g1.1 Sb-Lt/Labrador tea-dwarf birch/sedge/peat moss	
20	d1.3 Aw/beaked hazelnut	FFF		
21	c1 Labrador tea-mesic Pj-Sb	PPP		
22	d1.7 Aw/beaked willow or d1.8 Aw/forb	PPP		
23	b1 blueberry Pj-Aw	PNN	SB - b3.3 Aw-Sw-Sb/feather moss	FFN
24	i1.1 Sb/Labrador tea/cloudberry/peat moss	GGG		
25	g1.2 Sb-Pj/feather moss	PPP		
26	c1.3 Pj-Sb/feather moss	PPP		
27	b1.2 Pj-Aw/blueberry-green alder	PPP	CS -similar to b1.2 Pj-Aw-Bw/Canada buffaloberry	
28	b1.1 Pj-Aw/blueberry-bearberry	PPP		
29	b1.3 Pj-Aw/blueberry-Labrador tea	PPN	SB - b4 Canada buffalo-berry Sw	PPN
30	NO FIT	NNN		
31	b1.1 Pj-Aw/blueberry-bearberry	PPP		
32	b3 blueberry Aw-Sw	PPN		
33	b3 blueberry Aw-Sw	PNN		
34	d1.1 Aw/Canada buffalo-berry	PPG	SB - b3.1 Aw-Sw-Sb/Canada buffalo-berry	FPP
35	d2.1 Aw-Sw/Canada buffalo-berry	PPP	SB - b3.1 Aw-Sw-Sb/Canada buffalo-berry	FPP
36	b3.2 Aw-Sw/blueberry-green alder	PPN		
37	d2.1 Aw-Sw/Canada buffalo-berry	PPF	SB - b3 Canada buffalo-berry Aw-Sw-Sb	FPP
38	d2.6 Aw-Sw/beaked willow	PPP		
39	d low-bush cranberry	PNN		
40	d low-bush cranberry	PNN	SB - b3 Canada buffalo-berry Aw-Sw-Sb	PPN
41	b4 blueberry Sw-Pj	PPN		
42	d2.1 Aw-Sw/Canada buffalo-berry	PPP	SB - b3.1 Aw-Sw-Sb/Canada buffalo-berry	PPP
43	d2.6 Aw-Sw/beaked willow	PPF		
44	NO FIT	NNN	NO FIT	NNN
45	NO FIT	NNN		

46	d2.6 Aw-Sw/beaked willow	PPP		
47	h1 Labrador tea/horsetail Sw-Sb	PPN		
48	NO FIT	NNN		
49	g1 Labrador tea-subhygric Sb-Pj	PPN		
50	a1 lichen Pj	PPN		

3.2 Apparent Environmental Gradients

Timoney et al. (1993) conducted ordination, classification, and statistical analysis of vegetation and site data from the subarctic forest-tundra transition, which revealed that plant species occurrence and community composition were strongly correlated with soil pH, moisture, texture and latitude. Base-rich, loamy soils derived from Paleozoic bedrock show greater species richness and the favouring of calciphiles, compared to Shield-derived soils. A parallel paper by Timoney et al. (1992) present significant findings illustrating how some environmental variables, such as soil base status and regional slope, compensate for the synoptic climate gradient. While these gradients are discussed in the context of the subarctic forest-tundra transition, some of these same gradients were evident in the study area.

Based on the 2004 field observations and preliminary ecosite classification, the study area vegetation appears to be strongly influenced by some of the same gradients reported by Timoney et al. (1992 and 1993), particularly calcareousness and depth to carbonates (*chemogradient*).

Strongly calcareous parent materials were common in the study area, producing shallow solum depths (commonly less than 30 cm), with a corresponding shallow depth to carbonates. Interestingly, effective rooting depth is often coincident with the depth to carbonates, possibly indicating a vegetation response. Depth to carbonates has been found to be an important factor in the growth of conifers (Kishchuk, 2000).

Many common plant species from the more northern sections of the study area are normally associated with different base statuses in the soil (e.g., *Arctostaphylos rubra*, *Hedysarum alpinum* in moderately calcareous sites; *Dryas integrifolia* in extremely calcareous sites), which is consistent with the findings of Timony et al. (1992). The higher base status may also account for the limited observation of certain acid-loving ericaceous species, otherwise common in the Boreal Forest, such as blueberry (*Vaccinium myrtilloides*) and Labrador Tea (*Ledum groenlandicum*). The observed lower lichen covers were also consistent with calcium-rich soils.

Landform or topographic gradient (*topogradient*) is also a key environmental variable affecting forest ecosystems in the study area, as would generally be expected. While level and gently undulating landscapes are predominant, this gentle topographic gradient is periodically broken by abrupt changes in the environmental gradient due to changes in local landform. These steep topographic gradients are most evident along the beach ridges and steep, wave-cut escarpments, which frequent the south shore of Great Slave Lake, as well as in proximity to the spectacular waterfalls and cliffs common along major rivers. Hillside seepage was apparent at several plots along the beach ridges. Seepage areas were also observed on riverine slopes near waterfalls at several Territorial Parks in the study area. In both cases the seepage appeared to be associated with the glacial till/bedrock contact.

It should also be recognized that a significant portion of the plots established between the Alberta border and Hay River, lie within the riparian zone of the Hay River itself. These plots along with any future plots within riparian zones, should be stratified into a distinct plot group prior to data analysis. Riparian forests typically reflect a unique microclimate, which may compensate for the regional climate gradient.

Suspected permafrost was observed during the pilot project (e.g., plot #49) and could be considered an indicator of the regional climate gradient.

There has been a notable impact by intensified buffalo grazing in the plots along the highway (plots #32-39). Grazing appears to have thinned the understorey and compacted the soil in some locations. Overall, these plots likely represent a maximum for buffalo-related disturbance in this area. Plot #39 (Figure 2) was especially impacted: the soil is compacted, the vegetation is thin, there are broken trees, and woody debris is increased in the area. In fact, the whole area smelled like a pasture. Future FEC plots may need to be put farther away from concentrations of buffalo to prevent such high disturbance from impacting data analysis. The buffalo also appear to be a vector for increasing the presence of certain weedy species in the forest, including *Taraxacum officinale*.

Figure 2. Plot #39. Left: an apparently grazed understorey. Right: A small white spruce from plot that was found snapped off at the base.

A more thorough literature review may reveal more details on the differences between Northern Alberta and the study area in terms of environmental gradients. The obvious influence of arctic gradients, make the study area increasingly dissimilar to the region covered by *Field Guide to Ecosites of Northern Alberta* the farther one moves away from the Northwest Territories-Alberta border. For this reason, the applicability of this field guide is limited to only the extreme southern portion of the Hay River Lowlands Ecoregion.

Future FEC surveys should be restricted to the period July 1st to August 15th to minimize variance in species presence and abundance data due to differences in the emergence and senescence of various plant species.

3.3 Utility of the Manual and Field Forms

The procedures and field forms found in the *Ecological Land Survey Site Description Manual – 2nd Edition* (Alberta Sustainable Resource Development, 2003) were generally applicable to the data collection needs of the FEC pilot project. However, given the broad target audience of the manual, not necessarily every parameter listed in the field forms is relevant to the needs of the NWT FEC project.

Appendix C discusses specific issues regarding the field form and the collection of specific ecological parameters

4.0 FUTURE SAMPLING AND ANALYSIS CONSIDERATIONS

4.1 Introduction

The pilot project results obviously provide some insights for developing a comprehensive sampling design in advance of the main data collection program. It is also an opportunity to clarify the project purpose and scope. What are the end products and how will they be used? What science and past experience can the project draw on for the field sampling design and for subsequent data analysis? How do we ensure costs-effectiveness, efficiency, and scientific credibility?

Answers to these and other important questions help to refine the sampling and analysis approach used, allowing effort to be focused on ecological factors of greatest importance.

4.2 Overview of Ecosystem Sampling and Classification Approaches

> *"A classification system is of limited operational use if ecosystems cannot be allocated to classes quickly in the field using a few easily identified diagnostic features. Ultimately there should be sufficient classes to characterize the wide range of conditions that prevail…yet few enough to keep the classification relatively simple and the number of resulting management options reasonable." (Sims et al., 1997).*

Most ecological site classifications in Canada, present some form of integrated vegetation/soil taxonomic units, derived from a multivariate statistical analysis of ecological plot data. Most of the science and analytical techniques underlying these classifications originate from the integration of the *community* and *continuum* concepts of vegetation ecology, the classification and ordination methods of mathematical ecology, and the mapping traditions of geography and soil science (Ponomarenko and Alvo, 2001).

Fortunately, there is a substantial body of ecological classification knowledge and experience to draw from. An excellent starting point is a review of the science behind ecological classification and its history presented in *Perspectives on Developing a Canadian Classification of Ecological Communities* (Ponomarenko and Alvo, 2001). A paper by Barnes (1986) also presents a discussion of various forest classification systems and emphasizes the distinction made by Rowe (1984) between taxonomic and cartographic approaches to ecological classification. There are also published reviews of specific site classification projects in other parts of Canada. Sims and Uhlig (1992) and Sims et al. (1986) provide excellent discussions about the development of Forest Ecosystem Classification in Ontario, as well as the province's site classification history. Similarly, a paper by Corns and Annas (1986) provides insights into the development of the first ecological site guide in Alberta, which laid the foundation for subsequent guides (e.g., Beckingham and Archibald, 1996a).

The most common approach in western Canada is the "multi-factor *integrated* approach" (Grossman et al., 1998), whereby all major ecological factors (e.g., natural vegetation, soils, and landscape features) are collectively used to define ecological site types (e.g., Beckingham and

Archibald, 1996a; Beckingham and Archibald, 1996b). This type of ecological site classification places more emphasis on grouping vegetation communities with respect to major environmental gradients, with the expectation that they will respond to disturbance or management in a similar manner (Cleland et al., 1994). In this approach the concept of the *edatope* (a matrix or grid of moisture and nutrient regimes) is central to the grouping of similar plots.

An alternative approach is the "multi-factor *component* approach" (Grossman et al., 1998), wherein separate vegetation and soil classifications are developed (e.g., Sims et al., 1997; Zoladeski et al., 1995). The vegetation classifications are primarily based on variations in overstorey and understorey composition. Various combinations of vegetation and soil types are then analyzed to develop operational groups or 'treatment units' for management purposes (Sims et al. 1997; Racey et al., 1989). This more detailed approach focuses on the *plant community* level of classification, and roughly corresponds to the ecoelement level in the Canadian ELC.

The distinction between these two approaches to ecological site classification is important primarily due to cost. Of the two approaches, the component approach (i.e., a V-types and S-types system) is often the most expensive, usually requiring thousands of plots within a given region in order to reliably differentiate individual plant communities (Dr. Rob Wright, pers. comm.). The integrative approach is focused on defining forest ecosystems rather than individual components, thus usually requiring fewer plots (i.e., hundreds vs. thousands).

4.3 Environmental Gradients and Sampling Specifics

4.3.1 Gradient-Based Sampling Approaches

While a given vegetation community may be widely distributed regionally, it should not be assumed that these communities will have identical site characteristics (Grossman et al., 1994). Each may have developed from different combinations of environmental variables and may have different responses to disturbance and management (Grossman et al., 1994). Ecological site classification attempts to identify the links between plant communities and environmental gradients across a given landscape. As such, a gradient-based sampling approach is crucial (Ponomarenko and Alvo, 2001).

Most environmental gradients affecting forest vegetation distributions commonly derive from differences in climate, topography, bedrock geology, surficial geology (soil parent materials), and groundwater regime (e.g., seepage). Additionally, in the NWT, the regional permafrost gradient may also be of significance. Some apparent local gradients observed during the pilot project were previously discussed in section 3.2

The most common gradient-based methodology recommended for ecological sampling is stratified random sampling, both for its statistical validity and the ability to capture the range of ecological variation (Grossman et al., 1994; Dr. Rob Wright, pers. comm.). For example, a nested, stratified random sampling design based on landform and ecoregions was used by Orloci and Stanek (1979) for an ecological classification in the southern Yukon, Canada. The study results showed that these stratifying variables accounted for a statistically significant portion of the regional variation in the ecological dataset. A similar approach was used for development of an ecosite classification system for Saskatchewan, where stratification occurred at the ecoregion, ecodistrict, soil landscape unit, and surficial geology unit levels, to capture both the local and regional environmental gradients (Dr. Rob Wright, pers. comm.). This sampling approach takes advantage of the integrated capture of environmental gradients inherent in ecological land classification maps – this could be described as an *indirect* gradient sampling approach (gradient is implicit).

Grossman et al., (1994) also discuss a variant of the stratified random sampling, called 'gradsect sampling'. The gradsect sampling approach is more *gradient-direct* (gradient is explicit), with transects placed along the strongest regional and local environmental gradients in accessible areas, capturing the greatest range of vegetation/gradient interactions with the least sampling effort (Gillison and Brewer 1985; Austin and Heyligers, 1989). The gradsect method has been proven statistically to capture ecological patterns more efficiently and more cost-effectively than most traditional statistical designs (Gillison and Brewer 1985). Gradsect sampling is particularly applicable when it is not possible to cover all areas of the study area, due to budget and accessibility restrictions (Grossman et al., 1994). Additionally this method builds a stronger understanding of vegetation-environmental relationships and key ecological processes (Grossman et al., 1994), as it offers more direct control of stratifying variables.

Grossman et al. (1994) summarize the general gradsect sampling process, as follows:

1. Key environmental variables are selected based on prior understanding of the principle factors driving the distribution of the vegetation in the study area;
2. Selected variables are broken down into three to five ecologically-relevant classes to produce environmental theme maps;
3. The resulting theme maps are overlaid to generate a 'biophysical' map representing the various combinations of variables and classes, and in turn reflecting the major environmental gradient complexes.

The gradsect methodology may also be further refined to include levels of environmental stratification within each gradsect (Austin and Heyligers, 1989). This modified gradsect approach utilizes a two-stage sampling design: (1) gradsects are selected; (2) further local environmental stratification and replication are performed along each gradsect.

Since, the result is a map similar to an ecological land classification (ELC), one might ask why not just use the existing ELC stratification? The answer is, it depends on the level of detail of ELC itself and the data, which went into its construction, as well as the specific needs of the project. If the existing ecological map base is sufficiently detailed and captures the principal gradients, a standard ELC-based stratified sampling approach may be more applicable. In the absence of a suitable scale of ELC, and if detailed digital datasets at the appropriate scale are available, the gradsect method may theoretically be the best approach.

The gradsect approach is probably worth exploring further, especially with modern GIS software and digital datasets commonly available to facilitate overlay analysis. Some digital inputs that would be required for a GIS-based gradsect sampling design include:

- Climate data (including ecoclimatic zones);
- Bedrock and surficial geology maps (and soil maps where available);
- Vegetation and species distribution maps (e.g., inventory maps and other sources);
- Permafrost zone maps;
- Environmental impact assessment data (e.g., Mackenzie Gas Project EIA);
- Digital Elevation Models (DEMs) (for both regional and local landform and site parameters);

A combined approach may be the most expedient. The study area would first be stratified by ecoregion, ecodistrict, soil landscape unit, and soil map unit or surficial geology units (where available), and within each major stratification, plots could be distributed across all major identifiable gradients (i.e., slope positions, landforms, parent materials, forest cover and wetland types, etc.) to capture as much ecological variation as possible (Ponomarenko and Alvo, 2001)

While sampling will understandably focus on accessible areas, some portion of plots (perhaps 10 to 20%) should be away from road network. Restriction of sampling to road corridors may lead to a biased and unrepresentative samples, as roads tend to follow specific landforms in response to engineering and borrow material requirements. In areas with navigable rivers and lakes, fixed-wing aircraft and/or boat could be used to gain access for plot establishment, thereby reducing dependency on costly helicopters.

4.3.2 Additional Sampling Considerations

Most of Canada has already gone through the process of planning, writing, and publishing various ecosystem classification guides. There are also many experts that have experiences to learn from. Dr. Rob Wright, who is currently finalizing the new Saskatchewan Ecosite guide, was briefly consulted regarding his experience with FEC data collection, management and analysis (Dr. Rob Wright, pers. comm.).
.
Dr. Wright indicated that the effort put into planning and data management is one of the most important factors that will govern the success of the FEC program. More specifically, he emphasized that data management was the most expensive aspect of an FEC project and can be the deciding factor between success and failure. Therefore, the project work plan must clearly indicate how the entire project will be managed, and how data will be collected, stored and analyzed.

Before initiating the main data collection program, selection of data variables and analytical techniques must be finalized. Upon deciding on what analysis will be used and what variables need to be collected, appropriately structured, field-expedient forms should be constructed to allow consistent, easy entry of data. Based on Dr. Wright's experience, some of the most important points to consider in an FEC data collection program, are as follows:

- If data is being collected with a justification of "because we might use it later", then that data does not need to be collected. Minimizing the amount of data collected at each plot will maximize the amount of plots that can be completed.

- The number of teams collecting the data should be minimized and their expertise maximized. Poorly collected data that needs to be cleaned up will delay the project and cost a large amount of money, and will reduce data integrity.

- Considering the substantial cost of field data collection, the focus should be only on those parameters that will be of significance in differentiating ecosites.

Regarding data storage and management specifics, Dr. Wright stressed that analysis of FEC plot data is highly complex, and that it may be necessary to work with a professional programmer to create a database that will facilitate analysis. In Saskatchewan's case, the programmer ensured that the database was robust enough to handle complex statistical analysis, quickly, and with the least delays.

The Saskatchewan data was entered via an automated text recognition system. However, substantial time was wasted repairing the structure of the data that was lost in this process, as the data forms were not sufficiently designed for this process. Ultimately, whether or not the NWT data should be entered by a text recognition system, will depend on a cost-comparison between regular data-entry text-recognition system, including extra resources expended on planning, training, and obtaining.

Dr. Wright also emphasized the need to recognize the steep climate gradient in the NWT, which is expressed by quick changes in synoptic climate over relatively short distances in comparison with other parts of the boreal forest. He recommended that the first version of the FEC guide restrict itself to smaller area (e.g., the Hay River Lowlands), to reduce the impacts of climate variability and make the most of a smaller dataset. Too many extremes in gradient require too many plots to capture in a statistically valid fashion.

The relatively late start in creating an ecosystem classification system for this region has also created an opportunity to take advantage of recent wetland research that was not available during period most existing guides were developed. The prominence of wetlands in this region, as well as adherence to the ecosystem-based forest management paradigm, should require that wetlands be given more priority in these guides. One very important source of information is the Canadian Wetland Classification System (National Wetlands Working Group, 1997). This system is based on environmental gradients (Zoltai and Vitt, 1995) and is designed for use by non-experts. By using the CWCS, the project could be integrated with an international-scale methodology for consistently classifying wetlands. Ultimately, this integration would increase the scientific credibility and utility of the guide.

4.4 Use of Existing Plot Data

If existing data from ecologically equivalent areas in neighboring jurisdictions (i.e., British Columbia, Alberta, Yukon and Saskatchewan) is to be included in the data analysis, this data should be obtained and reviewed prior to finalizing the field sampling plan, to ensure that the core attributes are consistent between the existing and new plot data. Specifically, the existing plot data must (Grossman et al., 1994):

- Be sufficiently recent to reflect present vegetation;
- Be georeferenced to allow revisiting;
- Include species structural and cover data, key environmental and site history information.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- ❖ Provisional classifications of the pilot project plot using the *Field Guide to the Ecosites of Northern Alberta* (Beckingham and Archibald, 1996a) produced generally unsatisfactory results. Few plots fit well into the ecosites defined in the Alberta guide, probably related to the steep climate gradients evident in the NWT (Dr. Rob Wright, pers. comm.).

- ❖ There are obvious differences between Northern Alberta and the study area in terms of environmental gradients, particularly climate. At best, this field guide is limited to the most southern portion of the Hay River Lowlands Ecoregion only.

- ❖ While 177 species of plants were observed, several indicator species needed for keying in the Northern Alberta guide were not observed or rarely encountered in the plot data, including:
  - *Prunus virginiana*, *Aralia nudicaulis*, *Corylus cornuta* (not observed).
  - *Vaccinium myrtilloides* (uncommon, possibly due to the high base status of most soils, since it is acidophilic);
  - *Viburnum edule* (not observed north of Enterprise);
  - *Maianthemum canadense* (very rarely encountered); and
  - *Ledum groenlandicum* (found only in poorest/wettest regimes).

- ❖ The study area is underlain mostly by highly calcareous parent materials, which result in high base status soils, with shallow depth to carbonates. Soil base status is known to produce a strong environmental gradient, directly impacting plant community composition, particularly with regard to the proportions of calciphilic and acidophilic species. Some species present in some of the plots are direct indicators of high base status (e.g., *Arctostaphylos rubra*, *Hedysarum alpinum* in moderately calcareous sites; *Dryas integrifolia* in extremely calcareous sites). The higher base status may also account for the absence or near absence of certain acid-loving ericaceous species and the frequently low lichen covers.

- ❖ While level and gently undulating landscapes are predominant, abrupt changes in the topographic gradient are associated with beach ridges and wave-cut escarpments, and waterfalls and cliffs along major rivers. Hillside seepage is common in these areas, often associated the glacial till/bedrock contact.

- ❖ A significant portion of the plots are within or in proximity to the riparian zone of the Hay River. This may account for the poor fit of some plots during classification with the Alberta guide, as such ecotones are usually avoided during plot sampling.

- ❖ The impact of bison was clearly evident at plots north of Fort Providence (plots #32 to 39), with the soil often compacted and the understorey thinned. The buffalo also appear to be a vector for spreading certain weedy species in the forest (e.g., *Taraxacum* *officinale*). The exact nature of the ecological impacts of Bison are indeterminate at this time.

- Permafrost was observed at several plots, including upland sites.

- The *Ecological Land Survey Site Description Manual* was generally applicable to the needs of the FEC pilot project. However, not necessarily every parameter listed in the field forms is relevant to the needs of the NWT FEC project. A thorough review of procedures is in order.

- Focusing data collection in road accessible areas, and the reconnaissance of target stands prior to sampling, contributed substantially to field crew productivity.

- The pilot project results and related discussion provides substantial insights for planning the main FEC data collection program and subsequent analysis.

5.2 Recommendations

- Dependency on guides from adjacent jurisdictions is not recommended. A NWT-specific guide is needed for ecosystem-based forest management, as well as use in environmental assessment.

- Future sampling should take into account the possible effects of microtopography within the stand. Certain taxa, such as bryophytes and lichens, often have a highly heterogeneous distribution based on microhabitat. This may limit the utility of the data.

- Sampling for the first version of the FEC guide should focus on the Hay River Lowlands, to reduce the impacts of climate variability and make the most of a smaller dataset in a statistically valid manner.

- Before initiating the main data collection program, selection of data variables and analytical techniques must be finalized in light of project goals and objectives. This requires a solid understanding of the environmental gradients driving ecosystem character and distribution.

- Analysis of FEC plot data is highly complex, and requires a very robust and specific database structure to facilitate analysis. Since ecosite classification databases have been developed for similar projects in other provinces (e.g., Saskatchewan Environment), responsible agencies should be contacted to inquire as to whether their existing databases would be available for use by RWED. Given the importance of an effective database structure, a database programmer should be consulted during any modifications to such a database.

- The pilot project data should be entered into provisional database tables to assist in identifying specific database needs and for preliminary analysis.

- Various common sampling approaches should be explored, including the basic stratified random sampling and the more gradient-specific 'gradsect approach'.

- Data collection effort should be focused on ecological parameters of greatest importance to the analysis and future functionality of the future guide. Data should not be collected "because we might use it later". Minimizing the amount of data collected at each plot to that which is essential, will maximize the amount of plots that can be completed.

- The number of field teams collecting the data should be minimized and their expertise maximized. Poorly collected data that requires excessive clean-up will add additional costs and delays to the project, and may put data integrity into question.

- Field-expedient forms need to be constructed to allow accurate and consistent entry of FEC data; more discussion is needed.

- Continue to focus data collection in road accessible areas in order to reduce costs, as well as limit travel time to maximize rate-of-progress. However, some portion of plots (perhaps 10 to 20%) should be away from road network to reduce the biases associated with roads. In order to conduct cost-effective sampling of off-road areas, navigable rivers and lakes, fixed-wing aircraft and/or boat should be considered to gain, thereby reducing dependency on costly helicopters.

- Continue practice of conducting a brief aerial reconnaissance of target stands prior to sampling, which increases field crew productivity by confirming accessibility and avoiding unsuitable stands.

- Restrict the survey to the period July 1st to August 15th to minimize variance in species presence and abundance data due to differences in the emergence and senescence of various plant species.

- Riparian plots should be dealt with as distinct plot group during sampling and data analysis, as riparian forests typically reflect a unique microclimate.

- Future FEC plots should be placed farther away from concentrations of buffalo to prevent such high disturbance from impacting data analysis.

- The use of existing plot data should be assessed during the early stages of the project. The assessment should focus on ensuring that the data is sufficiently current and georeferenced, and those key data parameters are present.

- Assess the utility of the existing Canadian Wetland Classification System (National Wetlands Working Group, 1997) for dealing with wetland areas.

While every effort was made to maximize available resources, this list of recommendations should not be considered exhaustive. Further research and discussion is warranted.

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APPENDICES

APPENDIX A - PHOTO PLATE SUMMARIES

Numerous photos were taken of the fifty FEC plots that were done for this project. An Adobe Acrobat (.pdf) file was created for each plot. Each file, if available, contains a photo of the stand, soil profile, and understorey. The header on each file contains the plot number, date, ecosite classification, and stand type. In order to reduce the file size of this document the photo plate summaries are not included in the main text body, but were provided in an accompanying CD-ROM.

APPENDIX B - TAXONOMY RECOMMENDATIONS

The following discussion is intended to outline taxonomy problems encountered during fieldwork and how taxonomic issues may affect the project in the future.

The vascular plant, bryophyte, and lichen taxonomy in this region is not standardized in a consistent, accessible, and up-to-date manner. In *Ecological Land Survey Site Description Manual – 2nd Edition* (Alberta Sustainable Resource Development, 2003), the only taxonomic standard mentioned is the *Alberta Plants and Fungi – Master Species List and Species Group Checklists* published by Alberta Environment (1993). The problem with using this checklist as a taxonomic standard is that, as an internal Alberta Environment document, it is difficult to acquire and has not been recently updated. Vascular plant taxonomy has changed significantly in the last 11 years, and with projects like the *Flora of North America*, the taxonomy of vascular plants and bryophytes will continue to change in the years to come. What this means for this project is that to be relevant, needs to keep the taxonomy used in the guide should be consistent, accessible, and an updated taxonomic standard needs to be established.

For this pilot project, *Vascular Plants of the Continental Northwest Territories* by Porsild and Cody (1980), was used for identification and naming of vascular plants. Until a new flora is published, this will remain the standard for identification of vascular plants for most people. The one group that was not fully identified using Porsild and Cody (1980) is the genus *Salix*. For this group, the program *IntKey* was used with the files provided under *Interactive Identification of New World Salix (Salicaceae) using Intkey* on the Alaska Natural Heritage website (http://aknhp.uaa.alaska.edu/willow/) (Argus, 2001 onwards; Dallwitz, 1980; Dallwitz, Paine, and Zurcher, 1993 onwards; Dallwitz, Paine, and Zurcher, 1995; Dallwitz, Paine, and Zurcher, 2000). *Salix* taxonomy is discussed more fully below.

The problem with solely using Porsild and Cody (1980) is two-fold. Firstly, direct synonyms may be extremely out of date and not in common usage. For example, the name *Hieracium scabriusculum* is used in Porsild and Cody, which is a rarely used synonym of *Hieracium umbellatum*. In these cases, users of the flora may have trouble going in between the names of this flora and more familiar names. Since these names are direct synonyms, they can easily be updated at a later time. Including a list of direct taxonomic synonyms with the guide(s) would make their application much more practical.

The second case is more serious. Taxonomic changes, where species have been split and lumped, are not so easily corrected. A good example of this is that of *Salix*. Most of the taxonomy in Porsild and Cody (1980) has not changed significantly in the last 11 years. However, certain, key groups that were poorly investigated at the time when Porsild and Cody (1980) have had more correct taxonomy applied to them.

Solving problems with lumped or split species will need to be dealt with before extensive work is done on the ecosite guide. Updated names for the North American flora are available on websites like the Integrated Taxonomic Information System (ITIS) at http://www.itis.usda.gov/. Simply using an updated checklist like ITIS or *Alberta Plants and Fungi* is that the current identification resources do not match the updated checklists. The solution to this problem is to continue using Porsild and Cody (1980) as a main identification resource and either target "problem" groups using an alternative resource like the (currently incomplete) *Flora of North America* or *IntKey*. If a group is not going to be particularly important in the project's data, a certain amount of lumping (e.g.- *Carex sp.*) may be acceptable. However, I strongly recommended that in the early stages of this project, species should be identified to the furthest extent possible until it is known whether or not the presence of that species is providing important data. Certain groups may not be practical to use because of difficulties spotting or identifying a species. These cases could be left out entirely, or certain important species could be required for identification. For example, for groups like *Carex*, common or important species could be used in the guide(s) as long as users are provided with photos or drawings, a set of identifying characters, and an illustrated glossary defining technical terms.

As taxonomy changes, keeping up with more recent taxonomy may not be practical and may not significantly change the usage of the guide(s) produced by this project. Any future updates would have to be done concurrently with the update of the guide(s). If updating the taxonomy of the guide is not practical or necessary, an out of date taxonomy could be used as long as that old taxonomy does not provide inaccurate information about those ecosites. Regardless of this, using up to date taxonomy from the early stages of this project should prevent taxonomy from creating too many problems in the future.

So, when problems are encountered using Porsild and Cody (1980) the suggested process would be to:

1) Investigate the most up-to-date taxonomy using *Flora of North America*, or ITIS. Use W3MOST (http://mobot.mobot.org/cgi-bin/search_vast) for bryophytes not covered by ITIS. Nomenclature for lichens can be looked up in *Lichens of North America* by Brodo et al. (2001).
2) Find out how important full identification of a group is. Is identification of that group practical? Can that group be simply lumped, or key species identified without impeding the goals of the project? Is further investigation (and full identification) needed to know if the species is important enough to the project?
3) If not, determine what resources should be used for the identification of that group as a standard for use with this manual.

Below are suggestions regarding some specific groups dealt with during our fieldwork:

Rosa:

Hybridization and phenotypic plasticity among *Rosa* tends to make identification of *Rosa acicularis*, and *Rosa woodsii* difficult (Looman and Best, 1987; Tesky, 1992). In my experience, the only reliable character for non-specialists is to use the mature fruit (August to October). The keys in Porsild and Cody (1980) only apply to fully mature specimens that clearly are not hybridized. A third species, *Rosa blanda*, is uncommon in the study region and can be separated using the lack of thorns and larger leaves. In cases where *Rosa* cannot be easily separated as *Rosa blanda*, I would suggest that if there are no mature fruit, the shrubs in question should be listed as *Rosa spp*. In the study area, the species found were either *R. woodsii* or *R. acicularis*.

Salix:

Since Porsild and Cody (1980) was published, extensive changes have been made to the taxonomy of *Salix* (Argus, 1999; Argus, 2001 onwards; Argus, 2004). A good example of this is the taxonomy of *Salix myrtillifolia* and *Salix pseudomyrsinites* (Argus, 1999; Argus, 2001 onwards). *Salix pseudomyrsinites* was recently separated as a distinct species from *Salix myrtillifolia* var. *pseudomyrsinites* (Andersson) Ball and Dorn (Dorn 1975). Separating these two species should be useful, since they are recognized as having distinct habitats (Argus, 1973). Most species of *Salix* have had their ecological characteristics and preferences for moisture and nutrient regime documented to some degree (Argus, 1973; Coladonato, 1993; Porsild and Cody, 1980; Viereck and Little, 1972). Since many species of *Salix* are common plants in the study area, and are somewhat difficult to identify, special consideration should be given to their treatment in this study.

The problem with using *Salix* in too much detail is that many species are very difficult to identify reliably in the field. Field workers could do cover for *Salix* separated by height class (e.g., prostrate/decumbent-shrubs under 3m-shrubs over 3m-trees) and, if possible, by species. Regardless of how *Salix* is treated, field workers should be collecting voucher specimens for each species at *all* of the plots, taking care to note the measured height and micro-habit of the plant. Specimens with floral parts would preferably be collected. A botanist would then identify the collected specimens with the use of a herbarium and George Argus' *Salix* treatment for *Intkey* (Argus, 2001 onwards).

Betula:

Betula glandulosa, *Betula pumila*, and *Betula nana* are common species throughout the study area and are known for challenging taxonomy and difficulties in identification (Flora of North America Editorial Committee, 1993; De Groot et al., 1997). Extensive hybridization between these species leaves most vegetative identification using available keys unreliable. For this project, identifications of this complex were done using the fruiting characters from the keys in Porsild and Cody (1980). However, Porsild and Cody (1980) incorrectly lumps *B. glandulosa* with *B. nana* ssp. *exilis* (Flora of North America Editorial Committee, 1993; De Groot et al., 1997). Since the moisture and nutrient requirements of these species are similar (De Groot et al.,

1997) the cost of spending time separating these species would be quite high compared to the benefits of having them separated. The only major difference appears to be their respective tolerances to temperature extremes (De Groot et al., 1997). Given the difficulty separating these species, I would suggest continuing to use the taxonomy in Porsild and Cody (1980), while keeping in mind the taxonomy of this group for any analysis and discussion. See the taxonomic discussion on the Flora of North America web site
(http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=233500248)
for a detailed discussion of the issues around the *B. pumila/glandulosa/nana* complex.

A note on the differing taxonomy of FNA and ITIS:

Two taxonomic resources mentioned above are the *Flora of North America Project*, and *Integrated Taxonomic Information System* (ITIS). The *Flora of North America Project* is an expert treatment of all of North America's vascular and non-vascular plants. ITIS has it's own, separate taxonomy that is modified as new taxonomic evidence is found. Most of the taxa covered by these systems are very similar, but when using these systems one should be aware that there are differences to be found in treatments of different species.

Voucher Specimens

Any voucher specimens should be deposited in a recognized herbarium. Unknowns can be confirmed at a later date and can be stored for free, indefinitely. Mosses should be sent to the Devonian Botanical Gardens (UAMH). Vascular plants should be sent to one of the following:

- W. P. Fraser Herbarium (SASK)
- Devonian Botanical Gardens (UAMH)
- University of Alberta (ALTA)
- Agriculture and Agri-Food Canada (DAO)
- Canadian Museum of Nature (CAN)

Contact information and addresses of these institutions can be retrieved from the *Index Herbariorum*, available online at http://sciweb.nybg.org/science2/IndexHerbariorum.asp.

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APPENDIX C - MANUAL AND FORM CHANGES

There are a number of issues to discuss regarding the methodologies and forms included in the *Ecological Land Survey Site Description Manual*.

Soil Parameter Issues

Some soil parameters are clearly non-quantitative, highly subjective, and would be of dubious value in multivariate analysis.

Extraneous soil parameters include:

- **Horizon boundary distinctiveness and form –** digital picture and depth range information captures this sufficiently;
- **Soil consistency and plasticity –** extremely subjective, especially under field conditions with varying soil moisture;
- **Faint mottles –**not used in soil drainage or moisture regime determination; difficult to see and distinguish from other forms of oxidation;
- **Colour aspect** (soil matrix and mottles) **–** unnecessary;
- **Roots –** very subjective, especially when describing a jumbled mass of various sized roots; horizonation, texture, structure and effective rooting depth (a less subjective root parameter) provide adequate information regarding rooting and potential root restriction.

While soil colour may be considered optional, it is useful for classifying soils in the Chernozemic and Podzolic Orders, and may also be of use correlating specific parent materials (especially different tills) with existing soil and surficial geology maps and reports.

Field pH was not conducted due to the highly unreliable nature of most field test kits. Laboratory analysis is highly recommended if pH is determined to be necessary. However, pH has a high degree of variability at the site level, often exhibited as a high coefficient of variation in sample data. As a result of this variability, subsampling across the site is required (typically five or more) at each site to gain a reliable sample; this can be time-consuming and hence costly.

There is a difference in *effervescence/calcareousness classes* in the Alberta manual versus that found in many Canadian soil manuals. In the Alberta manual a *very weak* class is added and *very strong* and *extremely calcareous* classes are dropped). Consistency in such an ecologically key parameter is important, especially when integrating with existing data sets from other sources and differences should be noted.

Given the importance of mottle identification in the determination of soil drainage class and moisture regime, extra care must be taken to distinguish true mottling from other pedological (e.g., iron or manganese concretions) or geological phenomena (e.g., Cretaceous iron flecks, which were observed in some soils north of Fort Providence).

Vegetation Parameter Issues

Naming Species

The methodology pages 81-85 of the *Ecological Land Survey Site Description Manual* (Alberta Sustainable Resource Development, 2003) describing the 7-letter naming system is overly complicated and error-prone. Some of the problems are:

- In general, naming conventions as simple as possible. If necessary, a “cheat sheet” could be included with each clipboard listing the rules of nomenclature, and common species codes that may be confusing (e.g., *Stellaria longipes* and *S. longifolia*). If workers do not know a species code, it is likely not encountered regularly and would not use up too much time being written out in full. If there is a problematic name, workers could note the code that they are using with the name written in full in the comments or notes sections.

- Codes for naming voucher specimens should be simplified. On p.82, the manual recommends naming species using the collector's last initial followed by a stratum layer code, followed by a three-digit number. The genus name or a descriptive four-letter code should be used, followed by a number (e.g., Sali sp1, Sali sp2, Forb sp1, Grass sp1, Moss sp1, Lich sp1 etc.). A more simple system is going to result in fewer errors. As long as each name uniquely identifies a specimen and as long as that name is carefully labeled on the voucher specimen using with the collector's name, plot number, and collection name, voucher specimens should be adequately referenced.

- Page 85 of the site description manual suggests using “$” signs for spacers for less-than 7-letter genera names. This step adds another level of unnecessary complexity to the naming of species. However, if this is important enough to the naming of species, boxes could be provided for each letter of the species name (10 boxes per line) to separate the genus, species, and subspecies levels. In the case where 7 letters are used for a genus, the spaces normally used for the genus and species would be used, with blanks representing the spacers. Alternatively, the name could be written out in full.

Shrub Height Classes

For practical reasons, shrubs should be generalized by layer using the tallest cover class over a given area. However, care should be taken to not generalize too much. If there is a separate area in the plot with the same species in a taller or shorter height class, those shrubs should be treated separately.

Subshrubs

A consistent definition of what species are shrubs and which are forbs is needed. Several species, such as *Rubus pubescens*, and *Cornus canadensis* in the Northwest Territories are occasionally classed "subshrubs". *Field Guide to Ecosites of Northern Alberta* lists *Cornus canadensis* as herb, while the Site Description manual treats *Cornus canadensis* as a low shrub.

One can follow *Field Guide to Ecosites of Northern Alberta* to determine the whether or not a subshrub is treated as a forb or a shrub for major species. Porsild and Cody (1980) is a good source for the remaining species in the field. When the data is fully collected, this reference and be used to verify that the strata assigned match those of any data sources being used for this project. Data can be cleaned up during the data-entry process, but for the sake of efficiency, it would be a good idea to get stratum layers correctly assigned in the field.

Percent Cover

Several clarifications are needed on the methodology of assigning cover values:

- Individual shrubs were assigned a single stratum corresponding to their maximum height, rather than those strata in which they occurred.

- At the beginning of the project, time should be taken to correlate between workers for cover and distribution evaluations.

- Fungal and epiphyte covers: The presence of mushrooms is too ephemeral and covers for epiphytes too vague for any of this data to be useful. During the first 50 plots, only one mushroom was found.

Distribution

Ideally, this very subjective and time consuming variable should not be collected unless absolutely needed to make the Northwest Territories data compatible with other data sources. If this variable is going to be used, more guidelines are needed.

One question that came up was the relation between distribution and cover. This is only vaguely implied in the Site Description Manual. In evaluating distribution, one must note that cover is only indirectly related to distribution. It is obvious that if a species has a distribution of 11 or 12, there should be a relatively high cover. On the other hand, distribution is directly related to the plant size and the number of individuals. For very small plants (e.g., *Mitella nuda*), one could easily have a relatively low cover, while having a "high" distribution. For example, *Mitella nuda* has an average leaf area of about 4 cm^2. One could have 100 plants per square meter for a total of 400 cm^2 or a cover of 400 cm^2/10000 cm^2 *100 = 4%. With 100 plants per square meter, I would give a distribution of 10. An average-sized plant, such as *Cornus canadensis* has an average leaf area of about 80 cm^2 and with 100 plants per square meter would have a distribution of 10 and a cover of 80%. The same holds true for those cover classes with clusters of plants. Unless there are very large numbers of plants, *Mitella nuda* is going to have, on average, much smaller clusters than a species like *Cornus canadensis*. With this in mind, I would not place too much emphasis on this relationship. A more clear explanation of this is needed in any procedures that workers will be using.

Fig. 1 – Right: Area covered by 100 stems of *Mitella nuda*; Left: area covered by 100 stems of *Cornus canadensis.*

Mosses presented a second set of difficulties in defining the individual, in order to evaluate distribution. For the sake of clarity, I am noting how I evaluated these covers. For this project, rather than treat small patches as individuals, I treated one stem as one individual. Since mosses usually cluster, this meant that distributions of 1, 2, 5, and 10 were exceedingly rare.

Vigour

Like distribution, vigour is too subjective to be useful in analysis. However, if compatibility with other data sets requires that this variable be collected, some recommendations on how to standardize this are given below.

Below are some of the rules that I used in the field to determine vigor:

0 Dead - No chlorophyll present. This may require more thorough examination in late-season mosses, where they have already gone senescent.
1 Poor - Species less robust than normal, no reproductive parts; may have extensive disease or mechanical damage.
2 Fair - Species with of average size, some flowers, and fruit; may have minor damage from disease.
3 Good - Species appearing robust with more than normal flowers and fruit; no disease.
4 Excellent - Species appearing exceptionally robust often with an exceptional amount of flowers and fruits; no disease.

In specimens where light competition apparently has caused resources to be put into larger leaves and stems, rather than reproductive parts, I downgraded the vigor code of the plant.

Average Stratum Height

A standardized unit for each layer needs to be defined - shrubs and trees should be in metres and herbs, graminoids, mosses, and lichens should be in centimeters.

Adjacent Species

Occasionally, low densities of certain indicator species may result in an important species not being included in the plot. Depending on how this would affect the data, adjacent indicator species may need to be noted. If this is the case, how far away should one be searching, how uncommon should these plants be? In a couple of plots, *Alnus crispa* was not present in the plot, but some large *A. crispa* shrubs occurred in a low density outside of the plot.

Miscellaneous Issues

Field Form

There were also several things that could be improved or clarified on the form layout and how the forms are filled out:

- Sections of the form, like “Plot Area” and “Plot Shape” should either be printed automatically on the sheet, or if there is more than one type of plot shape used, a check box system would be more efficient (e.g., plot shape: square: ☑ circle: ☐).

- A check box "collected" column would be highly desirable, to indicate that a voucher has been collected for a given species.

- In cases where more than one sheet is used for the vegetation or soils, a box for indicating page numbers is needed (i.e., ‘Page 1 of 2’). Tracking multiple pages is a lot less error-prone when pages are numbered appropriately.

- On the vegetation sampling data sheet, cover classes should be separated. Evaluating and entering the data is a lot easier when all of the trees, shrubs, herbs, bryophytes, and lichens are separated.

Nutrient Regime Determination

- The chart on page 21 of *Field Guide to Ecosites of Northern Alberta* was much more effective for determining nutrient regime than that of the *Ecological Land Survey Site Description Manual.*

APPENDIX D - LIST OF OBSERVED SPECIES.

Species Code	Scientific Name	Current Nomenclature
Achi mil	Achillea millefolium	Achillea millefolium L.
Acte rub	Actaea rubra	Actaea rubra (Aiton) Willdenow
Agro sca	Agrostis scabra	Agrostis scabra Willd.
Agrostis sp	Agrostis sp	Agrostis sp
Agro tra	Agropyron trachycaulum	Elymus trachycaulus (Link) Gould ex Shinners
Agro tra tra	Agropyron trachycaulum var trachycaulum	Elymus trachycaulus ssp. trachycaulus (Link) Gould ex Shinners
Agro tra uni	Agropyron trachycaulum var unilaterale	Elymus trachycaulus ssp. subsecundus (Link) A.& D. Löve
Alnu cri	Alnus crispa	Alnus viridis subsp. crispa (Aiton) Turrill
Amel aln	Amelanchier alnifolia	Amelanchier alnifolia (Nutt.) Nutt. ex M. Roemer
Andr pol	Andromeda polifolia	Andromeda polifolia L.
Anem mul	Anemone multifida	Anemone multifida Poiret
Anem par	Anemone parviflora	Anemone parviflora Michaux
Ante ros	Antennaria rosea	Antennaria rosea Greene
Ante sp	Antennaria sp.	N/A
Aqui bre	Aquilegia brevistyla	Aquilegia brevistyla Hooker
Arct rub	Arctostaphylos rubra	Arctostaphylos rubra (Rehd. & Wilson) Fern.
Arct uva	Arctostaphylos uva-ursi	Arctostaphylos uva-ursi (L.) Spreng.
Aste cil	Aster ciliolatus	Symphyotrichum ciliolatum (Lindl.) A.& D. Löve
Aste jun	Aster juncifolius	Symphyotrichum boreale (Torr. & Gray) A.& D. Löve
Aste sib	Aster sibiricus	Aster sibiricus L.
Astr ame	Astragalus americanus	Astragalus americanus (Hook.) M.E. Jones
Aula pal	Aulacomnium palustre	Aulacomnium palustre (Hedw.) Schwaegr.
Betu gla	Betula glandulosa	Betula glandulosa Michaux
Betu occ	Betula occidentalis	Betula occidentalis Hooker
Betu pap	Betula papyrifera Marshall	Betula papyrifera Marshall
Betu pap com	Betula papyrifera var. commutata	Betula papyrifera Marshall
Betu pap neo	Betula papyrifera var neoalaskana	Betula neoalaskana Sargent
Betu pum	Betula pumila	Betula pumila Linnaeus
Betu sp	Betula sp	Betula sp.
Bryo spp	Bryophyte spp	Bryophyte spp
Cala can	Calamagrostis canadensis	Calamagrostis canadensis (Michx.) Beauv.
Cala ine	Calamagrostis inexpansa	Calamagrostis inexpansa Gray
Cala lap nea	Calamagrostis lapponica var. nearctica	Calamagrostis lapponica (Wahlenb.) Hartman
Camp rot	Campanula rotundifolia	Campanula rotundifolia L.
Card pra	Cardimine pratensis	Cardamine pratensis L.
Care aen	Carex aenea	Carex foenea Willdenow
Care atr ray	Carex atratiformis ssp. raymondii	Carex atratiformis Britton
Care aur	Carex aurea	Carex aurea Nuttall
Care cap	Carex capillaris	Carex capillaris Linnaeus
Care cap rob	Carex capillaris ssp. robustior	Carex capillaris Linnaeus
Care con	Carex concinna	Carex concinna R. Brown
Care dis	Carex disperma	Carex disperma Dewey
Care foe	Carex foenea	Carex siccata Dewey
Care gyn	Carex gynocrates	Carex gynocrates Wormskjöld ex Drejer
Care las ame	Carex lasiocarpa var. americana	Carex lasiocarpa Ehrhart subsp. americana (Fernald) Hultén
Care lept	Carex leptalea	Carex leptalea Wahlenberg
Care ric	Carex richardsonii	Carex richardsonii R. Brown
Care sci	Carex scirpoidea	Carex scirpoidea Michaux
Care sp	Carex sp	Carex sp.
Care vag	Carex vaginata	Carex vaginata Tausch
Cera arv	Cerastium arvense	Cerastium arvense L.

Cham cal	Chamaedaphne calcyculata	Chamaedaphne calyculata (L.) Moench
Clad mit	Cladina mitis	
Clad ran	Cladina rangiferina	
Clad spp	Cladonia spp	
Clad ste	Cladina stellaris	
Corn can	Cornus canadensis	Cornus canadensis L.
Corn sto	Cornus stolonifera	Cornus sericea L. ssp. sericea L.
Cypr cal	Cypripedium calceolus	Cypripedium parviflorum var. pubescens (Willdenow) O. W. Knight
Dicr fus	Dicranum fuscescens	Dicranum fuscescens Turn.
Dicr pol	Dicranum polysetum	Dicranum polysetum Sw.
Dicr sp	Dicranum sp	Dicranum sp.
Dicr spp	Dicranum spp.	Dicranum spp.
Drep ver	Drepanocladus vernicosus	Drepanocladus vernicosus (Mitt.) Warnst.
Drep unc	Drepanocladus uncinatus	Drepanocladus uncinatus (Hedw.) Warnst.
Dros rot	Drosera rotundifolia	Drosera rotundifolia L.
Elym inn	Elymus innovatus	Leymus innovatus (Beal) Pilger
Empe nig	Empetrum nigrum	Empetrum nigrum L.
Epil ang	Epilobium angustifolium	Chamerion angustifolium ssp. angustifolium (L.) Holub
Epil pal	Epilobium palustre	Epilobium palustre L.
Equi arv	Equisetum arvense	Equisetum arvense Linnaeus
Equi pra	Equisetum pratense	Equisetum pratense Ehrhart
Equi sci	Equisetum scirpoides	Equisetum scirpoides Michaux
Equi syl	Equisetum sylvaticum	Equisetum sylvaticum Linnaeus
Erig hys	Erigeron hyssopifolius	Erigeron hyssopifolius Michx.
Erio vag	Eriophorum vaginatum	Eriophorum vaginatum Linnaeus
Forb sp	Forb sp	N/A
Frag ves	Fragaria vesca	Fragaria vesca L.
Frag vir	Fragaria virginiana	Fragaria virginiana Duchesne
Gali bor	Galium boreale	Galium boreale L.
Gent acu	Gentiana acuta	Gentiana acuta Michx.
Geoc liv	Geocaulon lividum	Geocaulon lividum (Richards.) Fern.
Glyc str str	Glyceria striata var. stricta	Glyceria striata (Lam.) A.S. Hitchc.
Good rep	Goodyera repens	Goodyera repens (Linnaeus) R. Brown
Grass sp	Grass sp	Grass sp
Habe hyp	Habenaria hyperborea	Platanthera hyperborea (Linnaeus) Lindley
Habe obt	Habenaria obtusata	Platanthera obtusata (Banks ex Pursh) Lindley
Habe orb	Habenaria orbiculata	Platanthera orbiculata (Pursh) Lindley
Hedy alp	Hedysarum alpinum	Hedysarum alpinum L.
Hedy mac	Hedysarum mackenzeii	Hedysarum mackenzei Richards.
Hier sca	Hieracium scabruisculum	Hieracium umbellatum L.
Hylo spl	Hylocomnium splendens	Hylocomium splendens (Hedw.) Schimp. in B.S.G.
Hypn cup	Hypnum cupressiforme	Hypnum cupressiforme Hedw.
Hypnum sp.	Hypnum sp.	Hypnum sp.
Junc bal	Juncus balticus	Juncus arcticus var. balticus (Willdenow) Trautvetter
Juni com	Juniperus communis	Juniperus communis Linnaeus
Juni hor	Juniperus horizontalis	Juniperus horizontalis Moench
Lari lar	Larix laricina	Larix laricina (Du Roi) K. Koch
Lath och	Lathyrus ochroleucus	Lathyrus ochroleucus Hook.
Ledu dec	Ledum decumbens	Ledum palustre ssp. decumbens (Ait.) Hultén
Ledu gro	Ledum groenlandicum	Ledum groenlandicum Oeder
Lich sp	Lichen sp	
Linn bor	Linnaea borealis	Linnaea borealis L.
Loma rot	Lomatogonium rotatum	Lomatogonium rotatum (L.) Fries ex Fern.
Loni dio	Lonicera dioica	Lonicera dioica L. var. glaucescens (Rydb.) Butters

Maia can	Maianthemum canadense	Maianthemum canadense Desfontaines
Marc pol	Marchantia polymorpha	Marchantia polymorpha L.
Mert pan	Mertensia paniculata	Mertensia paniculata (Ait.) G. Don
Mite nud	Mitella nuda	Mitella nuda L.
Moeh lat	Moehringia lateriflora	Moehringia lateriflora (L.) Fenzl
Mone uni	Moneses uniflora	Moneses uniflora (L.) Gray
Orch rot	Orchis rotundifolia	Amerorchis rotundifolia (Banks ex Pursh) Hultén
Oryz asp	Oryzopsis asperifolia	Oryzopsis asperifolia Michx.
Oryz pun	Oryzopsis pungens	Piptatherum pungens (Torr.) Barkworth, comb. nov. ined.
Pedi lab	Pedicularis labridorica	Pedicularis labradorica Wirsing
Pelt spp	Peltigera spp	
Peta pal	Petasites palmatus	Petasites frigidus var. palmatus (Ait.) Cronq.
Peta sag	Petasites sagitattus	Petasites sagittatus (Banks ex Pursh) Gray
Pice gla	Picea glauca	Picea glauca (Moench) Voss, Mitt. Deutsch.
Pice mar	Picea mariana	Picea mariana (Miller) Britton, Sterns & Poggenburg, Sterns, & Poggenburg
Pinu ban	Pinus banksiana	Pinus banksiana Lambert
Plan eri	Platago eriopoda	Plantago eriopoda Torr.
Pleu sch	Pleurozium schrebneri	Pleurozium schreberi (Brid.) Mitt.
Poa pal	Poa palustris	Poa palustris L.
Poa pra	Poa pratensis	Poa pratensis L.
Poly str	Polytrichum strictum	Polytrichum strictum Brid.
Popu bal	Populus balsamifera	Populus balsamifera L.
Popu tre	Populus tremuloides	Populus tremuloides Michx.
Pote fru	Potentilla fruticosa	Dasiphora floribunda (Pursh) Kartesz, comb. nov. ined.
Pote tri	Potentilla tridentata	Sibbaldiopsis tridentata (Ait.) Rydb.
Ptil cri	Ptilium crista-castrensis	Ptilium crista-castrensis (Hedw.) De Not.
Ptil pul	Ptilidium pulcherimum	Ptilidium pulcherimum (G. Web.) Hampe
Pyro asa	Pyrola asarifolia	Pyrola asarifolia Michx.
Pyro gra	Pyrola grandiflora	Pyrola grandiflora Radius
Pyro sec	Pyrola secunda	Orthilia secunda (L.) House
Pyro chl	Pyrola chlorantha	Pyrola chlorantha Sw.
Rhiz pun	Rhizomnium punctatum	Rhizomnium punctatum (Hedw.) T.J. Kop.
Ribe lac	Ribes lacustre	Ribes lacustre (Pers.) Poir.
Ribe oxy	Ribes oxycanthoides	Ribes oxyacanthoides L.
Ribe tri	Ribes triste	Ribes triste Pallas
Rosa aci	Rosa acicularis	Rosa acicularis Lindl.
Rosa sp	Rosa sp	Rosa sp.
Rosa spp	Rosa spp.	Rosa spp.
Rosa woo	Rosa woodsii	Rosa woodsii Lindl.
Rubu aca	Rubus acaulus	Rubus arcticus ssp. acaulis (Michx.) Focke
Rubu cha	Rubus chamaemorus	Rubus chamaemorus L.
Rubu pub	Rubus pubescens	Rubus pubescens Raf.
Sali arb	Salix arbusculoides	Salix arbusculoides Anderss.
Sali ath	Salix athabascensis	Salix athabascensis Raup
Sali beb	Salix bebbiana	Salix bebbiana Sarg.
Sali bra	Salix brachycarpa	Salix brachycarpa Nutt.
Sali gla	Salix glauca	Salix glauca L.
Sali lut	Salix lutea	Salix lutea Nutt.
Sali myr	Salix myrtilloides	Salix pedicellaris Pursh
Sali psu	Salix pseudomyrsinites	Salix pseudomyrsinites Anderss.
Sali sco	Salix scouleriana	Salix scouleriana Barratt ex Hook.
Sali sp	Salix sp	Salix sp.
Sela sel	Selaginella selaginoides	Selaginella selaginoides (L.) Beauv. ex Mart. & Schrank
Sene pau	Senecio paupercula	Packera paupercula (Michx.) A.& D. Löve

Shep can	Shepherdia canadensis	Shepherdia canadensis (L.) Nutt.
Smil tri	Smilacina trifoliata	Maianthemum trifolium (Linnaeus) Sloboda
Soli dec ore	Solidago decumbens var. oreophila	Solidago simplex var. nana (Gray) Ringius
Soli sp	Solidago sp	Solidago sp.
Spha spp	Sphagnum spp	Sphagnum spp.
Spir rom	Spiranthes romanzoffiana	Amerorchis rotundifolia (Banks ex Pursh) Hultén
Stel log	Stellaria longipes	Stellaria longipes Goldie
Tara off	Taraxacum officinale	Taraxacum officinale G.H. Weber ex Wiggers
Thui rec	Thuidium recognitum	Thuidium recognitum (Hedw.) Lindb.
Tofi glu	Tofieldia glutinosa	Triantha glutinosa (Michaux) Baker
Tome nit	Tomenthypnum nitens	Tomenthypnum nitens (Hedw.) Loeske
Vacc myr	Vaccinium myrtilloides	Vaccinium myrtilloides Michx.
Vacc oxy	Vaccinium oxycoccus	Vaccinium oxycoccus Linnaeus
Vacc vit	Vaccinium vitis-idaea	Vaccinium vitis-idaea L.
Vibu edu	Viburnum edule	Viburnum edule (Michx.) Raf.
Vici ame	Vicia americana	Vicia americana Muhl. ex Willd.
Viol ren	Viola renifolia	Viola renifolia Gray
Zyga ele	Zygadenus elegans	Zigadenus elegans Pursh