

EOSD Land Cover Classification Legend Report

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Version 2

**Mike Wulder
Canadian Forest Service
Natural Resources Canada
Victoria, British Columbia**

**Trisalyn Nelson
TNT Geoservices
Victoria, British Columbia**

Executive Summary

Concern over the state of the earth's environment has resulted in an increased need for accurate land cover information. Ecologically, land cover mapping is necessary to provide input to scientific models, to ensure forest management is sustainable, and to monitor environmental change. However, land cover mapping is also required to meet political commitments made to international agreements such as the Kyoto Protocol and the Convention on Biological Diversity.

In large countries, such as Canada, satellite imagery is a useful tool for land cover mapping as it efficiently provides information over relatively large areas. The Canadian Forest Service's project, Earth Observation for Sustainable Development of Forests (EOSD), is mapping Canada's forests with satellite imagery.

The goal of this report is to *review the current EOSD Land Cover Classification Scheme to determine if it is suitable for national level mapping with Landsat imagery*. By reviewing several key land cover legends as well as the development of the proposed EOSD legend we are able to make recommendations on how to improve the EOSD land cover legend and to aid the efficiency of the mapping project. In this report we recommend a legend for the land cover mapping of the forested area of Canada with Landsat data. As of this version update, the recommended legend is in use by federal, provincial, and territorial mapping agencies undertaking the EOSD Land Cover mapping activities.

Our most significant conclusion is that with minor modifications the proposed EOSD legend will be appropriate for mapping Canada's land cover with Landsat imagery. EOSD wetland classes should be regrouped and the Wetland – Bryoid class removed. The EOSD legend should continue to be based on the hierarchical National Forest Inventory (NFI) Land Cover Classification Scheme as support from the Canadian forest Inventory Committee will aid in collaboration efforts with the NFI and provinces. As well, many of the provincial large area land cover classifications legends are similar to the EOSD legend allowing for partnerships and increased efficiency of land cover mapping. Land use and common classes, such as burn and harvest, should not be added to the EOSD legend. At present, techniques to classify land use and transitional areas with spectral information from Landsat spatial resolution satellites are not well developed.

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1.0 Introduction

Increasing concern over the state of the earth's environment has resulted in several large area land cover mapping projects. Accurate land cover mapping is important both ecologically and politically: ecologically, land cover mapping is important to assess environmental health, monitor change, and to use as input to scientific models. Politically, land cover mapping is necessary to meet the commitments to agreements such as the Kyoto Protocol, the international Convention on Biological Diversity, and the Framework Convention on Climate Change.

Reporting on land cover is relatively easy in small countries, while similar reporting for large countries such as Canada is onerous. Satellite imagery efficiently provides information on relatively vast areas, and is therefore a useful tool for land cover mapping in large countries; neither aerial photography nor field data can provide equal amounts of information as efficiently. Perhaps the best evidence of the usefulness of satellite imagery for land cover mapping is the existence of no less than 30 satellite based large area land cover mapping projects throughout the world (Wulder, 2001). Even within Canada, at both the federal and provincial levels, there are at least 8 large area land cover satellite mapping projects.

The Canadian Forest Service's project, entitled Earth Observation for Sustainable Development of Forests (EOSD), is interested in mapping Canada's forests and other land covers with satellite imagery (Wood et al. 2002). EOSD's mapping of Canada's land cover will help to meet Canada's commitment to international agreements. Land cover mapping of Canada will also provide information for the sustainable management of forests and as such may be used as input to scientific models for carbon modeling and forest change. As Canada is home to 10% of the world's total forests, the EOSD land cover mapping program is not only significant for understanding Canadian forests, but also for the international understanding of the state of the world's forests and environment.

Existing large areas land cover mapping projects suggests that there is a need for a closed, consistent legend to be used throughout the entire mapping area. The proposed closed legend for EOSD is based on the land cover classification legend used by the National Forest Inventory (NFI), which has been endorsed by the Canadian Forest Inventory Committee (CFIC). The CFIC is a federal/provincial agency that makes recommendations to the Canadian Council of Forest Ministers regarding forest inventory matters. In this report the proposed EOSD legend will be reviewed and recommendations for improvements to be considered will be noted.

This report is just one of several EOSD reports which aims at providing information necessary to ensure that the EOSD land cover mapping project is of the best possible quality, is effective, and efficient. One existing communication is a review of methods for satellite based land cover classification (Franklin and Wulder 2002). Other reports include a review of some of the constraints of large area mapping of land cover (Wulder, 2000) with Landsat TM imagery (Franklin and Wulder 2002) and an analysis of the EOSD large area remote sensing land cover mapping project (Wulder, 2002).

1.1 Report Objectives and Goals

The goal of this report is to *review the current EOSD Land Cover Classification Scheme to determine if it is suitable for national level mapping with Landsat imagery.*

More specifically the objectives of this report include:

1. To describe key existing legends and provide information on the context and development of the proposed EOSD legend.
2. To ensure that the land cover classes identified in the EOSD Land Cover Classification Scheme are obtainable from Landsat imagery.
3. To determine if there is compatibility between the EOSD Land Cover Classification Scheme and other land cover or land use classification schemes developed for use with satellite imagery with a spatial resolution similar to Landsat.
4. To make recommendations, based on objectives 2 and 3, for a prototype land cover classification legend for EOSD.

2.0 Terms and Concepts

The following is a list of key terms and definitions that will be used frequently throughout this report. The concepts and terms provide the context and background information for the report.

2.1 Land Cover Vs Land Use

Land cover and *land use* are terms that are often used interchangeably; however, they have different meanings. Land cover results from a complex mixture of natural and anthropogenic influences and is the composition and characteristics of land surface elements (Cihlar, 2000). In contrast, land use is characterized by economic uses of land and people's relationships with the environment (Avery and Berlin, 1992). For example, a land cover of forest, when considered as a land use, could be a park. To classify land use with satellite imagery often requires the use of supplementary information such as fieldwork and large scale aerial photography.

2.2 Legend Vs Classification Scheme

Although related, *classification schemes* and *legends* are different. In this report, a legend is simply considered a list of classes, often but not always developed from a classification scheme. A classification scheme (or system) is a tool designed to help an analyst make decisions about the classification of an object, such as a tree identification map that uses vegetation characteristics to classify a tree. Usually a classification scheme includes some type of decision tree and has classification levels. This distinction is important as the proposed EOSD legend is based on the NFI classification scheme. Both classification schemes and legends will be discussed throughout this report.

2.3 Land Cover Mapping Data Types

There are several data sources that can be used for land cover mapping. The data source directly impacts the methodology used for mapping. Although the EOSD land cover mapping project will use satellite imagery, other projects described below use different data types. A summary of the data types discussed in this report are shown in **Table 1**. The following sub-sections describe the relationship between data type and information content.

2.3.1 Field Data

The most detailed way of mapping land cover is with field data. Field data is collected by ground sampling or through observations made from an aircraft. The size of the data collection area is related to the level of detail required and the project budget; however, field data is generally collected for relatively small areas, often less than one hectare in size. Field data provides precise and detailed information about individual trees. For example, field data in a forested area may include diameter breast height, tree height, crown diameter, species, and coordinates of each individual tree. Field data has the potential to provide not only land cover data, but land use information. For example, in the field the difference between agricultural lands and grassy parks is easily distinguishable. There are two main drawbacks to mapping land cover with field data: 1) using field data, it is often difficult to assess regional patterns and access remote areas; 2) data collection is costly and time-consuming, making it almost impossible to map large areas.

2.3.2 Aerial Photography

Aerial photography is commonly used for land cover mapping. Aerial photographs are imaged by cameras mounted on aircraft and may have a scale between 1:500 and 1:100 000 (Wulder, 1998), though land cover mapping is usually done using aerial photographs with a resolution between 1:10 000 and 1: 40 000. Land cover mapping based on aerial photographs requires photo interpreters to manually draw polygons around areas that appear to have similar characteristics. Often the polygons are then manually digitized for map production. Aerial photographs allow for medium sized areas to be mapped at a level of detail appropriate for land cover mapping. A typical aerial photograph used for land cover mapping has an extent of 0.25 to 1 km². Most often, land cover maps are made from several aerial photographs.

Just as aerial photographs range in scale, they also range in spectral properties. Aerial photographs may be black and white, colour, or infrared depending upon the intended use and project budget. The flexibility of aerial photography makes it useful for land cover mapping, while additional benefits include the visibility of stand level patterns, the identification of some land uses, and the accuracy of maps produced by experienced photo interpreters. Compared with field data collection, data collection using aerial photography is inexpensive, though the cost of analysis is still high due to the manual work required. Manual interpretation is one of the difficulties in using aerial photography as manual interpreters may produce inconsistencies. When analyzing land cover, the polygon boundaries are often gradual, therefore making it likely that each interpreter will place the boundary in a slightly different location.

2.3.3 Satellite Imagery

Satellite imagery is increasingly being used for large area land cover mapping (Wulder, 2000). Satellites produce multispectral, panchromatic, thermal, and radar imagery. In this report we are concerned primarily with multispectral imagery. Satellite imagery also ranges in spatial and temporal resolution. Imagery may have coarse, fine, or even very fine spatial resolutions. Satellites with *coarse* spatial resolutions include MODIS, which has pixel sizes between 250 m and 1 km depending on the channel, and AVHRR, which has a pixel size of approximately 1 km. *Fine* spatial resolution satellites include Landsat, with a pixel size of 30 m, and SPOT, with pixel sizes between 10 m and 20 m (Cihlar, 2000). *Very fine* spatial resolution refers to a new generation of satellite, such as the recently launched IKONOS, which has a 1 m pixel. In this communications satellites are considered to have a fine spatial resolution unless otherwise specified.

There are several benefits to applying satellite imagery to large area mapping of land cover. Satellites with coarse and fine spatial resolutions are useful for large area land cover mapping, as a single image covers a relatively large area. The digital format of satellite imagery has many advantages over other land cover mapping data types. Mapping with digital data allows for the application of user-assisted procedures via supervised and unsupervised classifications (Franklin and Wulder 2002). The procedure for mapping land cover with any resolution of satellite data is relatively quick, consistent, and repeatable. Other benefits of using satellite imagery for land cover mapping include the visibility of

regional patterns and the availability of temporal data sets. Landsat 5 has a 16 day repeat cycle, which allows increased opportunity to select images that are cloud free.

Table 1. Generalized trends of data types for land cover mapping.

	Field Data	Aerial Photography	Coarse and Fine Satellite Imagery
Spatial Resolution	Very fine	1:5 00 - 1:100 000	10m - 4km
Spatial Extent	~ a few m to a hectare	12 - 2300 m sq.	~ several km sq. - >2600 km sq.
Spectral Resolution	N/A	Panchromatic, colour, and infrared	Panchromatic, visible (blue, green, red), infrared, near infrared, thermal
Information Content	Detailed data on individual trees such as diameter breast height, crown size, and species.	Provides information on location of large trees, broad vegetation types, and possibly the species of pure stands.	Separation of extensive masses of evergreen versus deciduous forests (stand-level to regional characteristics)
Usefulness for Large Area Land Cover Mapping	Useful for accuracy assessments, and locating training areas for satellite imagery.	Useful for medium area land cover mapping that requires detail. For large area mapping useful to assess accuracy, locate training areas, and provide supplementary information.	Useful as the primary data source for land cover mapping due to the large areas imaged, the existing temporal coverage, and digital format.
Pros	Provides detailed data and land use information.	More regional patterns recognizable and less expensive than field data, less detail than satellites, analysis is accurate when experienced photo interpreters are used, effective in remote areas, and some land uses can be interpreted.	Suitable and cost effective for large areas mapping, regional patterns identified, digital format allows automation of classifications, effective in remote areas, and good temporal cover.
Cons	Costly and time consuming to collect, difficult to map large areas, difficult to use in remote areas, and regional patterns not recognizable.	Less detail than field data, may be costly to capture images, costly to analyze, and difficult to map large areas.	Less detail than field data or photography, requires pre-processing before classification, and minimal land use information.

3.0 Development of the EOSD Land Cover Legend

The proposed legend for EOSD (Table 3) is developed from the National Forest Inventory (NFI) Land Cover Classification Scheme that is designed for use with aerial photography. The NFI Land Cover Classification Scheme is based on the British Columbia Land Cover Classification Scheme, which is also used with aerial photography (MOF, 1999). The NFI Land Cover Classification Scheme has been endorsed by the Canadian Forest Inventory Committee (CFIC), a federal/provincial agency that makes forestry inventory recommendations to the provinces and the Canadian Council of Forest Ministers. The CFIC's endorsement of the NFI Land Cover Classification Scheme makes it a useful starting point for developing a legend for large scale mapping in Canada.

A description of the current EOSD Classification Scheme will begin with an introduction to the British Columbia Land Cover Classification Scheme and the NFI Land Cover Classification Scheme.

3.1 British Columbia and NFI Land Cover Classification Scheme

The Resources Inventory Committee, established in 1990 as a result of the British Columbia Forest Resource Commission, is responsible for establishing standards for natural and cultural resource inventories. Two subset groups of the Resources Inventory Committee worked together to produce the British Columbia Land Cover Classification Scheme. The Terrestrial Ecosystems sub-committee was initiated to make recommendations on how to improve the provincial forest inventory. These recommendations became the basis for the British Columbia Land Cover Classification Inventory designed by the Vegetation Inventory Working Group. In the late 1990s the NFI adopted the British Columbia Land Cover Classification Scheme, and since then it has been approved by the CFIC and has gained support from the provinces.

An overview of the British Columbia Land Cover Classification Scheme is shown in the hierarchical keys in Figure 1 and Figure 2. The British Columbia Land Cover Classification Scheme has no land use or economic classes and is based on *current* land cover. Additional attributes may be added to the lowest levels when land use information is required. For example, Level 6 (Leading Species) may be used accurate and detailed species information is available. Although this classification scheme was developed specifically for British Columbia, efforts were made to ensure synergy exists between this and other classification schemes.

The British Columbia Land Cover Classification Scheme is used in conjunction with mid-scale aerial photographs (1:10 000 to 1:20 000). Once uniform areas are delineated with polygons and assessed using hierarchical classes: the polygon is first grouped as Vegetated or Non-Vegetated, then by land cover type, landscape position, and so on, to the lowest level identifiable. Attributes representing the cover for each polygon are assigned through photo interpretation, which is calibrated by air and ground surveys. The levels of the classification scheme can be seen in Table 2 and the possible classification outcomes are presented in more detail in Appendix I.

Table 2. British Columbia Land Cover Classification Scheme levels.

Vegetated	Non-Vegetated
Land Base	Land Base
Land Cover Type	Land Cover Type
Landscape Position	Landscape Position
Vegetation Types	Non-Vegetated Cover Types
Density Class	Non-Vegetated Categories
Leading Species	

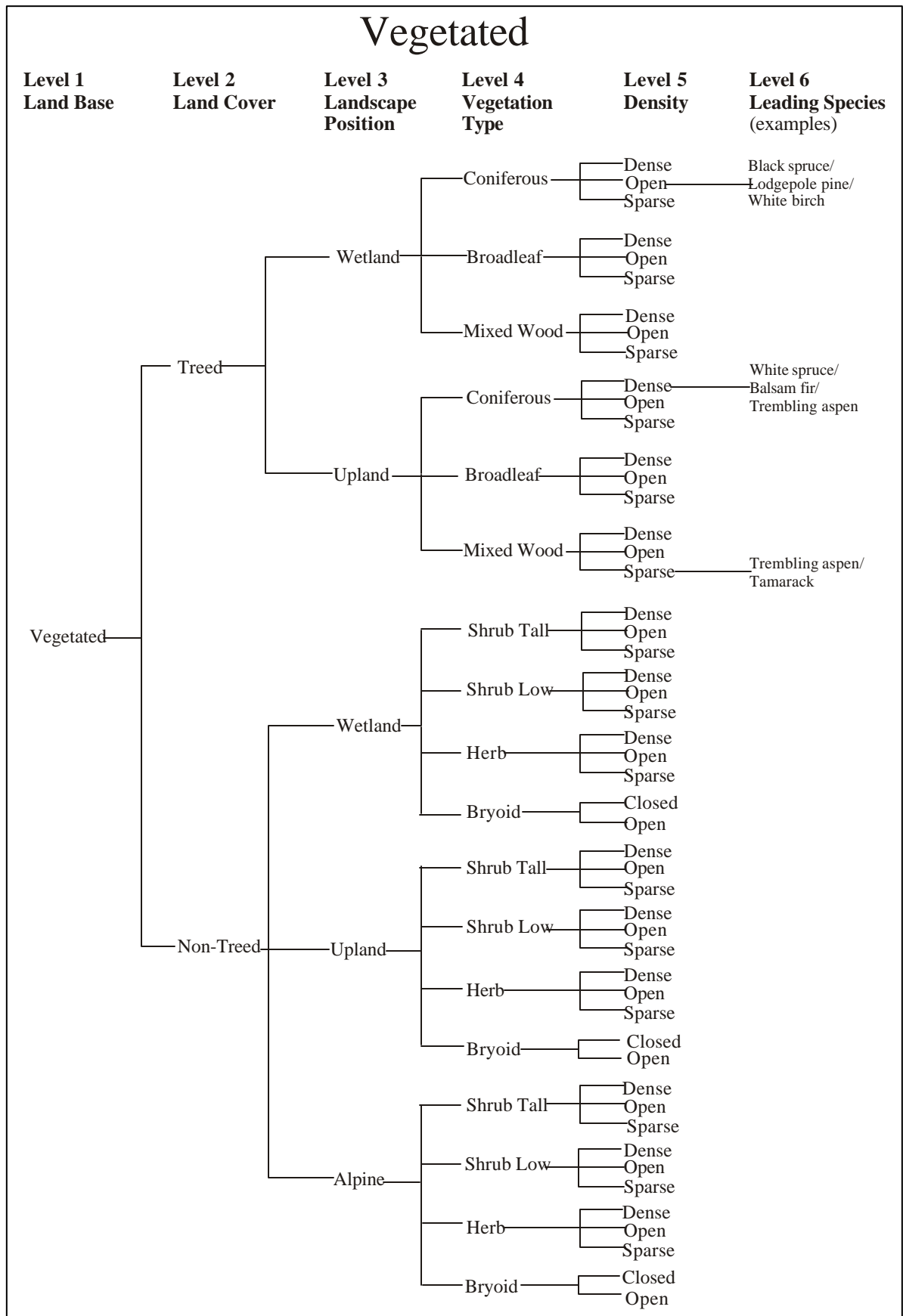


Figure 1 - Structure of the Land Cover Classification Scheme - Vegetated polygons

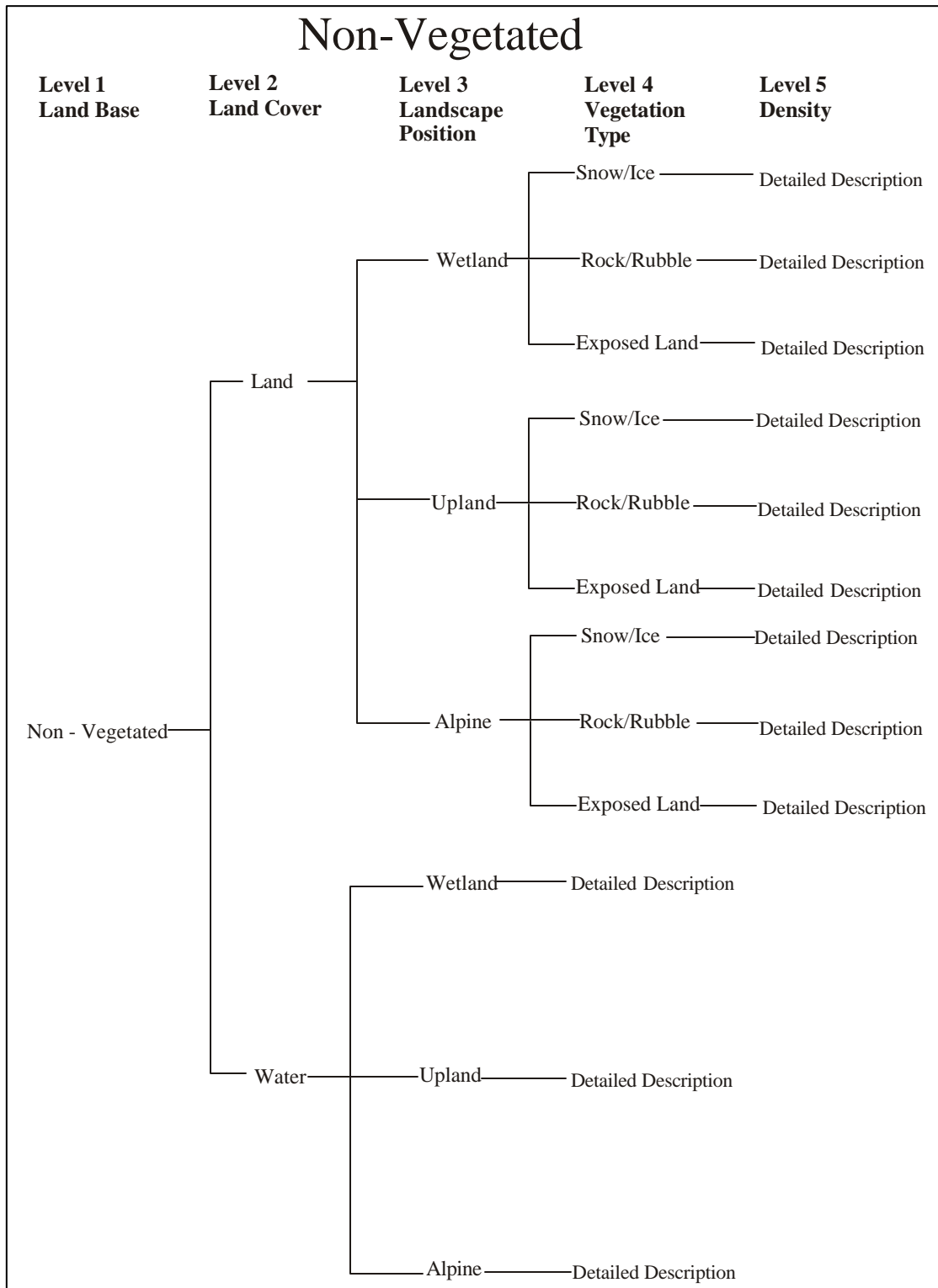


Figure 2 - Structure of the Land Cover Classification Scheme - Non-Vegetated polygons

3.2 The Proposed EOSD Land Cover Legend

The proposed EOSD Land Cover Legend (Table 3) is based on a combination of the British Columbia and NFI Land Cover Classification Scheme's Level 4 (Vegetation Type) and Level 5 (Density Class). For example, the Coniferous – Dense class in the proposed EOSD legend is a combination of *Coniferous* a level four classification and *Dense* a level five classification. The proposed EOSD legend has been *adjusted for large area mapping using Landsat TM imagery*, and therefore is not an exact replica of the EOSD Level – 4 and Level – 5 classes. For detailed definitions of the legend classes refer to Appendix I.

The proposed EOSD legend is based on land cover, rather than land use. At 30 m resolution, most land use classes cannot be differentiated with spectral information alone. For example, high intensity residential area will not be spectrally distinguishable from a high intensity commercial area. Significant amounts of ancillary data are required to identify land use classes from satellite imagery. One of the by-products of a land cover legend is that relatively few non-vegetated classes are used. In the EOSD classification non-vegetated classes include Snow/Ice, Rock/Rubble, and Exposed Land. The Exposed Land class absorbs many land use classes, includes most all development classes. The Herb class is another group that includes many different types of land use: agricultural lands, parks, and golf courses are all considered part of the Herb class in the proposed EOSD legend.

Wetlands are problematic for land cover classifications. The spectral signature of vegetation located on wet and dry land will differ due to changes in moisture content. Therefore, the EOSD legend has separate wetland classes for each of the main vegetation types outlined in the NFI classification scheme.

Table 3. Proposed EOSD Classification Scheme. Based on the NFI Vegetation Type and Density Levels.

Class	Description
No Data	
Cloud	
Shadow	
Snow/Ice	Glacier/snow
Rock/Rubble	Bedrock, rubble, talus, blockfield, rubblely mine spoils, or lava beds.
Exposed Land	<5% vegetation. River sediments, exposed soils, pond or lake sediments, reservoir margins, beaches, landings, burned areas, road surfaces, mudflat sediments, cutbanks, moraines, gravel pits, tailings, railway surfaces, buildings and parking, or other non-vegetated surfaces.
Water	Lakes, reservoirs, rivers, streams, or salt water.
Shrub – Tall	At least 20% ground cover which is at least one-third shrub. Average shrub height \geq 2 m.
Shrub – Low	At least 20% ground cover which is at least one-third shrub. Average shrub height $<$ 2 m.
Herb	Vascular plant without woody stem (grasses, crops, forbs, graminoids). Minimum of 20% ground cover or one-third of total vegetation must be herb.
Bryoids	Bryophytes (mosses, liverworts, and hornworts) and lichen (foliose or fruticose, not crustose). Minimum of 20% ground cover or one-third of total vegetation must be a bryophyte or lichen

Wetland – Coniferous	Land with a water table near, at, or above the soil surface for enough time to promote wetland or aquatic processes. The majority of vegetation is coniferous.
Wetland – Broadleaf	Land with a water table near, at, or above the soil surface for enough time to promote wetland or aquatic processes. The majority of vegetation is broadleaf.
Wetland - Mixed Wood	Land with a water table near, at, or above the soil surface for enough time to promote wetland or aquatic processes. The majority of vegetation is mixed wood.
Wetland - Shrub – Tall	Land with a water table near, at, or above the soil surface for enough time to promote wetland or aquatic processes. The majority of vegetation is tall shrub.
Wetland - Shrub - Low	Land with a water table near, at, or above the soil surface for enough time to promote wetland or aquatic processes. The majority of vegetation is low shrub.
Wetland - Herb	Land with a water table near, at, or above the soil surface for enough time to promote wetland or aquatic processes. The majority of vegetation is herb.
Wetland - Bryoid	Land with a water table near, at, or above the soil surface for enough time to promote wetland or aquatic processes. The majority of vegetation is bryoid.
Coniferous – Dense	> 60% crown closure. Coniferous trees are 75% or more of total basal area.
Coniferous – Open	26-60% crown closure. Coniferous trees are 75% or more of total basal area.
Coniferous – Sparse	10-25% crown closure. Coniferous trees are 75% or more of total basal area.
Broadleaf – Dense	> 60% crown closure. Broadleaf trees are 75% or more of total basal area.
Broadleaf – Open	26-60% crown closure. Broadleaf trees are 75% or more of total basal area.
Broadleaf – Sparse	10-25% crown closure. Broadleaf trees are 75% or more of total basal area.
Mixed Wood – Dense	> 60% crown closure. Neither coniferous nor broadleaf trees account for 75% or more of total basal area.
Mixed Wood – Open	26-60% crown closure. Neither coniferous nor broadleaf trees account for 75% or more of total basal area.
Mixed Wood – Sparse	10-25% crown closure. Neither coniferous nor broadleaf trees account for 75% or more of total basal area.

4.0 Comparison of Land Cover Classification Schemes

The proposed EOSD land cover legend is based on the NFI land cover classification scheme. To determine the quality and appropriateness of the proposed EOSD legend both the legend and the classification scheme from which it was designed should be considered. In this section we compare the NFI Land Cover Classification Scheme with the US National Vegetation Classification Standard (NVCS) and the Land Cover Classification System (LCCS) of the Food and Agricultural Organization of the United Nations.

4.1 National Vegetation Classification Standard

The NVCS was designed by the Federal Geographic Data Committee's Vegetation Subcommittee and is based on The US Nature Conservancy classification system, developed from past federal classification systems and the International Classification and Mapping of Vegetation system proposed by UNESCO (1973). The purpose of the NVCS is to provide a classification system for use as a national minimum standard for US environmental mapping initiatives. Information on the NVCS has been obtained from a document produced by the Vegetation Subcommittee: Federal Geographic Data Committee (1997).

As with the NFI classification scheme, the NVCS is hierarchical: the levels of the NVCS include Division, Order, Physiognomic Class, Physiognomic Subclass, Physiognomic Group, Subgroup, Formation, Alliance, and Association. Land use information is incorporated into the Physiognomic Group, Subgroup, and Formation levels. The two lowest levels of the NVCS are concerned with floristic characteristics of vegetation. The NVCS was not designed for use with any specific technology and therefore the maximum level of detail, which can be classified using the NVCS can not be obtained from aerial photography. Although the NVCS has more detailed vegetation classes than the NFI, the latter has more non-vegetative classes. This distinction is not surprising, as the NFI is a *land cover* classification scheme whereas the NVCS is a *vegetation* classification scheme.

In a classification scheme, the hierarchical level to which a characteristic is assigned reflects its importance. Most of the NFI level characteristics are considered in the same order as NVCS characteristics. For example, an area is assessed first for the presence of vegetation, second for the type of vegetation, and third for the density of the vegetation. The NFI scheme considers landscape position before species, though in the NVCS scheme this is reversed, suggesting that landscape position is more important to the NFI scheme and species more important to the NVCS scheme. As well, the types of landscape positions identified in each scheme are different. In the NFI landscape position is based on drainage patterns which result from relative differences in elevation, whereas the NVCS landscape position is based on latitude. Landscape positions in the NFI scheme are Wetland, Upland, and Alpine and in the NVCS scheme includes classes such as Tropical, Temperate, and Subpolar.

Unlike the NVCS, which was not designed to be compatible with any specific technology, the NFI classification scheme was designed for use with aerial photography. Generally the NFI appears more appropriate for use with remotely sensed data. For example, the NVCS requires Non-Vegetated areas to have <1% vegetation cover, whereas the NFI scheme

requires <5% vegetation cover for the same class. It is unrealistic to obtain density accuracy of 1% using aerial photography or satellite imagery; the 5% break suggested by the NFI classification scheme is more appropriate for use with remotely sensed imagery (MOF, 1999).

A legend developed from the NFI Vegetation Type/Density level classes is similar to a legend produced from the NVCS Subclass level. The proposed EOSD classes are derived from the NFI Vegetation Type/Density level classes; therefore, at this point we will leave the comparison of the classification schemes and focus on the similarities and differences between legends produced by the NFI Vegetation Type/Density level classes and the NVCS Subclass level classes. In Table 4 we describe NVCS Subclass level classes and compare them with the NFI Vegetation Type/ Density Level classes described in the earlier Table 3.

There are many similarities between the NFI Vegetation Type/Density level legend and NVCS Subclass level legend, further known as the NFI legend and NVCS legend. The NFI and NVCS legends classify land cover and have no land use classes. Both legends include classes for coniferous/evergreen and broadleaf/deciduous, and mixed wood trees, shrubs, herbs, and bryoids. The thresholds used to separate open and closed classes are the same for both legends: closed classes require greater than 60% crown closure and open classes require 25-60% crown closure. The sparse class in the NFI legend is not represented in the NVCS legend. As well, different thresholds are used to separate large and small shrubs. The NVCS imposes a 0.5 m threshold whereas the NFI legend uses a threshold of 2 m. The Coniferous/Evergreen and Broadleaf/Deciduous classes in both legends require the cover type to be at least 75% pure. The definitions of mixed forest are similar also between legends. In the NFI Mixed Wood class coniferous/evergreen and broadleaf/deciduous trees must not account for more than 75% of the basal area; the NVCS class has the added restriction that coniferous/evergreen and broadleaf/deciduous must account for at least 25% of the area.

As previously mentioned, for a polygon to be grouped in any of the NFI classification scheme's vegetation classes it must have 5% vegetation cover, whereas the NVCS classification scheme requires a polygon to have 1% vegetation cover in order to be classified in a vegetation class. The different thresholds of the two systems result in different definitions of the vegetation and non-vegetation classes, which in turn effects the definitions of the legend classes. The result is that some NVCS vegetation classes are similar to NFI non-vegetation classes. For example, the NVCS vegetation classes Consolidated Rock Sparse Vegetation, Boulder/Gravel/ Cobble/Talas/Sparse Vegetation, and Unconsolidated Material Sparse Vegetation classes are all approximately equal to the non-vegetated NFI Rock/Rubble class.

Overall, the NVCS legend has fewer non-vegetation classes and more detailed vegetation classes than the NFI. The NVCS legend has classes for different species and heights of shrub classes, whereas the NFI only considers shrub height. As well, both NFI Herb and Bryophyte classes are broken into several classes in the NVCS legend. The NFI legend, however, has several wetland classes not represented in the NVCS legend.

There are differences between the NFI and NVCS classification schemes and legend; however the vegetation classes produced by the NFI and NVCS legends are approximately synonymous. The classes differ in thresholds and level of species detail though the legend structure is similar. To reclassify a map generated with the NVCS legend to the NFI legend would be quite simple, although reclassification of the NFI legend to the NVCS legend would be ineffective as the NVCS legend requires more detailed information. It should be noted that even the detail required by a legend created at the NVCS Subgroup level is unlikely to be extracted from satellite imagery.

Table 4. NVCS-Subclass legend, class description and comparison with proposed EOSD legend classes.

Class (Based on NVCS Subclass)	Description	Correlated EOSD Class(es)
Evergreen Open	Evergreen tree species contribute >75% of the total tree cover and the area has 60-100% crown closure.	Coniferous – Dense
Deciduous Closed	Deciduous tree species contribute >75% of the total tree cover and the area has 60-100% crown closure.	Broadleaf – Dense
Mixed Evergreen-Deciduous Closed	Evergreen and deciduous tree species each contribute 25-75% of total tree cover and the area has 60-100% crown closure. (Includes semi-deciduous, semi-evergreen, mixed evergreen deciduous xeromorphic, and mixed needle-leaved evergreen-cold-deciduous woody vegetation.)	Mixed Wood – Dense
Evergreen Open	Evergreen tree species contribute to > 75% of the total tree cover and the area has 25-60% crown closure.	Coniferous - Open
Deciduous Open	Deciduous tree species contribute to >75% of the total tree cover and the area has 25-60% crown closure.	Broadleaf - Open
Mixed Evergreen-Deciduous Open	Evergreen and deciduous tree species each contribute 25-75% of total tree cover and the area has 25-60% crown closure. (Includes semi-deciduous, semi-evergreen, mixed evergreen deciduous xeromorphic, and mixed needle-leaved evergreen-cold-deciduous woody vegetation.)	Mixed Wood - Open
Evergreen Shrubland	Shrubs > 0.5 m tall with individual clumps not touching or overlapping and evergreen species contribute > 75% of the total shrub cover. The area has > 25% canopy closure and trees account for < 25% canopy closure.	Shrub - Tall
Deciduous Shrubland	Shrubs > 0.5 m tall with individual clumps not touching or overlapping and deciduous species contribute to > 75% of the total shrub cover. The area has > 25% canopy closure and trees account for < 25% canopy closure.	Shrub – Tall
Mixed Evergreen-Deciduous Shrubland	Shrubs > 0.5 m tall with individual clumps not touching or overlapping, and evergreen and deciduous species each contribute 25-75% of total tree cover. The area has > 25% canopy closure and trees account for < 25% canopy closure. (Includes facultatively deciduous, extremely xeromorphic mixed evergreen-deciduous woody plants.)	Shrub – Tall
Evergreen Dwarf-Shrub	Shrubs 0.5 m tall with individual clumps not touching or overlapping and evergreen species contribute >75% of the total shrub cover. The area has > 25% canopy closure and trees	Shrub – Low

	account for < 25% canopy closure.	
Deciduous Dwarf-Shrub	Shrubs 0.5 m tall with individual clumps not touching or overlapping and deciduous species contribute > 75% of the total shrub cover. The area has > 25% canopy closure and trees account for < 25% canopy closure.	Shrub – Low
Mixed Evergreen-Deciduous Dwarf-Shrubland	Shrubs 0.5 m tall with individual clumps not touching or overlapping and evergreen and deciduous species each contribute 25-75% of total tree cover. The area has > 25% canopy closure and trees account for < 25% canopy closure. (Includes facultatively deciduous, extremely xeromorphic mixed evergreen-deciduous woody plants.)	Shrub – Low
Perennial Graminoid Vegetation	Herbaceous canopy cover > 25% and perennial graminoids contribute to > 50% of total herbaceous canopy cover.	Herb
Perennial Forb Vegetation	Herbaceous canopy cover > 25% and perennial forbs (including ferns and biennials) contribute to > 50% of total herbaceous canopy cover.	Herb
Hydromorphic Rooted Vegetation	Herbaceous canopy cover > 25% and non-emergent graminoid or forbs structurally supported by water and rooted in substrate (e.g.. pond weed and water lilies).	Herb
Annual Graminoid or Forb Vegetation	Herbaceous canopy cover > 25%.	Herb
Bryophyte Vegetation	Nonvascular cover > 25% and bryophytes dominate the nonvascular cover.	Bryoids
Lichen Vegetation	Nonvascular cover > 25% and lichens (foliose or fruticose) dominate the nonvascular cover.	Bryoids
Alga Vegetation	Nonvascular cover > 25% and algae dominate the nonvascular cover.	Bryoids
Consolidated Rock Sparse Vegetation	Vegetation between 1-10%. Includes cliffs, pavement, incl. pahohoe lava flows.	Rock/Rubble
Boulder, Gravel, Cobble, or Talas Sparse Vegetation	Vegetation between 1-10%. Includes lava flows.	Rock/Rubble
Unconsolidated Material Sparse Vegetation	Vegetation between 1-10%. Isolated herbs or occasional shrubs.	Rock/Rubble
Non-Vegetated	< 1% vegetation.	Snow/Ice Rock/Rubble Exposed Land Water
N/A		Shadow
N/A		All Wetland classes
N/A		Coniferous - Sparse
N/A		Broadleaf - Sparse
N/A		Mixed Wood - Sparse

4.2. FAO Land Cover Classification System

The Land Cover Classification System (LCCS), produced by the Food and Agricultural Organization of the United Nations, is intended to be an exhaustive classification system capable of capturing any land cover identified anywhere in the world (Di Gregorio and Jansen 2000). The LCCS is also intended to allow for correlation with existing classifications and legends. The intention of this approach is to allow for the selection of locationally appropriate classes without the development of impractical combinations of classifiers. A software tool has also been developed to aid in the correlation of existing classification structures with the LCCS. The goals of the developers of the LCCS are to aid in efforts towards standardization of land cover mapping efforts. The LCCS is intended to act as a basis for a reference classification system. The ability to correlate to other classifications is possible through the use of criteria based classes rather than classes based solely on nomenclature. The LCCS is based upon land cover (and is defined as “the observed (bio)physical cover on the earth’s surface.” The classification is intended to be scale and source independent. This implies that any class in the LCCS can be derived from any source of data (including field plots to satellite imagery). After the LCCS web site¹, the goals of the program are to:

- respond to the need for land cover data of a variety of end-users;
- apply the methodology in mapping exercises, independent of the means used, which may range from high resolution satellite imagery to aerial photography;
- link with existing classifications and legends, allowing comparison and correlation;
- support international ongoing initiatives on classification and definition of land cover; and
- harmonize principles and methodology for land cover mapping.

The classification is based upon two phases, an initial (dichotomous) phase with eight major land cover types, and a second (modular-hierarchical) phase that allows for the specification of greater detail. Dichotomous Phase of the LCCS includes,

- cultivated and managed terrestrial areas
- natural and semi-natural vegetation
- cultivated aquatic or regularly flooded areas
- natural and semi-natural aquatic or regularly flooded areas
- artificial surfaces and associated areas
- bare areas
- artificial water bodies, snow and ice, and
- natural water bodies, snow and ice

Elements of land use are present in the Dichotomous Phase. Satellite based interpretation of land cover would not necessarily allow for the determination of managed versus unmanaged, natural versus un-natural, etc. Additionally, ancillary data would be required within the dichotomous phase to indicate the persistence of water (to determine flood regularity and

¹ <http://www.lccs-info.org/>

duration). This Dichotomous Phase is followed by a Modular-Hierarchical Phase. It is within this second phase that land cover classes may be created by combining sets of pre-defined classifiers. The classifiers are developed to nest within each of the elements of the Dichotomous Phase (see Figure 3). The intent is then to create the most appropriate / descriptive class based upon combining of the pre-defined classifiers. Once the Dichotomous Phase class is defined, there are a series of eight cover specific descriptors that can then be applied. The cover specific descriptors, of the Modular-Hierarchical Phase, allow for the definition of detailed land cover characteristics appropriate to that Dichotomous Phase element. For instance, for a forested area, the Dichotomous Phase categories of,

- primarily vegetated,
 - terrestrial, and
 - (semi) natural vegetation
- will be defined. With Modular-Hierarchical Phase elements that may be defined, including,
- life form and cover (land cover),
 - height (land cover),
 - macro pattern (land cover),
 - leaf type (land cover),
 - leaf phenology (land cover),
 - stratification (land cover),
 - land form (environmental variables),
 - lithology/soils (environmental variables),
 - climate (environmental variables),
 - altitude (environmental variables),
 - erosion (environmental variables), and
 - floristic aspect (specific aspects).

Of the Modular-Hierarchical Phase elements, the nature of the differing attributes is noted in brackets, such as land cover, environmental variables, and specific aspects. When developing a particular class it is not necessary to define all of the above attributes of a particular class. The software that is available in support of LCCS aids in the class development. The intent is to step users through the hierarchy, enabling the development of mutually exclusive classes. (In practice, some problems with using the LCCS software for class development were encountered and will be described below.)

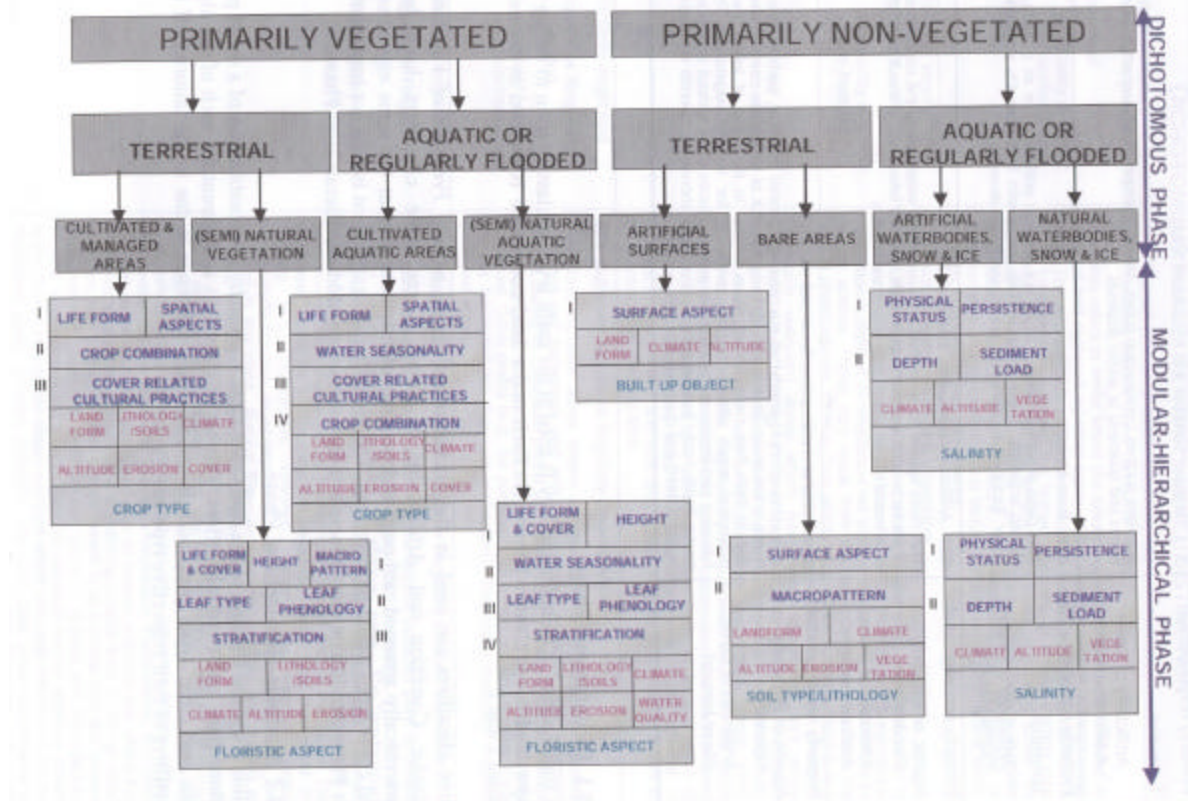


Figure 3. Overview of the LCCS, including the two phases and classifiers (From Di Gregorio and Jansen 2000).

Most EOSD classes may be correlated reasonably to a LCCS class (Table 5). The quality and appropriateness of the matches requires further discussion. In the LCCS for each class a code and a formula area also developed. The class codes define which LCCS classes are included in making up the particular class (a Boolean formula). The class formula allows for unique numeric identification of the developed class. The exhaustiveness of the EOSD classification is no longer ensured when mapped to the LCCS standard, as the inter-class divisions occur at different locations, such as crown closure and height criteria of the forested classes. The shrub classes are over specified in the LCCS scheme with respect to Landsat level information content. The EOSD wetland classes are not well captured with the LCCS. As mentioned, some issues emerged when attempting to correlate the LCCS and EOSD classifications. The issues will be noted by LCCS program module heading.

Classification:

When using the classification module of the LCCS program, where the classes of the EOSD legend may be transformed in to LCCS classes, some issues are evident. Some issues are due to the fact that LCCS classes (as one progresses down the classification tree) are very specific. The user must descend down the tree to a point where the “select attribute” button becomes highlighted or activated. At this point he/she will now be able to select whether the defined land cover class is a single or mixed unit. It is not until reaching this point that the user is able to save the selected land cover class. As an example, when converting the

EOSD class *bryoids* (minimum 20% groundcover) into LCCS, we wanted to create a class that stopped at the level “*lichens*” or perhaps the next level down “*lichens / mosses*”, but were not able to stay at this level because the “*selected attribute*” button was not yet activated. It was not until the next level down where the user selects one of “*sparse / closed / open*” that the button is activated. At this level, to fully capture the EOSD bryoid class we would need to select four groups or categories as follows:

- Lichens/ Mosses --- lichens ----- closed (> 65%)
- Lichens/ Mosses --- lichens ----- open (65- 15%)
- Lichens/ Mosses --- mosses ----- closed (>65%)
- Lichens/ Mosses --- mosses ----- open (65 – 15%)

This would be acceptable except for the fact that the program only allows a maximum of three mixed groups. For most of the areas under consideration for the forested area of Canada, many of the classes present in the Dictomous Phase of the LCCS hierarchy were not pertinent. For example classes such as “*cultivated & managed terrestrial areas*”, “*cultivated aquatic or regularly flooded area*”, and “*artificial surfaces, artificial water bodies*” were too specific for the resolution of our imagery, requiring land use or other ancillary information

Translator Module:

When choosing the import button, and bringing up the “*class selection for imported legend*”. Upon selecting the “*retrieve from legend*” button, the user is unable to select a mixed class from the legend. An error message occurs saying “you cannot import a mixed class, only the components of a mixed class”. To mitigate this, we had to manually enter the LCCS codes and formulas for any mixed classes. At this point, there is only space to enter two mixed classes whereas the in the classification module, you were permitted to enter three classes.

The LCCS is a useful classification scheme, especially when generality and the capture of multiple land cover domains is of interest. In some respects, the LCCS is on an equivalent information level as the NFI level 6. The level of detail required to specify classes in the LCCS is often beyond the information content available when classifying Landsat imagery. To fully compare the LCCS to the EOSD classification, it would be required to map the LCCS classes to the NFI level 6 classes, then map up to the Landsat appropriate EOSD-NFI classes. The disaggregating would be necessary to develop classes that are appropriate for the classification of Landsat imagery.

Table 5. LCCS legend, class description and comparison with proposed EOSD legend classes (also included are LCCS codes and associated formulas).

LCCS Label LCCS Code LCCS Formula	LCCS Description	Correlated EOSD Class(es)
Needle leaved Closed Forest 20098 A3A10B2C1D2	The main layer consists of needle leaved closed forest. The crown cover is more than (70-60)%. The height is in the range of >30 - 3m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks.	Coniferous – Dense
Broadleaved Closed Forest 20095 A3A10B2C1D1	The main layer consists of broadleaved closed forest. The crown cover is more than (70-60)%. The height is in the range of >30 - 3m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks.	Broadleaf – Dense
Mixed Forest 20099-15045 A3A10B2C1D2E1-E3	The main layer consists of needle leaved evergreen closed forest. The crown cover is more than (70-60)%. The height is in the range of >30 - 3m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks.	Mixed Wood – Dense
Needle leaved Woodland 20140 A3A11B2C1D2	The main layer consists of needle leaved woodland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks.	Coniferous - Open
Broadleaved Woodland 20137 A3A11B2C1D1	The main layer consists of broadleaved woodland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks.	Broadleaf - Open
Mixed Woodland 20141-15045 A3A11B2C1D2E1-E3	The main layer consists of needle leaved evergreen woodland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks.	Mixed Wood - Open
Needle leaved Sparse ((20-10) - 4%) Trees 20235-6022 A3A14B2C3D2-A15	The main layer consists of needle leaved sparse trees. The crown cover is between (20-10) and 1%. The sparseness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range. The vegetation is spread over the area in patches.	Coniferous - Sparse

Broadleaved Sparse ((20-10) - 4%) Trees 20232-6022 A3A14B2C3D1-A15	The main layer consists of broadleaved sparse trees. The crown cover is between (20-10) and 1%. The sparseness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range. The vegetation is spread over the area in patches.	Broadleaf - Sparse
Mixed Sparse ((20-10) - 4%) Trees 20236-9018 A3A14B2C3D2E1-A15E3	The main layer consists of needle leaved evergreen sparse trees. The crown cover is between (20-10) and 1%. The sparseness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range. The vegetation is spread over the area in patches.	Mixed Wood - Sparse
Closed High Shrubland (Thicket) Open High Shrubs (Shrubland) Open High Shrubs (Shrubland) 20018-13395 / 20022-13395 / 20022-13395 A4A10B3-B8 / A4A11B3-B8 / A4A11B3-B8	The main layer consists of closed shrubland. The crown cover is more than (70-60)%. The height is in the range of 5 - 0.3m but may be further defined into a smaller range. The main layer consists of open shrubland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of 5 - 0.3m but may be further defined into a smaller range. The main layer consists of open shrubland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of 5 - 0.3m but may be further defined into a smaller range.	Shrub – Tall
Closed Dwarf Shrubland (Thicket) Open Dwarf Shrubs (Shrubland) Open Dwarf Shrubs (Shrubland) 20018-12050 / 20022-12050 / 20022-12050 A4A10B3-B10 / A4A11B3-B10 / A4A11B3-B10	The main layer consists of closed shrubland. The crown cover is more than (70-60)%. The height is in the range of 5 - 0.3m but may be further defined into a smaller range. The main layer consists of open shrubland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of 5 - 0.3m but may be further defined into a smaller range. The main layer consists of open shrubland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of 5 - 0.3m but may be further defined into a smaller range.	Shrub – Low
Open Grassland 20045 A6A11	The main layer consists of open grassland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified.	Herb
Open Lichens Open Mosses Closed Mosses 21439 / 21440 / 2143 A8A11 / A9A11 / A9A10	The main layer consists of open lichens. No other layer is specified. The main layer consists of open mosses. No other layer is specified. The main layer consists of closed mosses. No other layer is specified.	Bryoids
Built Up Area(s) Consolidated Material(s) Unconsolidated Material(s)	The land cover consists of built up area The land cover consists of consolidated material(s). The land cover consists of unconsolidated material(s).	Exposed Land

5001 / 6001 / 6004 A1 / A1 / A2		
Bare Rock(s) Gravels, Stones And/Or Boulders Bare Rock And/Or Coarse Fragments - Stones 6002-1 / 6002-2 / 6002-9 A3-A7 / A3-A8 / A3-A15	The land cover consists of bare rock and/or coarse fragments. Coarse fragments can be further specified into gravel, stones and/or boulders. The land cover consists of bare rock and/or coarse fragments. Coarse fragments can be further specified into gravel, stones and/or boulders. The land cover consists of bare rock and/or coarse fragments. Coarse fragments can be further specified into gravel, stones and/or boulders.	Rock/Rubble
Woodland Forest Forest 40007 / 40003 / 40003 A3A13 / A3A12 / A3A12	The main layer consists of woodland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The main layer consists of closed forest. The crown cover is more than (70-60)%. The main layer consists of closed forest. The crown cover is more than (70-60)%.	Wetland - Treed
Open Shrubs Closed Shrubs Closed Shrubs 40011 / 40009 / 40009 A4A13 / A4A12 / A4A12	The main layer consists of open shrubs. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The main layer consists of closed shrubs. The crown cover is more than (70-60)%. The main layer consists of closed shrubs. The crown cover is more than (70-60)%.	Wetland - Shrub
Open Medium To Tall Forbs Open Medium To Tall Grassland 40022-44611 / 40024-44611 A5A13B4-B15 / A6A13B4-B15	The main layer consists of open forbs. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of 3 - 0.03m but may be further defined into a smaller range. The main layer consists of open grassland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of 3 - 0.03m but may be further defined into a smaller range.	Wetland - Herb
Snow /Ice 8005 / 8008 A2 / A3	The land cover consists of snow. The land cover consists of ice. A further specification can be made in moving or stationary ice.	Snow / Ice
N/A		No Data
N/A		Cloud
N/A		Shadow

The LCCS classification system, while not appropriate to meet the goals of EOSD, may provide a useful structure for a national land cover classification scheme for Canada. EOSD land cover mapping will cover a large portion of Canada, leaving only agricultural and far non-forested northern areas unmapped. The LCCS may provide a structure for the merging of maps produced over these three domain areas. Each of the domain areas can continue to map the specific jurisdictional land covers to best meet the national needs – these land cover maps could then be combined using the LCCS as a guide. The content of the mapped information may be altered (degraded) through the correlation with the LCCS from the domain specific land cover maps, but a cohesive national land cover map could be developed. The draft development of a potential land cover classification for Canada based upon the LCCS would be a useful exercise.

5.0 Comparison of Satellite Land Cover Classification Legends

To this point, we have compared the NFI and the NVCS and LCCS classification schemes and potential legends: the NFI classification scheme was designed for use with aerial photography and the NVCS classification scheme was designed without a specific technology in mind. The following is a discussion of classification *legends* designed specifically for large area mapping with satellite imagery. Reviewing large area satellite classification legends has two purposes:

1. to enable us to locate unnecessary or missing classes within the proposed EOSD legend;
2. to provide information on the successes and difficulties of working with tested legends, thereby allowing modification of the EOSD legend for maximum success.

Although the classifications systems compared below are all used for large area mapping with satellite data, the methods of classification differ significantly between projects. In particular, the level to which classification systems are automated differs and the amount and types of ancillary data used differs; therefore, the level of detail in each legend also differs.

5.1 Canada's Centre for Remote Sensing Large Area Land Cover Satellite Mapping Legend

Canada's Centre for Remote Sensing (CCRS) uses a large area, land cover, satellite mapping legend based on the NVCS. The CCRS legend and correlated EOSD classes are shown in Table 6. The CCRS legend was designed for use with AVHRR satellite data. Although the CCRS legend is similar to the NVCS – Subclass legend described above, there are a few differences. Only classes that are different than the NVCS legend described above will be discussed in this section.

There are several differences between the NVCS legend and the derived CCRS legend. The most notable is the large number of mixture classes used in the CCRS legend and the inclusion of some wetland classes. Other differences include the separation of the NVCS – Closed Evergreen class into Mature and Young in the CCRS classification, while, the NVCS Evergreen-Open classes is divided into Medium and Low density classes in the CCRS classification.

Although both legends have shrubs, only the NVCS divides shrubs by height. The CCRS legend only considers tall shrubs. Agricultural classes are also different. True to land cover mapping, the NVCS does not separate agriculture classes from other herbs, while the CCRS legend has three separate classes for row crops based on density. The CCRS legend uses an Urban and Built-up class that is not identified in the NVCS legend. As well, there are more non-vegetation classes in the CCRS legend, such as Mostly Bare Disturbed Areas and Rock Outcrop, and a recent burn class has been included.

Some differences between the NVCS and CCRS legends are due to the fact that while the NVCS was not designed for use with a specific technology the CCRS legend was designed for use with satellite imagery. Although the CCRS legend is designed for use with both spatially coarse and fine data, it is likely not appropriate for use with Landsat resolution

imagery. Perennial and Annual Graminoid classes, of which there are 16, are almost all mixture classes. For example, these classes contain mixtures such as herb, moss, and shrubs; grass and shrub; and cropland and woodland. These types of mixture classes are suitably used with coarse spatial resolution imagery, but are not suitably used with fine spatial resolution imagery.

Table 6. CCRS Large Area Land Cover Satellite Mapping Legend.

Class	Description	Correlated EOSD Class(es)
Closed Evergreen Mature	> 60% crown closure, > ~60 years, temperate or subpolar needle-leaved evergreen, and evergreen species contribute to > 75% of the total tree area.	Coniferous – Dense
Closed Evergreen Young	> 60% crown closure, > ~30-40 years, temperate or subpolar needle-leaved evergreen, and evergreen species contribute to > 75% of the total tree area.	Coniferous – Dense
Closed Deciduous	> 60% crown closure, cold-deciduous, and deciduous species contribute to > 75% of the total tree area.	Broadleaf – Dense
Closed Mixed Coniferous	> 60% crown closure, mixed needle-leaved evergreen and cold-deciduous closed tree, and coniferous species contribute to > 50% of the total tree area.	Mixed Wood – Dense
Closed Mixed Deciduous	> 60% crown closure, mixed needle-leaved evergreen and cold-deciduous closed tree, and deciduous species contribute to > 50% of the total tree area.	Mixed Wood – Dense
Medium Density Evergreen	40-60% crown closure, temperate or subpolar needle-leaved evergreen open tree, evergreen species contribute to > 75% of the total tree area, and may include sub-classes for Moss-shrub or Lichen understory.	Coniferous – Open
Low Density Evergreen	25-40% crown closure, temperate or subpolar needle-leaved evergreen open tree, evergreen species contribute to > 75% of the total tree area, and may include sub-classes for Moss-shrub or Lichen understory.	Coniferous – Sparse
Open Deciduous - Low Regenerating Broadleaf Cover	Cold deciduous open tree canopy.	Broadleaf - Open Broadleaf - Sparse
Open Mixed Evergreen/Deciduous - Low Regenerating Broadleaf Cover	Mixed needle-leaved evergreen and cold-deciduous open tree.	Mixed Wood - Open Mixed Wood - Sparse
Deciduous Shrubs - High	Subalpine or subpolar cold-deciduous shrubland.	Shrub - Tall Shrub - Low
Perennial Graminoid Vegetation - Grassland, Prairie Region	Medium-tall temperate or subpolar grassland.	Herb
Perennial Graminoid Vegetation - Wetlands	Saturated temperate or subpolar wetlands.	Wetland -Herb

Perennial Graminoid Vegetation - Herb/Moss/Shrub	Medium-tall temperate or subpolar grassland with a sparse needle-leaved evergreen or mixed tree layer and trees are < 25% of cover.	Herb
Perennial Graminoid Vegetation - Treed wetlands	Saturated temperate or subpolar wetlands with a sparse needle-leaved evergreen tree.	Wetland - Coniferous
Perennial Graminoid Vegetation - Grass and Shrubs	Short sod polar grassland.	Shrub - Low
Perennial Graminoid Vegetation - Shrubs and Grass	Polar grassland with sparse shrub layer.	Herb
Perennial Graminoid Vegetation - Shrubs, Grass, and Water Bodies	Polar grassland with sparse shrub layer and water bodies.	Wetland - Shrub - Low
Perennial Graminoid Vegetation - Heather and Herbs	Polar grassland with shrub dwarf-shrub layer.	Herb
Perennial Graminoid Vegetation - Heather, Herbs, and Water Bodies	Polar grassland with shrub dwarf-shrub layer and water bodies.	Wetland - Herb
Perennial Graminoid Vegetation - Low Vegetation Cover	Polar grassland with shrub dwarf-shrub layer and bare soil or rock outcrops.	Shrub - Low
Perennial Graminoid Vegetation - Low Vegetation Cover With Snow	Polar grassland with shrub dwarf-shrub layer, bare soil or rock outcrops, and snow.	Herb Exposed Land Snow/Ice
Annual Graminoid or Forb Vegetation - Cropland- Woodland	Mosaiced land with woodland and cropland.	Herb
Annual Graminoid or Forb Vegetation - Woodland- Cropland	Mosaiced land with cropland and woodland.	Herb
Annual Graminoid or Forb Vegetation - Annual Row Crop - High Biomass	Temperate or subpolar annual row-crop forbs and grasses with high biomass	Herb

Annual Graminoid or Forb Vegetation – Annual Row Crop – Medium Biomass	Temperate or subpolar annual row-crop forbs and grasses with medium biomass	Herb
Annual Graminoid or Forb Vegetation – Annual Row Crop – Low Biomass	Temperate or subpolar annual row-crop forbs and grasses with low biomass	Herb
Lichens/Moss/Shrub	Temperate or subpolar lichen vegetation with a sparse tree layer. < 25% tree cover.	Bryoid
Moss/Shrubs/Lichen	Temperate or subpolar lichen vegetation with a sparse tree layer. < 25% tree cover.	Bryoid
Sparse Vegetation	1-10% vegetation. Consolidated rock sparse vegetation.	Rock/Rubble Exposed Land
Rock Outcrop	Pavement with sparse vascular vegetation such as rock outcrop and low vegetation cover.	Exposed Land
Recent Burns	Unconsolidated, sparsely vegetated soil flats.	Exposed Land
Mostly Bare Disturbed Areas	Unconsolidated, sparsely vegetated soil flats.	Exposed Land
Low Vegetation	Unconsolidated, sparsely vegetated soil flats.	Herb Exposed Land
Urban and Built-up	< 1% vegetation	Exposed Land
Water Bodies	< 1% vegetation	Water
Mixes of Water and Land		Wetland - Conifer Wetland - Broadleaf Wetland - Mixed Wood Wetland - Shrub - Tall Wetland - Shrub - Low Wetland - Herb Wetland Bryoid
Snow/Ice		Snow/Ice
Clouds		Clouds
N/A		Shadow

The CCRS legend has not been tested, though a version was used to map land cover in Canada with AVHRR imagery. The most notable difference between the proposed CCRS legend and the one actually used is the reduced number of herb classes. Herb classes include Heather and Herbs; Low Vegetation Cover; Very Low Vegetation Cover; Bare Soil and Rock; and High, Medium, and Low Biomass Cropland. For a detailed view of the classes used in the AVHRR land cover mapping of Canada refer to Table 7.

Table 7. Classes used for AVHRR Land Cover Mapping of Canada.

Classes
Evergreen Needleleaf - Low Density – Southern Forest
Evergreen Needleleaf - High Density Forest
Evergreen Needleleaf - Medium Density - Northern Forest
Evergreen Needleleaf - Medium Density - Southern Forest
Evergreen Needleleaf - Low Density - Northern Forest
Deciduous Broadleaf Forest
Mixed Needleleaf Forest
Mixed Intermediate Uniform Forest
Mixed Intermediate Heterogeneous Forest
Mixed Broadleaf Forest
Burns - Low Green Vegetation Cover
Burns - Green Vegetation Cover
Transition Treed Shrubland
Wetland/Shrub Land - High Density
Wetland/Shrub Land - Medium Density
Grassland
Barren Land - Shrubs and Lichen Dominated
Barren Land - Lichen and Others
Treeless - Heather and Herbs
Treeless - Low Vegetation Cover
Treeless - Very Low Vegetation Cover
Treeless - Bare Soil and Rock
Cropland - High Biomass
Cropland - Medium Biomass
Cropland - Low Biomass
Mosaic Land - Cropland-Woodland
Mosaic Land - Woodland-Cropland
Mosaic Land - Cropland-Other
Urban and Built-up
Non-Vegetated Land
Water
Ice/Snow

5.2 USGS National Land Cover Dataset (Satellite Imagery)

One of the key large area satellite mapping projects in the US is the National Land Cover Dataset (NLCD). Definitions of the NLCD legend and a comparison with the EOSD legend can be viewed in Table 8. The NLCD legend is based on the Anderson Land Use/Cover Classification Scheme. The NLCD legend includes land use classes, and as a result there are often several NLCD classes that represent one EOSD class. For example, the proposed EOSD Herb class is represented by NLCD classes Grasslands /Herbaceous, Pasture/Hay, Row Crops, Small Grains, Fallow, and Urban/Recreational Grasses; the EOSD Exposed Land class is represented by NLCD classes Low Intensity Residential, High Intensity Residential, and Commercial/Industrial/Transportation.

The key similarities between the NLCD and EOSD legends are the deciduous/broadleaf, coniferous/evergreen, and mixed forest classes. In both legends, the deciduous/broadleaf, coniferous/evergreen, classes require the cover type to be at least 75% pure, while mixed forest have similar species composition definitions: coniferous/evergreen and broadleaf/deciduous trees must not account for more than 75% of the basal area. Although the species composition of forest classes is the same, in both legends a minimum tree height of 6 m is required by the NLCD legend, whereas minimum tree height is 2 m in the proposed EOSD legend.

In the NLCD legend, burns and clear cut are represented by a Transitional class. There is no such class in the proposed EOSD legend; burn and possibly clear cut areas are grouped, along with several other classes, in the Exposed Land class. The Transitional class is a unique way of dealing with burn and clear cut areas as their transitional nature makes them difficult to classify. In the NLCD areas are removed from the transitional classes once they have 25 % or greater cover.

A 1992 NLCD accuracy assessment was performed on four regions in the US: New England, New Jersey/New York, the mid-Atlantic, and the southeast. One of the most difficult classes to accurately capture was the Transitional class due to the temporary clearing and regeneration of trees. The Transitional class was most often confused with forest and shrubs, while burns were confused with shadow. Often the transitional class required manual interpretation (Howard, pers com, 2001). Similar problems exist within the agricultural classes due to crop rotation: Hay/Pasture was often confused with Row Crops and Grasslands/Herbaceous. Coniferous and Evergreen areas were located accurately, while the Mixed Forest class was confused primarily with the Evergreen forest class.

In all but the southeast region, Woody Wetlands were often confused with the forest class. Emergent Wetlands were most often confused with Woody Wetlands. Wetlands were difficult to map, in part, as wetlands were sometimes dry during image acquisition, and so whenever possible, the US National Wetland Inventory data set was used to map wetland areas.

Even with ancillary data, land use classes tend to have lower accuracy than land cover classes when extracted from satellite imagery. Difficulties separating the residential, commercial, Quarry/Strip Mine/Gravel Pits, and Urban/Recreational Grasses classes were common.

Table 8. NLCD legend, class description and comparison with proposed EOSD legend classes.

Class	Description	Correlated EOSD Class(es)
Open Water	All areas of open water; generally with < 25% cover of vegetation/land cover.	Water
Perennial Ice/Snow	All areas characterized by year-long surface cover of ice and/or snow.	Snow/Ice

Low Intensity Residential	Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80% of the cover. Vegetation may account for 20-70% of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.	Exposed Land
High Intensity Residential	Includes highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for < 20% of the cover. Constructed materials account for 80-100% of the cover.	Exposed Land
Commercial/Industrial/Transportation	Includes infrastructure (e.g. roads, railroads) and all developed areas not classified as High Intensity Residential.	Exposed Land
Bare Rock/Sand/Clay	Perennially barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, beaches, and other accumulations of earthen material.	Rock/Rubble Exposed Land
Quarries/Strip Mines/Gravel Pits	Areas of extractive mining activities with significant surface expression.	Exposed Land
Transitional	Areas of sparse vegetative cover (< 25%) that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clear cuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood).	
Deciduous Forest	Areas dominated by trees where $\geq 75\%$ of the tree species shed foliage simultaneously in response to seasonal change. Natural or semi-natural woody vegetation, generally > 6 m tall. The tree canopy accounts for 25-100% of the cover.	Broadleaf - Dense Broadleaf - Open
Evergreen Forest	Areas dominated by trees where 75% or more of the tree species maintain their leaves all year. Canopy is never without green foliage and natural or semi-natural woody vegetation, generally > 6 m tall. Tree canopy accounts for 25-100% of the cover.	Coniferous - Dense Coniferous - Open
Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent > 75% of the cover present. Natural or semi-natural woody vegetation, generally > 6 m tall. Tree canopy accounts for 25-100% of the cover.	Mixed Wood - Dense Mixed Wood - Open
Shrubland	Areas dominated by shrubs (< 6 m tall). Shrub canopy accounts for 25-100% of the cover. Shrub cover is generally > 25% when tree cover is < 25%. Shrub cover may be < 25% in cases when the cover of other life forms (e.g. herbaceous or tree) is < 25% and shrubs cover exceeds the cover of the other life forms.	Shrub - Tall Shrub - Low
Orchards/Vineyards/Other	Areas dominated by non-natural woody vegetation. Non-natural woody vegetative canopy accounts for 25-100% of the cover. The non-natural woody classification is subject to the availability of sufficient ancillary data to differentiate non-natural woody vegetation from natural woody vegetation. Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals	

Grasslands/ Herbaceous	Upland areas characterized by natural or semi-natural herbaceous vegetation. Herbaceous vegetation accounts for 75-100% of the cover. Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is < 25%, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.	Herb
Pasture/Hay	Herbaceous vegetation accounts for 75-100% of the cover. Include areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.	Herb
Row Crops	Herbaceous vegetation accounts for 75-100% of the cover. Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.	Herb
Small Grains	Herbaceous vegetation accounts for 75-100% of the cover. Areas used for the production of graminoid crops such as wheat, barley, oats, and rice.	Herb
Fallow	Herbaceous vegetation accounts for 75-100% of the cover. Areas used for the production of crops that do not exhibit visible vegetation, as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage.	Herb
Urban/ Recreational Grasses	Herbaceous vegetation accounts for 75-100% of the cover. Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.	Herb
Woody Wetlands	Areas where forest or shrubland vegetation accounts for 25-100% of the cover and the soil or substrate is periodically saturated with or covered with water.	Wetland - Conifer Wetland - Broadleaf Wetland - Mixed Wood Wetland - Shrub - Tall Wetland - Shrub - Low
Emergent Wetlands	Areas where perennial herbaceous vegetation accounts for 75-100% of the cover and the soil or substrate is periodically saturated with or covered with water.	Wetland - Herb
N/A		Wetland - Bryoid
N/A		Cloud
N/A		Shadow
N/A		Coniferous - Sparse
N/A		Broadleaf - Sparse
N/A		Mixed Wood - Sparse

5.3 FAO Forest Resource Assessment 2000 for North America

The Food and Agricultural Organization of the United Nations (FAO) is involved with several land cover mapping projects. The proposed legend for one such project, the FAO Forest Resource Assessment 2000 for North America (further known as the FAO legend), is presented in Table 9. This legend has not yet been implemented (Davis, pers com, 2001). Few of the proposed FAO legend classes relate to classes in the proposed EOSD legend. The FAO legend incorporates land use classes and although it considers forest density, it does not have species classes. Forest classes are divided based on whether they are natural or managed, and agricultural land classes are determined by impact. Overall, there are few similarities between these legends. Landsat images were used in a pilot study of the FAO

legend and classification procedure; however, the classification was not automated and interpreters were used allowing land use information to be incorporated.

Table 9. Proposed legend for FAO's Forest Resource Assessment 2000 for North America.

Class	Description	Correlated EOSD Class(es)
Water	Sea and major inland water bodies.	Water
Other Land Cover	Snowcaps, rocky areas, and burn areas.	Snow/Ice Rock/Rubble Exposed Lands
Snow Cover	Areas below the tree line which are unidentified due to snow cover.	Snow/Ice
Forest Plantations	People-made forest plantations.	
Agricultural Plantations	Agriculture and homestead gardens. Including tea gardens, oil-palm, coconut, rubber plantations, and homestead mixture of trees and shrubs.	Herb
Low Woody Vegetation	Woody vegetation < 5 m. May be dense or open.	Shrub - Tall Shrub - Low
Fragmented Forest Fraction 40-70%	Mosaic of forest and shrubs or other land cover.	
Fragmented Forest Fraction >70%	Mosaic of forest and shrubs or other land cover.	
Open Forest	Majority of vegetation > 5 m in height; crown closure 10-40%. Vegetation is continuous and natural.	Deciduous - Sparse Coniferous - Sparse Mixed Wood - Sparse
Closed Forest	Majority of vegetation > 5 m in height; crown closure 40-70%. Vegetation is continuous and natural.	Deciduous - Open Coniferous - Open Mixed Wood - Open
Closed Forest - Dense	Majority of vegetation > 5 m in height with a crown closure > 70%. Vegetation is continuous and natural.	Deciduous - Closed Coniferous - Closed Mixed Wood - Closed
Regrowth	Areas cleared with new vegetation (natural or replanted) and a height less than 5 m.	
Agriculture Impact - Short Fallow	Based on visual estimate calculated as $Fallow = \frac{Cropping\ area * 100}{Cropping + Fallow\ Area}$, where $Fallow > 32$.	Herb
Agriculture Impact - Long Fallow	Based on visual estimate calculated as $Fallow = \frac{Cropping\ area * 100}{Cropping + Fallow\ Area}$, where $Fallow < 33$.	
Cloud	Area not interpretable due to cloud.	Cloud
Cloud Shadow	Area not interpretable due to the shadow of a cloud.	Shadow
Mountain Shadow	Area not interpretable due to the shadow of a mountain.	Shadow
Outside Study Area	Area outside region of interest.	
N/A		Bryoid
N/A		All Wetland classes

5.4 Global Observation of Forest Cover

Global Observation of Forest Cover (GOFC) is an international group aimed at improving the quality and availability of satellite observations of forests and the information derived from these data. They are particularly concerned with providing tools to assist in the sustainable development of forests. GOFC also leads an international effort to produce a land cover map of the world, by compiling information provided by different countries. Many organizations such as the FAO, NASA, and CCRS are involved in GOFC.

GOFC uses a global *continuous* land cover legend as seen in Table 10. The GOFC legend proposes a unique way of classifying forest that does not break up classes based on percentage of species or crown closure. Instead, each forest pixel in an image is four attributes: the ratio of broadleaf to needle leaf, the ratio of evergreen to deciduous, the percent canopy closure, and tree height. At present, the accuracy of the first four attributes is about 25% and height is considered accurate to 3 m.

The continuous nature of the GOFC legend allows for the sharing of data in a flexible way. For example, the forest classes of a map produced with GOFC's continuous legend could be regrouped into EOSD forest classes and visa versa. One incompatibility between the two legends is that GOFC does not represent wetlands at all, and splits the EOSD Herb class into Croplands and Grasslands.

Table 10. GOFC's Continuous Land Cover Legend.

Classes						Correlated EOSD Class(es)
Water						Water
Snow and Ice						Snow/Ice
Barren or Sparsely Vegetated						Exposed Land
Built-up						Exposed Land
Croplands						Herb
Grasslands						Herb
Forest	Class Name	Continuous Field Variable	Variable Range	Initial Accuracy	Ultimate Accuracy	
	Leaf type	Broadleaf/needle-leaf ratio	0 - 100%	~ 25%	~ 10%	All forest classes
	Leaf longevity	Evergreen/deciduous ratio	0 - 100%	~ 25%	~ 10%	All forest classes
	Canopy cover	% canopy cover	0 - 100%	~ 25%	~ 10%	All forest classes
	Canopy height	height	0 - 100m	~ 3m	~ 1m	All forest classes
Forest special theme: flooded forest						
N/A						All Wetland classes

N/A		All Shrub Classes
N/A		Cloud
N/A		Shadow
N/A		Rock/Rubble
N/A		Bryoids

5.5 Provincial Large Area Mapping

Many provinces have large area satellite mapping programs. Analyzing provincial programs will help meet the goals outlined in section 5.0; additional benefits include:

1. determining the types of classes that are important to Canadian Users, and
2. determining if there is the potential to share the mapping workload with provinces using similar land cover legends.

The following describes all existing provincial large area satellite mapping legends and outlines some of the similarities and differences between the provincial legends and the proposed EOSD legend.

5.5.1 British Columbia

British Columbia's large area mapping is part of the Baseline Thematic Mapping program using 1:250 000 aerial photography. In Table 11, British Columbia's legend class definitions are presented and compared with classes from the proposed EOSD legend. British Columbia's large area mapping is based on land use. Many of British Columbia's land use classes can be regrouped so as to correlate with proposed EOSD classes. For example, Barren Surfaces, Mining, and Urban classes are considered part of the EOSD Exposed Land class. However, other British Columbia land use classes such as Recreation Activities and Residential Agriculture Mixtures can not be regrouped in the proposed EOSD classes as they span more than one class. For example, areas in the British Columbia Recreational Activity class may be grouped into several different EOSD classes such as Exposed Land, Herb, or any of the forested classes.

The forest classes outlined in the British Columbia and EOSD legends are significantly different. In the EOSD legend, forest classes are based on vegetation type and density, whereas in the British Columbia legend forest classes are based on management. For example, the British Columbia system classifies forest as Old Forest, Young Forest, Recently Logged, and Selectively Logged. Management based forest classes are not necessarily spectrally separable, therefore ancillary information is required. Overall, there is low compatibility between the EOSD and British Columbia large area satellite mapping legends, making collaborative mapping efforts difficult.

Table 11. British Columbia's Baseline Thematic Mapping land use legend.

Class	Description	Correlated EOSD Class(es)
Agriculture	Land based agriculture activities undifferentiated by crop. (ie. land is used as the producing medium)	Herb
Residential Agriculture Mixtures	Areas where agriculture activities are intermixed with residential and other buildings with a building density of between 2 - 0.2 per hectares.	Exposed Land
Alpine	Areas virtually devoid of trees at high elevation.	
Subalpine Avalanche Chutes	Areas below the tree line that are devoid of forest growth due primarily to snow avalanches. Usually herb or shrub covered.	Herb Low Shrub
Barren Surfaces	Rock barrens, badlands, sand and gravel flats, dunes, and beaches where unvegetated surfaces predominate.	Exposed Land
Recently Burned	Areas virtually devoid of trees due to fire within the past 20 years. Forest < or equal to 15% cover.	Exposed Land
Estuaries	Salt water mud flats and intertidal areas at the mouth of rivers and creeks where the vegetation is influenced by frequent flooding (at least yearly).	Wetland - Herb Wetland - Shrub - Low
Old Forest	Forest >= 140 years old and > 6 m in height. Areas defined as Recently Logged and Selectively Logged land uses are excluded from this class.	
Young Forest	Forest < 140 years old and > 6 m in height. Areas defined as Recently Logged and Selectively Logged land uses are excluded from this class.	
Glaciers and Snow	Glaciers and permanent snow. Depending on the date of imagery, ephemeral snow may be included in this class.	Snow/Ice
Recently Logged	Timber harvesting within the past 20 years, or older if tree cover is < 40% and under 6 m in height.	
Selectively Logged	Areas where the practice of selective logging can be clearly interpreted on the Landsat TM image and TRIM aerial photography.	
Mining	Land used now (or in the past and remains unreclaimed) for the surface extraction of minerals or quarry materials.	Exposed Land
Rangelands	Unimproved pasture and grasslands based on cover rather than use. Cover includes drought tolerant grasses, sedges, and scattered shrubs up to 6 m in height and <35% forest cover. Sparse forest stands with an understorey of drought tolerant shrubs and herbs are included.	Herb
Recreation Activities	Land used for private or public outdoor recreational purposes. Ski resorts and golf courses are included. This class does not include recreational areas within built-up portions of cities, towns, and villages, which are mapped as urban areas. This class includes waterfront cottage areas if they are at least 200 m wide.	Herb Exposed Land

Urban	All compact settlements including built up areas of cities, towns, and villages as well as isolated units away from settlements such as manufacturing plants, rail yards, and military camps. In most cases residential use will predominate in these areas. Includes open space which forms an integral part of the urban agglomeration (e.g. parks, golf courses).	Exposed Land
Wetlands	Wetlands including swamps, marshes, bogs, or fens. This class excludes lands with evidence or knowledge of haying or grazing in drier years.	Wetland - Conifer Wetland - Broadleaf Wetland - Mixed Wood Wetland - Shrub - Tall Wetland - Shrub - Low Wetland - Herb Wetland - Bryoid
Fresh Water	Fresh water bodies (lakes, reservoirs, and wide portions of major rivers).	Water
Salt Water	Salt water (oceans). Areas defined as Estuaries are excluded from this class.	Water
N/A		Cloud
N/A		Shadow
N/A		Rock/Rubble
N/A		Shrub - Tall
N/A		Shrub - Low
N/A		Bryoids
N/A		Coniferous - Dense
N/A		Coniferous - Open
N/A		Coniferous - Sparse
N/A		Broadleaf - Dense
N/A		Broadleaf - Open
N/A		Broadleaf - Sparse
N/A		Mixed Wood - Dense
N/A		Mixed Wood - Open
N/A		Mixed Wood - Sparse

5.5.2 Alberta

Alberta's large area satellite mapping legend is compatible with the proposed EOSD legend. Alberta legend classes are defined and compared with EOSD classes in Table 12. Most of the Alberta classes shown have detailed subclasses, though the subclasses provide information beyond the scope of the EOSD legend. Both legends are based on land cover and have classes for open and closed coniferous, deciduous/broadleaf, and mixed wood forest. The Alberta legend only has two forest density classes; open forest has 6-50% crown closure and closed forest has > 50% crown closure. In contrast the EOSD legend has three density classes (dense > 60%, open 26-40%, and sparse 10-25%). The species composition of classes differs slightly between legends, as the Alberta legend requires Deciduous Dominated and Coniferous Dominated Forest classes to have more than 80% pure species, whereas the EOSD legend only requires 75% species purity.

There are other differences between the two legends. For example, the Alberta legend has unique Upland and Industrial, Burn, and Clear Cut classes, while the EOSD legend has all of

the above classes grouped in to the Exposed Land class. As well, the Alberta legend separates Agriculture and Grassland classes that are combined into the EOSD Herb class. Another important difference is that the Alberta legend groups shrub based on density whereas the EOSD system groups shrub by height. Finally, the EOSD class for Bryoids (moss and lichen) is not included in the Alberta legend.

Overall the differences between the EOSD and Alberta legends are minor. Reconfiguring Alberta's large area maps to be represented by the EOSD legend, and visa versa, would be practical and is recommended. Due to the significant similarities between the Alberta and EOSD legends, Alberta's land cover mapping experience provides valuable insight into the potential problems and successes of the EOSD classification legend.

The overall accuracy of the Alberta large area map is between 88-92% (Sanchez, pers com, 2001). The ability to differentiate between coniferous and deciduous forests and their associated density classes is high (92%); however, the Mixed Wood forest class is classified with less accuracy (88%). The different density in the shrub classes are also being accurately identified. The high classification accuracy is likely due to the large number of control points used in the classification. As well, the accurate locating of density information is aided by the use of texture information (Sanchez, pers com, 2001).

The Burn class is proving more difficult to locate than the forest classes, as the Burn class causes significant difficulty due to regrowth. It is difficult to determine when an area classified as burn is no longer a burn. Sanchez (pers com, 2001) suggests that one way to deal with these areas would be to manually identify all areas that were burnt in the past.

Like the Burn class, wetland classes are relatively difficult to map with satellite imagery. Some wetlands are not found, as during the time of imagery acquisition the area was dry. As well, only about half of the wetland classes are being located in the imagery. The Alberta classification scheme has eight wetland subclasses (Table 13). The most commonly located wetlands include Shrubby Wetlands, Graminoid Wetlands, and Black Spruce Bogs. Black Spruce Bogs cannot be differentiated based on understory, and locating Undifferentiated Wetlands requires large amounts of fieldwork. The number of Lichen Bogs and Sphagnum Bogs located with Landsat imagery is also limited. There are several reasons wetland classes may not be found using satellite imagery, such as that it is possible that these classes do not exist or that they are in such small areas that the resolution of the imagery does not allow them to be located. As well, the spectral resolution of Landsat imagery, in Alberta's case, may not be sufficient for extracting some wetland classes.

Table 12. Alberta's large area land cover classification legend.

Class	Description/Subclasses	Correlated EOSD Class(es)
Upland and Industrial	Urban (cities, towns, mostly residential and downtown core areas). Commercial and industrial (industrial parks, heavy oil sand development, refineries, hydro generating facilities); major roads, highways and railways; cutlines and trails; surface mines (coals) gravel pits, spoil piles; farmstead and/or ranch (including shelter belts).	Exposed Land
Agricultural	Cropland (including cereal crops and forage); irrigated land; agricultural clearing (recently cleared land).	Herb
Clear Cuts	Graminoid (grasses/sedges) dominated clear cut; tree/shrub dominated clear cut; tree dominated clear cut (replanted – immature trees, < 20 years old).	Exposed Land
Burns	Graminoid (grasses/sedges) dominated burn; tree/shrub dominated burn; tree dominated burn; new burn.	Exposed Land
Open Forested Land (6-50% crown closure); Coniferous Dominated Forest	Open black, pine, white, and undifferentiated. > 80% coniferous cover based on occurrence.	Coniferous - Open Coniferous - Sparse
Closed Forested Land (>50% crown closure); Coniferous Dominated Forest	Closed black, pine, white, and undifferentiated. > 80% coniferous cover based on occurrence.	Coniferous - Dense
Open Forested Land (6-50% crown closure); Deciduous Dominated Forest	Open Aspen and Balsam Poplar. > 80% deciduous cover based on occurrence.	Broadleaf - Open Broadleaf - Sparse
Closed Forested Land (>50% crown closure); Deciduous Dominated Forest	Closed Aspen, Balsam Poplar, and Riparian Poplar. > 80% deciduous cover based on occurrence.	Broadleaf - Dense
Open Forested Land (6-50% crown closure); Mixed Wood Dominated Forest	Open coniferous dominated mixed wood (60-80% deciduous cover), or closed deciduous dominated mixed wood (60-80% deciduous cover), or open coniferous and deciduous cover (20-60%). 20-80% mixed wood cover based on occurrence.	Mixed Wood - Open Mixed Wood - Sparse
Closed Forested Land (>50% crown closure); Mixed Wood Dominated Forest	Closed coniferous dominated mixed wood (60-80% deciduous cover), or closed deciduous dominated mixed wood (60-80% deciduous cover), or closed coniferous and deciduous cover (20-60%). 20-80% mixed wood cover based on occurrence.	Mixed Wood - Dense
Closed Shrubland (>25% shrub cover and <6% tree cover)	Closed riparian shrub; closed coulee shrub thicket; closed upland shrub.	
Open Shrubland	Open riparian shrub; open coulee shrub thicket; open upland shrub; open sagebrush flat.	

Grassland (<25% shrub cover and <6% tree cover); Graminoids (grasses and sedges)	Fescue grassland; mixed grassland; sandhill grassland; coulee grassland.	Herb
Upland Fords (<6% graminoid)	Upland ford meadow.	Herb
Wetlands	Emergent wetland (cattails); graminoid wetlands (sedges/grasses/forbs); shrubby wetlands (willow and birch); sphagnum bog; lichen bog; Black Spruce Bog (sphagnum understory); Black Spruce Bog (lichen understory); undifferentiated wetlands.	Wetland - Conifer Wetland - Broadleaf Wetland - Mixed Wood Wetland - Shrub - Tall Wetland - Shrub - Low Wetland - Herb Wetland - Bryoid
Water	Lake, pond, reservoir, river, and stream.	Water
Barren (<6% vegetation cover)	Permanent ice and snow; rock; talus, and/or avalanche chute; exposed soil; alkali flat and/or mud flat; upland dune field; alluvial deposit; beach; badland; blowout zone.	Snow/Ice Rock/Rubble
Cloud/Haze		Cloud
N/A		Shadow
N/A		Shrub - Tall
N/A		Shrub - Low
N/A		Byoids

Table 13. Ability to locate Alberta wetland classes

Wetland Class	Ability to Locate Class on Landsat TM imagery
Emergent Wetland (cattails)	Sometimes
Graminoid Wetlands (sedges, grasses, and forbs)	Yes
Shrubby Wetlands (willow and birch)	Yes
Sphagnum Bog	Limited
Lichen Bog	Limited
Black Spruce Bog (sphagnum understory)	Black Spruce Bog found but understory not discernable.
Black Spruce Bog (lichen understory)	Black Spruce Bog found but understory not discernable.
Undifferentiated Wetlands	Limited

5.5.3 Saskatchewan

The Saskatchewan large area land cover mapping project is split into two sub-project; the Southern Digital Land Cover (SDLC) which is based on agriculture, and forestry-based Northern Digital Land Cover (NDLC). The SDLC and the NDCL have different classification legends.

5.5.3.1 NDLC

The NDLC classification scheme has 24 classes and is not a pure land cover classification (Table 14), as land use components are required to meet the needs of different groups involved in the mapping project. The NDCL legend has a Recent Burn and a Revegetating Burn class. Recent Burns (<1year) are easily identified though accurate dating of older burns is more difficult. The Revegetating Burn class usually includes trees up to about 3 years old. Due to difficulty with dating burns, areas are left as Revegetating Burn until they start to spectrally separate into another class. Burn classes frequently require manual adjustments.

NDLC forest classes are defined differently than the proposed EOSD forest classes, though the NDLC could be easily aggregated to the proposed EOSD classes. For example, the NDLC has two density classes for Hardwood, Jack Pine, and Spruce classes, with Hardwood approximately equal to the EOSD Broadleaf class; Jack Pine and Spruce can be regrouped into the EOSD Coniferous class. The NDLC forest classes are further partitioned into open and closed classes. The open class requires 10-55% crown closure whereas the closed classes require > 55% crown closure. As mentioned, the EOSD legend has three density classes (dense > 60%, open 26-40%, and sparse 10-25%).

The NDLC wetland classes appear to be based on regional ecology, though some of the wetland classes are directly related between legends. For example, the NDLC Tree Bog, Herbaceous Fen, and Shrub Fen are approximately the same as EOSD forested wetland classes Wetland – Tree (Coniferous, Broadleaf, and Mixed Wood), Wetland – Herb and Wetland – Shrub (Tall and Low). The NDCL Marsh class is also similar to the EOSD Wetland – Herb class; however, Open Bog spans several EOSD wetland classes.

As a result of the NDCL legend land use components, there are classes such as Settlements /Roads/Urban and Cutover. Most land use classes would be part of either the EOSD Exposed Land and Herb classes.

Table 14. Northern Saskatchewan’s large area land cover classification legend.

Class	Description/Subclasses	Correlated EOSD Class(es)
Hardwood: Open Canopy	Trembling Aspen, Balsam Popular, or White Birch represent > 75 % of cover by volume. 10-55 % crown closure.	Broadleaf - Open Broadleaf - Sparse
Hardwood: Closed Canopy	Trembling Aspen, Balsam Popular, or White Birch represent > 75 % of cover by volume. > 55 % crown closure.	Broadleaf - Dense
Jack Pine: Open Canopy	Jack Pine represents > 75 % of cover by volume. > 10-55 % crown closure.	Coniferous - Open Coniferous - Sparse
Jack Pine: Closed Canopy	Jack Pine represents > 75 % of cover by volume. > 55 % crown closure.	Coniferous - Dense
Spruce: Open Canopy	White Spruce and Black Spruce represents > 75 % of cover by volume. < 55 % crown closure.	Coniferous - Open Coniferous - Sparse
Spruce: Closed Canopy	White Spruce and Black Spruce represent > 75 % of cover by volume. > 55 % crown closure.	Coniferous - Dense

Recent Burn	An area showing evidence of recent burning (< 2 years old) natural or prescribed, typified by spectral content producing reddish to dark red to purple reflectance on TM imagery when viewed using bands 5,4,3. The color, shape, size, pattern, and context help in identifying recent burns. There is little to no regeneration or visible revegetation. Additional ancillary data in the form of fire maps help to date fires < 2 years old.	
Revegetating Burn	An area showing evidence of burning (> 3 years old) natural or prescribed, typified by spectral content producing a pinkish reflectance on TM and ETM+ imagery when viewed using bands 5,4,3. The color, shape, size, pattern, and context help to identify recent burns. There is regeneration or revegetation visible. Additional ancillary data in the form of fire maps help to date fires > 3 years old.	
Treed Rock	An area containing hardwood, softwood, or a mixture of two of the following: Jack Pine, Black Spruce, White Spruce, Trembling Aspen, Balsam Popular, or White Birch. < 10% crown closure.	
Mixed Hardwood/ Softwood, Softwood/ Hardwood Open and Closed Canopy	An area of hardwood and softwood combinations in which neither hardwood or softwood account for > 75% of cover by volume. Species may include Jack Pine, Black Spruce, White Spruce, Trembling Aspen, Balsam Popular, or White Birch. 10-100% crown closure.	Mixed Wood - Dense Mixed Wood - Open Mixed Wood - Sparse
Treed Bog	An area consisting of decomposing peat moss and lichen with stunted black spruce and shrubs. Crown closure 10-25%.	Wetland - Coniferous Wetland - Broadleaf Wetland - Mixed Wood
Herbaceous Fen	An area consisting of nutrient rich water and decomposing peat supporting vascular and nonvascular plants grasses, sedges, and reeds. Cover is > 5% vegetation and < 10% woody plants.	Wetland - Herb
Water	An area typified by black spectral reflectance on TM or ETM+ imagery when viewed through channels 5,4,3. These areas include lakes, rivers, streams, and reservoirs. Color, shape, size, pattern, and context along with additional forms of ancillary data are used to identify these areas.	Water
Barren Land	An area of exposed rock, soil, or sand dunes (any unvegetated area).	Rock/Rubble Exposed Land
Mixed Softwoods: Jack Pine/Spruce, Spruce/Jack Pine Open and Closed	An area of softwood where no species is >75% of cover by volume.	Coniferous - Dense Coniferous - Open Coniferous - Sparse
Open Bog	An area consisting of low nutrient water and decomposing peat moss, lichen, and sparse Black Spruce cover. Shrubs may include: Labrador Tea, Black Spruce, and Bog Cranberry.	Wetland - Bryoid
Marsh	A periodically wet or continually flooded but non peat-forming area supporting grasses and sedges.	Wetland - Herb

Cutover	An area of deforestation, vegetated and non-vegetated, less < 20 years old. Ancillary data required to correctly classify due to the anthropogenic and temporal nature of this land cover/land use class.	
Mud/Saline	Water saturated soil and salt water containing no vegetation.	Water
Pasture		Herb
Shrub Fen	An area consisting of nutrient rich water and decomposing peat supporting low shrubs, forbs, grass, moss, and sparse tree cover. Species may include: Willow, Dwarf Birch, Bog Rosemary, and Tamarack.	Wetland - Shrub - Tall Wetland - Shrub - Low
Settlements/ Roads/Urban Structures/ Scarified Lands	Urban, commercial, industrial, major roads, highways, railways, cutlines, trails, surface mines, gravel pits, spoil piles, farmstead, ranch, cropland, and agricultural clearing areas.	Exposed Land Herb
Cloud/Shadow	An area containing cloud, shadow, and haze. Shadow is typified by a dark spectral reflectance similar to water, and white to gray blue spectral reflectance for cloud and haze when TM and ETM+ imagery is viewed through channels 5,4,3. These classes are not a representation of the land cover but atmospheric anomalies influencing the spectral reflectance of the land.	Cloud Shadow
Unclassified	An area of unidentifiable land cover > 3 pixels.	Unclassified
N/A		Snow/Ice
N/A		Bryoid
N/A		Shrub - Tall
N/A		Shrub - Low

5.5.3.2 SDLC

The SDLC legend classes and comparisons with the proposed EOSD classes are shown in Table 15. We were unable to locate SDLC class descriptions, and so the class descriptions provided below are based on the NDLC legend. The classes used in the NDLC and SDLC are approximately the same. However, agriculture is a more important component of the SDLC land cover classification. Four agriculture classes are used: Cropland, Hay Crops Native Dominant Grasslands, and Pastures. These agricultural classes can all be grouped into the EOSD Herb class.

Table 15. Southern Saskatchewan's large area land cover classification legend.

Class	Description/Subclasses	Correlated EOSD Class(es)
Cropland	?	Herb
Hay Crops (Forage)	?	Herb
Native Dominant Grasslands	?	Herb
Tall Shrub	?	Shrub - Tall
Pastures (Seeded)	?	Herb

Grasslands)		
Hardwood: Open Canopy	Trembling Aspen, Balsam Poplar, or White Birch represent > 75 % of cover by volume. 10-55 % crown closure.	Broadleaf - Open Broadleaf - Sparse
Hardwood: Closed Canopy	Trembling Aspen, Balsam Poplar, or White Birch represent > 75 % of cover by volume. > 55 % crown closure.	Broadleaf - Dense
Jack Pine: Open Canopy	Jack Pine represents > 75 % of cover by volume. > 10-55 % crown closure.	Coniferous - Open Coniferous - Sparse
Jack Pine: Closed Canopy	Jack Pine represents > 75 % of cover by volume. > 55 % crown closure.	Coniferous - Dense
Spruce: Open Canopy	White Spruce and Black Spruce represents > 75 % of cover by volume. < 55 % crown closure.	Coniferous - Open Coniferous - Sparse
Spruce: Closed Canopy	White Spruce and Black Spruce represent > 75 % of cover by volume. > 55 % crown closure.	Coniferous - Dense
Mixed Woods	An area of hardwood and softwood combinations in which neither hardwood or softwood account for > 75% of cover by volume. Species may include Jack Pine, Black Spruce, White Spruce, Trembling Aspen, Balsam Poplar, or White Birch. 10-100% crown closure.	Mixed Wood - Dense Mixed Wood - Open Mixed Wood - Sparse
Treed Rock	An area containing hardwood, softwoods, or a mixture of two of the following: Jack Pine, Black Spruce, White Spruce, Trembling Aspen, Balsam Poplar, or White Birch. < 10% crown closure.	
Recent Burn	An area showing evidence of recent burning (< 2 years old) natural or prescribed, typified by spectral content producing reddish to dark red to purple reflectance on TM imagery when viewed using bands 5, 4, 3. The color, shape, size, pattern, and context help in identifying recent burns. There is little to no regeneration or revegetation visible. Additional ancillary data in the form of fire maps help to date fires < 2 years old.	
Revegetating Burn	An area showing evidence of burning (> 3 years old) natural or prescribed, typified by spectral content producing a pinkish reflectance on TM and ETM+ imagery when viewed using bands 5, 4, 3. The color, shape, size, pattern, and context help to identify recent burns. There is regeneration or revegetation visible. Additional ancillary data in the form of fire maps help to date fires > 3 years old.	
Cutover	An area of deforestation, vegetated and non-vegetated, less < 20 years old. Ancillary data required to correctly classify due to the anthropogenic and temporal nature of this land cover/land use class.	
Water	An area typified by black spectral reflectance on TM or ETM+ imagery when viewed through channels 5,4,3. These areas include lakes, rivers, streams, and reservoirs. Color, shape, size, pattern, and context along with additional forms of ancillary data are used to identify these areas.	Water
Marsh	A periodically wet or continually flooded but non peat-forming area supporting grasses and sedges.	Wetland - Herb
Herbaceous Fen	An area consisting of nutrient rich water and decomposing peat supporting vascular and nonvascular plants grasses, sedges, and reeds. Cover is > 5% vegetation and < 10% woody plants.	Wetland - Herb
Mud/Sand/ Saline	Water saturated soil and salt water containing no vegetation.	Water

Shrub Fen	An area consisting of nutrient rich water and decomposing peat supporting low shrubs, forbs, grass, moss, and sparse tree cover. Species may include Willow, Dwarf Birch, Bog Rosemary, and Tamarack.	Wetland - Shrub - Tall Wetland - Shrub - Low
Treed Bog	An area consisting of decomposing peat moss and lichen with stunted black spruce and shrubs. Crown closure 10- 25%.	Wetland - Coniferous Wetland - Broadleaf Wetland - Mixed Wood
Open Bog	An area consisting of low nutrient water and decomposing peat moss, lichen, and sparse Black Spruce cover. Shrubs may include Labrador Tea, Black Spruce, and Bog Cranberry.	Wetland - Bryoid
Farmstead	?	Exposed Land Herb
Roads	?	Exposed Land
N/A		Cloud
N/A		Shadow
N/A		Snow/Ice
N/A		Shrub - Low

5.5.4 Manitoba

The definitions of the Manitoba legend, as well as comparative EOSD classes, can be seen in Table 16. Like many of the legends discussed in this report, the Manitoba legend is primarily based on land cover while including some land use classes such as Cultural Features, Forest Cutovers, Roads and Trails, and Forage Crops. The Manitoba legend incorporates land use classes, which are not spectrally distinct. When there is difficulty separating an area, spectrally manual editing is used. As well, existing shape files are often used to locate Cultural Features.

Manitoba forest species classes are the same as those in the proposed EOSD legend; however, only the deciduous class is divided by density. The Open Deciduous class, determined by topography, vegetation, and density, is primarily located in the Interlake regions where land is marginal and often cattle graze below the canopy. Agricultural Croplands, Grassland/Rangeland, and Forage Crops in the Manitoba legend represent the EOSD Herb class. Components of the Cultural Features and Road and Trails classes are part of the EOSD Herb class; Marsh and Fens and Treed and Open Bog classes represent all the EOSD wetland classes.

As suggested by other organizations mapping land cover, burns older than one year are difficult to classify. Clear cuts or Forest Cutovers are difficult to identify as well due to replanting, and remaining slash and shrubs. In the Manitoba system, areas remain in the Burnt Areas and Forest Cutover class until the trees are greater than 6 m in height (Dixon, 2001).

Table 16. Manitoba's large area land cover classification legend.

Class	Description	Correlated EOSD Class(es)
Agricultural Cropland	Consists of all lands dedicated to the production of annual cereal, oil seed, and other specialty crops. These lands would normally be cultivated on an annual basis. This class would be broken into three crop residue classes: 0% -33%, 34% -66%, and 67% -100%.	Herb
Deciduous Forest	Forest in which 75% -100% of the canopy is deciduous. Dominant species are Trembling Aspen, Balsam Poplar and White Birch. May include small patches of grassland, marsh or fens < 2 hectares in size.	Broadleaf - Dense
Water Bodies	Consists of all open water including lakes, rivers, streams, ponds, and lagoons.	Water
Grassland/Rangeland	Consists of mixed native and/or tame prairie grasses and herbs. May also include scattered stands of associated shrubs such as Willow, Chokecherry, Saskatoon, and Pincherry. Many of these areas are also used for cutting hay while others are grazed. Both upland and lowland meadows fall into this class. There is normally < 10% shrub or tree cover.	Herb
Mixed Wood Forest	A forest type in which 25% -75% of the canopy is coniferous. May include patches of treed bogs, marsh or fens < 2 hectares in size.	Mixed Wood - Dense Mixed Wood - Open Mixed Wood - Sparse
Marsh and Fens	Grassy, wet areas with standing or slowly moving water. Vegetation consists of grass, sedge sods, and common hydrophytic vegetation such as cattail and rushes. Areas are frequently interspersed with channels or pools of open water.	Wetland - Herb
Treed and Open Bogs	Peat covered or peat-filled depressions with a high water table. The bogs are covered with a carpet of Sphagnum spp. and Ericaceous shrubs and may be treeless or treed with Black Spruce and/or Tamarack.	Wetland - Conifer Wetland - Broadleaf Wetland - Mixed Wood Wetland - Shrub - Tall Wetland - Shrub - Low Wetland - Bryoid
Treed Rock	Areas of exposed bedrock with < 50% tree cover. The dominant species is Jackpine and occasional areas of shrub.	
Coniferous Forest	Forest in which 75% -100% of the canopy is coniferous. Jackpine and Spruce are combined under this class. May include patches of treed bogs, marsh or fens < 2 hectares in size.	Coniferous - Dense Coniferous - Open Coniferous - Sparse
Burnt Areas	Burned forested areas with sporadic regeneration. May include pockets of unburnt tree stands.	Exposed Land
Open Deciduous	Consists of lands characterized by rough topography, shallow soil, or poor drainage, which supports the growth of shrubs such as Willow, Alder, Saskatoon and/or stunted trees such as Trembling Aspen, Balsam Poplar, and Birch. An area could contain up to 50% scattered tree or shrub cover.	Broadleaf - Open Broadleaf - Sparse
Forage Crops	Consists of perennial forage such as alfalfa and clover or blends of these with tame species of grass. Fall seeded crops such as winter wheat or fall rye are included here.	Herb
Cultural Features	Built-up areas such as cities and towns, peat farms, golf courses, cemeteries, shopping centres, large recreation sites, auto wreckyards, airports, cottage areas, and race tracks.	Exposed Land Herb

Forest Cutovers	Areas where commercial timber has been completely or partially removed by logging operations. Includes areas that have been replanted.	
Bare Rock, Gravel and Sand	Exposed areas of bedrock with little or no vegetation, or exposed areas such as sand dunes and beaches. Also included are all gravel quarry/pit operations, mine tailings, burrow pits, and rock quarries.	Rock/Rubble
Road and Trails	All highways, secondary roads, trails, cut survey lines or right-of-way such as railway lines, and transmission lines.	Exposed Land Herb
N/A		
N/A		

5.5.5 Ontario

Ontario class definitions and comparable EOSD classes are shown in Table 17. More so than for other provinces, the Ontario legend is regionalized, dealing specifically with the Hudson Bay and James Bay areas. Land use classes not used in the EOSD legend include Agriculture, Settlement and Developed Land, and Mine Tailing/Quarries/Bedrock Outcrops/Mudflat classes. As with other legends, land use classes are primarily split between the EOSD Herb and Exposed Land classes. Ontario Marshes, Open Wetlands, and Tree Wetlands are used to represent all the wetland classes in the EOSD legend.

The Ontario legend has dense Deciduous, Coniferous, and Mixed Forested Classes, which are approximately the same as the dense EOSD Broadleaf, Coniferous, Mixed Wood classes; however, in the Ontario legend there is only one sparse class for all species. The crown closure required by the Ontario Sparse Forest Class is similar to the open EOSD forest crown closure requirement. Ontario's legend has unique successional forest classes. The Early Successional Forest class is used for any burn or clear cut, which is younger than 10 years, and the Successional Forest is a burn or clear cut which is greater than 10 years. In the EOSD classification, burn or clear cut areas become part of the exposed class. As secondary growth reaches a crown closure of 5%, the exposed area becomes part of the Shrub-Low or Herb classes.

Table 17. Ontario's large area land cover classification legend.

Class	Description	Correlated EOSD Class(es)
Water	The delineation of water bodies is based on the spectral signature of the imagery and is not derived from a secondary map source. Hence, the boundaries of water bodies may differ from those on topographic base maps.	Water
Marshes	Tidal marshes of the Hudson Bay-James Bay lowlands freshwater coastal marshes, and inland marshes (seasonal marshes, cattail marshes, and grassy meadow marshes).	Wetland - Herb

Open Wetlands	Open fens (including grassy fens with open pools occurring most extensively in the Hudson Bay-James Bay lowlands), open bogs (including bogs with some partial cover of stunted trees occurring generally in the province but most extensively in the Hudson Bay-James Bay lowlands), and "string bogs" of the Hudson Bay-James Bay lowlands which have a high proportion of open water surface.	Wetland - Herb
Treed Wetlands	Fens with dense shrub and Tamarack tree cover occurring generally in the province but most extensively in the Hudson Bay-James Bay lowlands and bogs with low- to high-density tree cover. Some degree of overlap exists between treed bog and sparse conifer forest in more northerly parts of the province, especially in the Hudson Bay-James Bay lowlands.	Wetland - Conifer Wetland - Broadleaf Wetland - Mixed Wood Wetland - Shrub - Tall Wetland - Shrub - Low
Tundra Heath	Areas of dense ericaceous vegetation occurring on better-drained areas only in the Hudson Bay coastal zone.	Herb
Dense Deciduous Forest	Largely continuous forest canopy composed > 80% of deciduous species. Includes deciduous shrub cover on old burns and Alder Thicket swamps in the Hudson Bay-James Bay lowlands.	Broadleaf - Dense
Dense Coniferous Forest	Largely continuous forest canopy composed > 80% of coniferous species; includes dense conifer swamp in the Hudson Bay-James Bay lowlands. Includes mature conifer plantations, mostly pine, growing in evenly spaced rows mainly in Southern Ontario. Does not include artificially regenerated cutovers or burns in Northern Ontario.	Coniferous - Dense
Mixed Forest	Largely continuous forest canopy of both coniferous and deciduous species.	Mixed Wood - Dense
Sparse Forest	Patchy or sparse forest canopy (~ 30-40% canopy closure) composed of either coniferous (mainly in northerly regions of Ontario) or deciduous species, or both.	Broadleaf - Open Coniferous - Open Mixed Wood - Open
Early Successional Forest	Forest growing on clear cuts and burns estimated at < 10 years of age.	
Successional Forest	Forest growing on clear cuts and burns estimated at > 10 years of age.	
Mine Tailing, Quarries, Bedrock Outcrops, and Mudflats	Areas of minimal vegetation cover including mine tailings, rock and gravel quarries, rocky Great Lakes shorelines, bedrock outcrops, and mudflats on the Hudson Bay and James Bay coast.	Exposed Land Rock/Rubble
Settlement and Developed Land	Clearings for human settlement, economic activity, and major transportation routes.	Exposed Land
Agriculture	Row crops, hay crops, open soil, open grassland with sparse shrubs, and orchard land.	Herb
Unclassified	Cloud and shadow areas within the provincial study area.	Cloud Shadow No Data
N/A		Snow/Ice
N/A		Shrub - Tall
N/A		Shrub - Low
N/A		Wetland - Bryoid

N/A		Broadleaf - Sparse
N/A		Coniferous - Sparse
N/A		Mixed Wood - Sparse

5.5.6 Quebec

Quebec's large area land cover classes and comparisons to the proposed EOSD classes can be seen in Table 17. The forest species classes are similar between legends, though Quebec's Coniferous trees are separated based on age and density. The Quebec legend has Hardwood trees separated based on tolerance to cold temperatures and mixed trees are grouped based on species dominance. The Quebec legend has several classes that the EOSD legend does not, such as Blowdown, Cut, Severe Epidemic, Partial Cut, Agriculture, and Urban and Industrial. In the Quebec legend there are two classes for all the wetlands: Bog and Wetland.

Table 18. Quebec's large area land cover classification legend. (Approximate translation from French.)

Class	Correlated EOSD Class(es)
Coniferous Mature Dense	Coniferous – Dense
Coniferous Mature Open	Coniferous - Open
Coniferous Young	Coniferous - Open
Coniferous Regenerating	Coniferous - Sparse
Mixed Coniferous Dominant (Young and Mature)	Mixed Wood - Dense
Mixed Hardwood Dominant (Young and Mature)	Mixed Wood - Dense Mixed Wood - Open Mixed Wood - Sparse
Mixed Regenerating	Mixed Wood - Dense Mixed Wood - Open Mixed Wood - Sparse
Hardwood Tolerant (to freezing)	Broadleaf
Hardwood Intolerant (to freezing)	Broadleaf
Hardwood Regenerating	Broadleaf - Sparse
Burn	Exposed Land
Blowdown	Exposed Land
Cut	Herb or Exposed Land
Severe Epidemic	
Partial Cut	
Agriculture	Herb
Urban and Industrial	Exposed Land
Bare and Dry	Exposed Land
Bog	Wetland - Herb
Lichen	Byoid
Water	Water

Wetland	Wetland - Conifer Wetland - Broadleaf Wetland - Mixed Wood Wetland - Shrub - Tall Wetland - Shrub - Low Wetland - Bryoid
N/A	Cloud
N/A	Shadow
N/A	Snow/Ice
N/A	Rock/Rubble
N/A	Shrub - Tall
N/A	Shrub - Low

5.5.7 Atlantic Provinces and Territories

None of the Atlantic Provinces have large area satellite mapping programs (Gillis, pers com, 2001). At present, the Yukon only inventories forests with aerial photographs (MacDonnel pers com, 2001). The Northwest Territories is developing a large area satellite mapping project, and its legend will be ready in the winter of 2002 (Croft pers com, 2001).

6.0 Complex Classes

6.1 Proposed EOSD Classes

6.1.1 Tall and Low Shrub

At 30 m spatial resolution, 2 m difference in shrub height is not likely to be discernable, though it is possible that there will be more than one spectrally separable shrub class. Therefore, we suggest leaving the shrub classes as is, with the understanding that the focus of the work should be on identifying the areas with tall shrub. Short shrub, although it may be used, has the potential to be a problematic class. If the shrub classes are problematic another suggestion may be to separate the shrubs based on density rather than height. The Alberta program has been successful in separating dense (cover > 50%) and open shrub (cover >25%-50%), and therefore Alberta's shrub definitions may be considered if the present tall and low classes are not adequate.

6.1.2 Wetlands

Moisture effects the spectral signatures of vegetation. The same vegetation growing on wet or dry land will have a different spectral signature. With this fact in mind, the proposed EOSD legend was developed with wetland classes that represent the seven main types of vegetation identified in the NFI Land Cover Classifications Scheme Level 4 (Table 3). However, work by other large mapping groups may suggest that seven wetland classes are not necessary. Even with only two wetland classes (Woody Wetland and Emergent Wetland), the NLCD project reports significant amounts of spectral overlap with wetland classes. Woody Wetland is often confused with other forest classes and Emergent Wetland is confused with Wood Wetland. With seven classes spectral overlap would be an even larger problem. Other work in Alberta suggests that the EOSD Wetland - Bryoid class may be difficult to find; we therefore recommend the removal of the wetland Bryoid class.

Remaining EOSD wetland classes can be combined into fewer groups (Figure 4). Wetland – Coniferous, Wetland – Broadleaf, and Wetland – Mixed Wood can all be grouped into Wetland – Treed. It is unlikely that Landsat level spatial resolution will provide enough detail to differentiate between Wetland - Shrub - tall and Wetland - Shrub - Low classes; therefore, both wetland shrub classes can be grouped into a single Wetland – Shrub class. The Wetland – Herb class should be left as is.

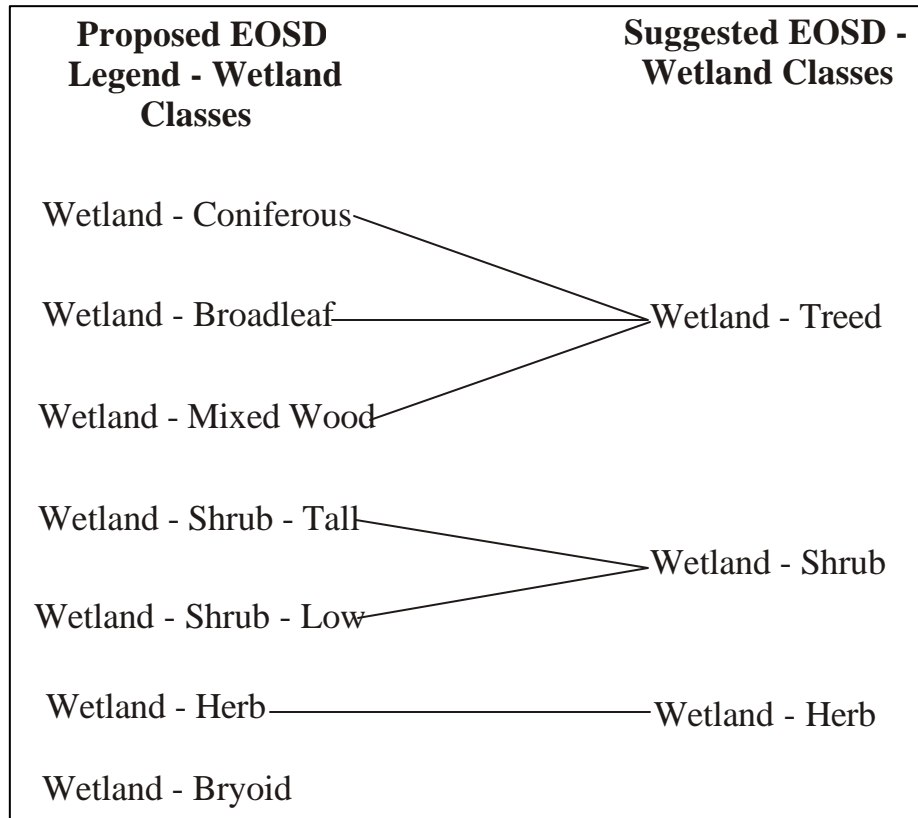


Figure 4. Suggested regrouping of EOSD wetland classes.

6.2 Non-Proposed EOSD Classes

6.2.1 Burn

The proposed EOSD legend does not specifically deal with burn areas. All people spoken to over the course of this project felt that burns were a problematic class for two reasons. First, the proposed EOSD legend is based on a land cover class, and burn is not a land cover. Second, a burn is a temporary state and part of the natural cycle of the boreal forest (Landry, pers com, 2001). Young burns are easily identified on imagery, as they stand out as black. However, determining when to move an area from the burn class is difficult. Any large area mapping project currently using a burn class reports difficult in defining and extracting burns older than one year from satellite imagery (Sanchez, pers com, 2001; Helton, pers com, 2001; Dixon, pers com, 2001). Most large area satellite mapping of burn areas requires significant manual interpretation. We suggest that a burn class not be incorporated, and that if a burn class is required only recent burns less than one year old should be included.

6.2.2 Insect Damage

None of the legends reviewed during this project have a class for insect damage. Depending upon the type of insect species, and stage and size of outbreak, the effects of the insect damage will differ. The physical heterogeneity of insect damage will be reflected in the

spectral signatures; distinct signatures may even represent one type of insect damage at different stages and intensities. The spatial nature of insect damage is also variable. Outbreak may cover large contiguous areas or may only effect small pockets of trees. Mapping insect damage with Landsat imagery would require a multitude of small classes varied by species and intensity and stage of the outbreak. Therefore, mapping insect damage is not suggested. Insect damage may be assessed during change detection and land cover mapping should not include an insect damage class.

6.2.3 Harvest

Harvested areas are not a land cover class, but an important component of a working forest, accounting for a significant amount of forest change. Much like recent burns, recently harvested areas are often easy to see on imagery. Work done in Alberta suggests that harvested areas in Boreal forests are easy to see. However, spectrally, harvested areas are not likely to be separated from other exposed areas. Harvested areas may be located during change detection. The use of ancillary information such as existing shape file, or manual interpretation supplemented with aerial photographs may make locating harvested areas possible. If the land cover mapping relies on spectral information only harvested areas cannot be identified. Like burn areas, harvested areas are transitional, and determining when to move a harvested area back into a forest class will be difficult.

6.2.4 Alpine

Although the NFI classification scheme, designed for use with aerial photographs, has an alpine group at the Landscape Position level, the proposed EOSD legend does not classify alpine areas separately. Incorporating alpine classes in the EOSD legend would require the addition of many classes, with each of the existing classes needing an alpine and non-alpine subgroup. It is not appropriate to nearly double the number of classes in the proposed EOSD legend in order to incorporate alpine classes; however, if alpine classes are important for some studies, post processing using a digital elevation model may aid in the identification of alpine areas.

6.2.5 Agriculture

Under the purposed EOSD legend agricultural land use areas are considered part of the Herb class. In the legends reviewed, agricultural areas may be included as part of a more general class, be represented by a single class, or be subset into several classes. Even classifying a single agricultural class from satellite imagery is difficult and requires ancillary information. For example, Roy Dixon works on Manitoba's large area mapping project and suggests that differentiating natural grasslands from agricultural areas can be problematic (Dixon, pers com, 2001). Agricultural areas are difficult to map as they change significantly over short time periods, appearing much different in the spring than in the fall. The use of spring imagery is useful in distinguishing between agricultural and natural lands (Dixon, pers com, 2001). However the majority of EOSD imagery will be collected in the summer months.

Mapping more than one agricultural class using satellite imagery is an even greater challenge. Several groups have reported difficulty classifying agricultural lands. Jim Hiley (pers com, 2001) states that Agriculture Canada has been using five classes for large area agricultural mapping: Water, Trees, Annual Cropland, Summer Fallow, and Perennial

Grasses (hay/pasture). Even with such a limited number of agricultural classes it is difficult to classify agricultural areas accurately. The NLCD mapping project reported a high level of confusion between their Pasture/Hay and Row Crops classes.

Agriculture and Agri-Food Canada are proposing an agriculture mapping program for the Prairies. The new agricultural legend (Table 19) has 8 agricultural classes. Agriculture and Agri-Food Canada are interested in working with the CFS on this new mapping initiative.

Due to the difficulties involved with mapping agriculture lands, and the fact that it is a land use and not a land cover class, we suggest the EOSD legend not add agricultural classes. However, opportunities for collaboration with Agriculture Canada allow for the inclusion of agricultural classes.

Table 19. Agriculture and Agri-Food Canada: Agricultural classes proposed for the Prairie Region Land Cover Inventory.

Classes	Description (if available)
Cropland - Spring Seeded	
Summer Fallow - High Residue	
Summer Fallow - Medium Residue	
Summer Fallow - Low Residue	
Sod Dominant - High biomass	Associated with legume hay and fall-seeded crops.
Sod Dominant - Medium biomass	Associated with tame hay.
Sod Dominant - Low biomass	Associated with native range and pasture.
Mixed Perennial Cover	Remnants of shrub, tree, some wetland and sod dominant classes.

6.2.6 Other Land Use Classes

The majority of land cover legends discussed in this report have at least 1 land use class. Land use information is useful for many applications and therefore it may be tempting to add land use classes to the EOSD legend. However, land use classes should not be added to the EOSD legend. Land use classes require ancillary information, and at present EOSD mapping will be done mainly with spectral information. Land use classes although useful provide little additional information necessary to meet the goals of EOSD.

7.0 Recommendations

The following is a summary of recommendations for the EOSD legend. These recommendations aim to ensure that the EOSD legend is practical, appropriate, and can efficiently be used with Landsat data. On one hand, it is important that the EOSD legend is scientifically valid; the legend used should not have classes that cannot be obtained using Landsat imagery and classes need to accurately represent current land cover. On the other hand, a federal project of this magnitude benefits from support and collaboration with other agencies. The recommendations aim to ensure that the EOSD legend is both scientifically valid and will have wide acceptance from other Canadian agencies. Experiences of other programs, as well as the needs of the EOSD program, are considered and reflected in the following recommendations. The EOSD with recommended changes is shown in Table 20.

1. Continue to use the NFI Land Cover Classification Scheme as the basis for the EOSD legend.

Although there are other high quality land cover classification schemes that could be used as the starting point for the EOSD legend, the NFI Land Cover Classification Scheme is the most appropriate scheme for two reasons. First, The NFI Land Cover Classification Scheme has the support of the Canadian Forest Inventory Committee (CFIC). Gaining CFIC support took *several* years and many iterations of the classification scheme. The support of the CFIC will improve the ability of the provinces and EOSD to collaborate. Later we will show that there may be many opportunities for EOSD to work with provinces on land cover mapping. Collaboration with provinces will improve efficiency for both the provinces and EOSD. As well, the use of the NFI scheme makes integration with the NFI seamless. A different classification scheme which does not have CFIC support will likely be harder to sell to the provinces.

Secondly, the NFI Land Cover Classification Scheme was designed for use with remotely sensed data. The NFI scheme is used with aerial photography and EOSD will use Landsat. The legend requires adjustments to be compatible with Landsat imagery. However, a classification scheme that is designed for use with remotely sensed imagery will require fewer changes than a scheme designed for use with other or no technology.

Table 20. Recommended EOSD legend.

Class	Description
No Data	
Cloud	
Shadow	
Snow/Ice	Glacier/snow
Rock/Rubble	Bedrock, rubble, talus, blockfield, rubblely mine spoils, or lava beds.
Exposed Land	River sediments, exposed soils, pond or lake sediments, reservoir margins, beaches, landings, burned areas, road surfaces, mudflat sediments, cutbanks, moraines, gravel pits, tailings, railway surfaces, buildings and parking, or other non-vegetated surfaces.
Water	Lakes, reservoirs, rivers, streams, or salt water.
Shrub - Tall	At least 20% ground cover which is at least one-third shrub; average shrub height greater than or equal to 2 m.
Shrub - Low	At least 20% ground cover which is at least one-third shrub; average shrub height less than 2 m.
Herb	Vascular plant without woody stem (grasses, crops, forbs, graminoids); minimum of 20% ground cover or one-third of total vegetation must be herb.
Bryoids	Bryophytes (mosses, liverworts, and hornworts) and lichen (foliose or fruticose; not crustose); minimum of 20% ground cover or one-third of total vegetation must be a bryophyte or lichen
Wetland - Treed	Land with a water table near/at/above soil surface for enough time to promote wetland or aquatic processes; the majority of vegetation is coniferous, broadleaf, or mixed wood.
Wetland - Shrub	Land with a water table near/at/above soil surface for enough time to promote wetland or aquatic processes; the majority of vegetation is tall, low, or a mixture of tall and low shrub.
Wetland - Herb	Land with a water table near/at/above soil surface for enough time to promote wetland or aquatic processes; the majority of vegetation is herb.
Coniferous - Dense	Greater than 60% crown closure; coniferous trees are 75% or more of total basal area.
Coniferous - Open	26-60% crown closure; coniferous trees are 75% or more of total basal area.
Coniferous - Sparse	10-25% crown closure; coniferous trees are 75% or more of total basal area.
Broadleaf - Dense	Greater than 60% crown closure; broadleaf trees are 75% or more of total basal area.
Broadleaf - Open	26-60% crown closure; broadleaf trees are 75% or more of total basal area.
Broadleaf - Sparse	10-25% crown closure; broadleaf trees are 75% or more of total basal area.
Mixed Wood - Dense	Greater than 60% crown closure; neither coniferous nor broadleaf tree account for 75% or more of total basal area.
Mixed Wood - Open	26-60% crown closure; neither coniferous nor broadleaf tree account for 75% or more of total basal area.
Mixed Wood - Sparse	10-25% crown closure; neither coniferous nor broadleaf tree account for 75% or more of total basal area.

2. Do not include transitional classes such as burn, insect damage, or harvest.

All programs using classes such as burn and harvest suggest transitional classes are difficult to use and cannot be used without significant manual input or ancillary data. Reasons for difficulty mapping transitional classes are outlined in sections 6.2.1 - 6.2.3. Experts in the areas such as fire mapping, suggest that including transitional classes is inappropriate in a

land cover mapping program and would cause significant difficulties (Landry, pers com, 2001). At present, the techniques used to ensure the *accurate* mapping of transitional areas with satellite imagery are not available. Therefore, we suggest that transitional classes not be added and that these classes continue to be grouped in the Disturbed Land category.

Although the inclusion of transitional classes is not appropriate for land cover mapping it may have a place in change detection. Further investigation of how transitional classes can be identified with change detection is suggested. As well, if specific users require information on transitional classes, they may want to combine the EOSD land cover map with ancillary data or additional manual interpretation to extract required information. There is a need for research investigating which focuses on the effective and accurate mapping of transitional areas.

3. The inclusion of alpine classes is not appropriate at this time.

The inclusion of alpine classes would result in a significant increase in the number of classes. There is no evidence that suggests an increase in alpine classes is warranted at this time; however, in the future, alpine areas may be detected during post processing using a digital elevation model.

4. Include agricultural classes only through collaboration.

Agriculture classes represent land use. Spectrally separating even a single agricultural class from other grassy areas is problematic. Therefore, it is suggested that agriculture classes not be included. Collaboration with Agriculture and Agri-Food Canada may allow agricultural classes to be included. Compatibility with the NFI classification scheme can still be maintained, as all of the agriculture, except Mixed Perennial Cover, can be regrouped into the NFI Herb class.

5. Regroup wetland classes and remove Wetland – Bryoid class.

Figure 4 shows the suggested regrouping of the wetland classes. Although wetland classes are necessary as the same vegetation on wet and dry land is not spectrally the same, having too many wetland classes will likely result in a large amount of spectral overlap between classes. Therefore, we suggest the grouping of treed wetlands into a single class, wetland shrubs into a second class, and wetland herbs into a final class. The Wetland – Bryoid class should be removed from the legend as the experiences of other land cover mapping groups suggest that it is unlikely to be found. The reason wetland bryoid classes are not found using Landsat imagery is unknown. It may be that the spectral information provided in Landsat imagery is not sufficient or that wetland bryoid areas are small. Further research into this question may be useful. As well, careful attention to the accuracy of the non-wetland Bryoid class is suggested.

6. Focus on Shrub – Tall classification.

Differentiating 2m difference in shrub height using Landsat imagery may not be possible. It may not be useful to have a Shrub – Low class, which is likely to be frequently confused with the Herb and Shrub – Tall class. However, it is suspected that there will be at least two spectrally different shrub classes, and therefore we suggest leaving the shrub classes as is. Analysts should be careful that the difference in the spectral properties of shrubs are related

to height, and if not the class names and descriptions may need to be changed accordingly. One possible suggestion is to base shrub classes on density rather than height. Work in Alberta suggests that differences in shrub density can be found using Landsat imagery.

8.0 Action Items

Aside from recommendations for the EOSD classification legend, research for this report found other issues and items to be addressed. The following is a list of action items to be addressed.

- 1) Similarities between the EOSD legend and most provincial legends are sufficient to allow for collaboration. Provinces should be contacted to determine their interest in collaboration. In particular Alberta, Saskatchewan, Manitoba, Ontario, and Quebec should be contacted. Significant portions of these provinces have already been mapped.
- 2) Follow up on the review of Alberta's classification system, which is presently underway. One goal of their review is to investigate the possible of classifying more specific species information.
- 3) Follow up on the research that may provide useful information on how to deal with transitional classes.
- 4) Follow up on the large area land cover mapping legend for the Northwest Territories, which should be available in Winter 2001.
- 5) During the time allotted for this project we were unable to obtain the legend descriptions for the SDLC. Continue to track down this information. We suggest re-contacting John Potter of the Information Services Corp. The SDLC has been complete and the experiences gained during agriculture classifications in Saskatchewan may provide useful information, particularly to Agriculture and Agri-Food Canada who are preparing undertaking similar work.
- 6) Continue to investigate the potential collaboration with Agriculture and Agri-Food Canada to ensure the federal mapping efforts are harmonized.

9.0 Conclusions

The key conclusion of this report is that with minor changes the proposed EOSD legend will be adequate for land cover mapping of Canada with Landsat imagery. Other conclusions are listed below.

- 1) The EOSD legend should continue to be based on the NFI land cover classification scheme as the support of the CFIC will aid in collaboration with the NFI and large area provincial inventory programs
- 2) Wetland classes should be regrouped and the Wetland – Bryoid class removed. Particular attention should be paid to shrub classes to ensure that spectral separability between tall and low shrub is related to height differences.
- 3) The compatibility between the EOSD and provincial legends is beneficial to all groups. Collaboration with provinces should be pursued.
- 4) Supplementary transitional, land use, and alpine classes should not be incorporated into the EOSD legend. Further research is need in mapping of transitional classes before they can be effectively incorporated into large area satellite land cover mapping projects
- 5) Follow-up on studies and legend reviews as they may provide useful information on how to deal with complex classes.

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Appendix I Details of British Columbia/NFI Land Cover Legend

(From MOF, 1999)

Level 1 - Classifying the Land Base

The first level of the classification scheme classifies the presence or absence of vegetation, as Vegetated or Non-Vegetated.

V = Vegetated

A polygon is considered Vegetated when the total cover of trees, shrubs, herbs, and bryoids (other than crustose lichens) covers at least 5% of the total surface area of the polygon.

N = Non-Vegetated

A polygon is considered Non-Vegetated when the total cover of trees, shrubs, herbs, and bryoids covers less than 5% of the total surface area of the polygon. Bodies of water are to be classified as Non-Vegetated.

Classifying Vegetated Polygons

If the polygon is classed as Vegetated the following levels apply.

(If classified as Non-Vegetated see *Classifying Non-Vegetated Polygons* for a description of further levels.)

Level 3 - Land Cover Type

The first determination for Vegetated polygons is whether they are Treed or Non-Treed.

T = Treed

A polygon is considered Treed if at least 10% of the polygon area, by crown cover, consists of tree species of any size. See Appendix X of the NFI Design Document for a list of tree species.

N = Non-Treed

A polygon is considered Non-Treed if less than 10%, by crown cover, of the polygon area consists of tree species of any size.

Level 3 - Landscape Position

Once the polygon has been classified as Treed or Non-Treed, the location relative to elevation and drainage is determined.

W = Wetland

Wetland has numerous definitions in the literature. The definition used for the classification is taken from Fraser et al. (1995):

Wetland is defined as land having the water table at, near or above the soil surface, or which is saturated for a long enough period of time to promote wetland or aquatic processes. These wetland processes are indicated by the presence of Organic or Gleysolic soils and hydrophytic vegetation. See wetland definitions later in this Appendix for a more complete description.

U = Upland

A broad class that includes all non-wetland ecosystems that range from very xeric to hygric soil moisture regimes.

A = Alpine

A polygon is considered Alpine when it is treeless (for practical purposes less than 1% tree cover can be included within the Alpine category), with alpine vegetation dominated by shrubs, herbs, graminoids, bryoids, and lichens. Rock, ice, and snow dominate much of the Alpine. Alpine does not typically include the parkland and krummholz forest types. Alpine is a classification level of Non-Treed areas above the tree line only.

Level 4 - Vegetation Type

Once the polygon is classed as Treed or Non-Treed and determined whether it is Wetland or, Upland, it is further classified by the type of vegetation within the unit:

Vegetated Treed

Treed units can be Coniferous, Broadleaf, or Mixed.

TC = Coniferous

Defined as those trees classified botanically as Coniferae; cone-bearing trees having needles or scale-like leaves, usually evergreen. These species are commonly referred to as conifer or softwoods. See Appendix X of the NFI Design Document for a list of species and species codes.

The polygon is classified as Coniferous when trees cover a minimum of 10% of the total polygon area by crown cover, and coniferous trees are 75% or more of the total tree basal area.

TB = Broadleaf

Defined as those trees classified botanically as Angiospermae in the subclass Dicotyledoneae. These species are commonly referred to as deciduous or hardwoods. See Appendix X of the NFI Design Document for a list of species and species codes.

The polygon is classified as Broadleaf when trees cover a minimum of 10% of the total polygon area by crown cover, and broadleaf trees are 75% or more of the total tree basal area.

TM = Mixed

The polygon is classified as Mixed when trees cover a minimum of 10% of the total polygon area by crown cover, but neither coniferous nor broadleaf trees account for 75% or more of the total tree basal area.

Vegetated Non-Treed Units

Non-Treed units can be Shrub, Herb, or Bryoid.

Shrub

Shrubs are defined as woody perennial plants, both evergreen and deciduous, that has a relatively low growth habit, and is generally multi-stemmed, rather than having one bole. It differs from a tree by its low stature (generally less than 10 m) and non-treelike form. A reporting break is made between Tall (greater than or equal to 2 m) and Low (less than 2 m) for wildlife management interpretation purposes. Other breaks may be used if preferred, as height data are estimated as a continuous variable.

For a polygon to be classed as Shrub, it must have a minimum of 20% ground cover of shrubs, or shrubs must constitute more than 1/3 of the total vegetation cover.

ST = Shrub Tall

A Shrub polygon with average height greater than or equal to 2 m.

SL = Shrub Low

A Shrub polygon with average shrub height less than 2 m.

Herb

Herbs are defined, for this system, as vascular plants without a woody stem, including ferns, fern allies, grasses, and grass-like plants.

The Herb class has two further subdivisions based on the proportion of forbs and graminoid plants. The subclasses Forbs and Graminoids are used when any one group accounts for greater than 50% of the herb cover.

Graminoids are defined as herbaceous plants with long, narrow leaves characterized by linear venation; including grasses, sedges, rushes, and other related species.

Forbs are defined as herbaceous plants other than graminoids, including ferns, club mosses, and horsetails.

If a polygon does not meet the definition of Shrub, then it can be classed as Herb if it has a minimum of 20% ground cover of herbs, or herbs constitute more than 1/3 of the total vegetation cover.

HE = Herb

A Herb polygon with no distinction between forbs and graminoids.

HF = Herb – Forbs

A Herb polygon with forbs greater than 50% of the herb cover.

HG = Herb – Graminoids

A Herb polygon with graminoids greater than 50% of the herb cover.

Bryoid

Bryoids are defined as bryophytes (mosses, liverworts, and hornworts) and lichens (foliose or fruticose; not crustose).

If a polygon does not meet the definition of Shrub or Herb, then it can be classed as Bryoid if it has greater than 50% of the vegetation cover in bryoids, or if bryoids constitute more than 1/3 of the total vegetation cover.

The Bryoid class has two further subdivisions based on the proportion of bryophytes and lichens. The class is subdivided into Bryophyte or Lichen when any one group accounts for greater than 50% of the bryoid cover.

BY = Bryoids

A Bryoid polygon with no distinction between mosses and lichens by cover.

BM = Bryoid – Moss

A Bryoid polygon with mosses, liverworts, and hornworts greater than 50% of the bryoid cover.

BL = Bryoid – Lichens

A Bryoid polygon with lichens (foliose or fruticose; not crustose) greater than 50% of the bryoid cover.

Level 5 - Density Class

Once a Vegetated polygon is classed up to Level 4, density is reported using the following density classes available by vegetation type. Note that these are reporting breaks only; interpreters can estimate density in a continuous manner (from 0% to 100%).

The density classes for Treed, Shrub, or Herb polygons are as follows:

DE = Dense

Shrub, or herb cover is between 61% and 100% crown closure for the polygon.

OP = Open

Shrub, or herb cover is between 26% and 60% crown closure for the polygon.

SP = Sparse

Shrub, or herb cover is between 20% and 25% crown closure for the polygon.

The density classes for Bryoid polygons are as follows:

CL = Closed

Cover of bryoids is greater than 50% of the polygon.

OP = Open

Cover of bryoids is less than or equal to 50% of the polygon.

Classifying Non-Vegetated Polygons

A polygon is considered Non-Vegetated when the total cover of trees, shrubs, herbs, and bryoids covers less than 5% of the total surface area of the polygon.

Level 2 - Land Cover Type

The first decision is whether a polygon is considered to be Land or a Water body. The cover type occupying greater than 50% of the polygon area is the cover type assigned.

L = Land

The portion of the landscape not covered by water (as defined below), based on the percentage cover area.

W = Water

A naturally occurring, static body of water, two or more metres deep in some portion, or a watercourse formed when water flows between continuous, definable banks. These flows may be intermittent or perennial; but do not include ephemeral flows where a channel with no definable banks is present. Islands within streams that have definable banks are not part of the stream; gravel bars are part of the stream. Interpretation is based on the percentage area covered.

Classifying Non-Vegetated Land Polygons

If the polygon is classed as Land the following steps and levels apply.

(If classed as Water see Land Cover Type - Water for a description of further levels.)

Level 3 - Landscape Position (Land)

This level describes the location of the polygon relative to drainage, and is described as Wetland or Upland.

W = Wetland

Land having a water table near, at, or above the soil surface, or which is saturated for a long enough period to promote wetland or aquatic processes. These wetland processes are indicated by the presence of Organic or Gleysolic soils and hydrophytic vegetation. See wetland definitions later in this Appendix for a more complete description.

U = Upland

A broad class that includes all non-wetland ecosystems that range from very xeric to hygric soil moisture regimes.

A = Alpine

A polygon is considered Alpine when it is treeless (for practical purposes less than 1% tree cover can be included within the Alpine category), with alpine vegetation dominated by shrubs, herbs, graminoids, bryoids, and lichens. Rock, ice, and snow dominate much of the Alpine. Alpine does not typically include the parkland and krummholz forest types. Alpine is a classification level of Non-Treed areas above the tree line only.

Level 4 - Non-Vegetated Cover Type (Land)

Once the polygon is classed as Non-Vegetated and determined whether it is Wetland, Upland or Alpine, it is further classified by the type of non-vegetated condition within the unit. Non-Vegetated polygons are divided into three groups: Snow/Ice, Rock/Rubble, and Exposed Land.

SI = Snow/Ice

Defined as either glacier or snow cover.

RO = Rock/Rubble

Defined as bedrock or fragmented rock broken away from bedrock surfaces and moved into its present position by gravity or ice. Extensive deposits are found in and adjacent to alpine areas and are associated with steep rock walls and exposed ridges; canyons and cliff areas also contain these deposits.

EL = Exposed Land

Contains all other forms of Exposed Land identified by a range of subclasses.

Level 5 - Non-Vegetated Categories (Land)

Classes are defined by the dominant material or feature of the non-vegetated area.

Snow/Ice has two subclasses - **Glacier** and **Snow Cover**:

GL = Glacier

A mass of perennial snow and ice with definite lateral limits, typically flowing in a particular direction.

SC = Snow Cover

Snow or ice that is not part of a glacier, but is found during summer months on the landscape.

Rock/Rubble has four subclasses:

BR = Bedrock

Unfragmented, consolidated rock contiguous with the underlying material.

RT = Rubble, Talus, Blockfield

Fragmented rock, broken away from bedrock surfaces and moved into its present position by gravity or ice.

MS = Rubbly Mine Spoils

Discarded overburden or waste rock moved to extract ore during a mining operation.

LB = Lava Bed

An area where molten rock has flowed from a volcano or fissure and cooled and solidified to form rock.

Exposed Land has 16 subclasses:

RS = River Sediments

Silt, gravel, and sand bars associated with former river channels and present river edges.

ES = Exposed Soil

Any exposed soil not covered by the other categories, such as areas of recent disturbance including mud slides, debris torrents, avalanches, or disturbances such as pipeline rights-of-way or cultivated fields, where vegetation cover is less than 5%.

LS = Pond or Lake Sediments

Exposed sediments related to dried-up lakes or ponds.

- RM = Reservoir Margin**
Land exposed by a drained or fluctuating reservoir. It is found above “normal” water levels and may consist of a range of substrates including gravel, cobbles, fine sediments, or bedrock.
- BE = Beach**
An area with sorted sediments reworked in recent time by wave action. It may be formed at the edge of fresh or salt water bodies.
- LL = Landing**
A compacted area adjacent to a road used for sorting and loading logs.
- BU = Burned Area**
Land showing evidence of recent burning, either natural or prescribed. Vegetation of less than 5% crown cover is present at the time of polygon description.
- RP = Road Surface**
An area cleared and compacted for the purpose of transporting goods and services by vehicles. Older roads that are used infrequently or not at all may cease to be classified as non-vegetated.
- MU = Mudflat Sediment**
Flat plain-like areas associated with lakes, ponds, rivers, or streams, dominated by fine-textured sediments. They can be associated with freshwater or estuarine sources.
- CB = Cutbank**
Part of a road corridor created upslope of the road surface by excavation into the hillside.
- MO = Moraine**
An area of debris transported and deposited by a glacier.
- GP = Gravel Pit**
An area exposed through the removal of sand and gravel.
- TS = Tailings**
An area containing the solid waste material produced by the mining and milling of ore.
- RR = Railway Surface**
A roadbed with fixed rails, may contain single or multiple rail lines.
- BP = Buildings and Parking**
Buildings and associated developments such as roads and parking areas.

OT = Other

A Non-Vegetated polygon where none of the other exposed land categories can be reliably chosen.

Classifying Non-Vegetated Water Polygons

If the polygon is classed as Water the following categories apply:

Level 3 - Landscape Position (Water)

The landscape position relative to drainage is determined.

W = Wetland

Land having a water table near, at, or above the soil surface, or which is saturated for a long enough period to promote wetland or aquatic processes. These wetland processes are indicated by the presence of Organic or Gleysolic soils and hydrophytic vegetation. See wetland definitions later in this Appendix for a more complete description.

U = Upland

A broad class that includes all non-wetland ecosystems that range from very xeric to hygric soil moisture regimes.

A = Alpine

A polygon is considered Alpine when it is treeless (for practical purposes less than 1% tree cover can be included within the Alpine category), with alpine vegetation dominated by shrubs, herbs, graminoids, bryoids, and lichens. Rock, ice, and snow dominate much of the Alpine. Alpine does not typically include the parkland and krummholz forest types. Alpine is a classification level of Non-Treed areas above the tree line only.

Level 4 - No Level 4 for Water

There are no classes at this level (Land Cover Type) for Water.

Level 5 - Water Categories

Four categories have been identified: Lake, Reservoir, River/Stream, and Salt Water.

LA = Lake

A naturally occurring static body of water more than two metres deep in some portion. The boundary for the lake is the natural high water mark.

RE = Reservoir

An artificial basin affected by impoundment of water behind a human fabricated structure such as a dam, berm, dyke, or wall.

RI = River/Stream

A watercourse formed when water flows between continuous, definable banks. Flow may be intermittent or perennial, but does not include ephemeral flow where a channel with no definable banks is present. Gravel bars are part of a stream, while islands within a stream that have definable banks are not.

SW = Salt Water

A naturally occurring body of water containing salt or generally considered to be salty.

Definitions

The following terms are defined for use in the Land Cover Classification Scheme.

Vegetated Land Definitions

Alpine: Treeless (for practical purposes less than 1% tree cover can be included within the Alpine category), with alpine vegetation dominated by shrubs, herbs, graminoids, bryoids, and lichens. Rock, ice, and snow dominate much of the Alpine. Alpine does not typically include the parkland and krummholz forest types. Alpine is, by definition, treeless, therefore there is no further classification level of Treed/Non-Treed under this category.

Broadleaf: trees classified botanically as Angiospermae in the subclass Dicotyledoneae (Bones 1993). These species are referred to as hardwoods. These species are commonly referred to as deciduous or hardwoods.

Bryoids: are defined as bryophytes (mosses, liverworts, and hornworts) and lichens (foliose or fruticose; not crustose).

Coniferous: trees classified botanically as Coniferae; cone-bearing trees having needles or scale-like leaves, usually evergreen. These species are commonly referred to as conifer or softwoods.

Forbs are defined as herbaceous plants other than graminoids, including ferns, club mosses, and horsetails.

Graminoids are defined as herbaceous plants with long, narrow leaves characterized by linear venation; including grasses, sedges, rushes, and other related species.

Herbs: vascular plants without a woody stem, including ferns, fern allies, grasses, and grass-like plants.

Krummholz: scrubby, stunted growth form of trees, often forming a characteristic zone at the limit of tree growth at high elevations.

Non-Treed: a polygon is considered Non-Treed if less than 10%, by crown cover, of the polygon area consists of tree species of any size.

Parkland: landscape characterized by strong clumping of trees due to environmental factors.

Shrubs: woody perennial plants, both evergreen and deciduous, that has a relatively low growth habit, and is generally multi-stemmed, rather than having one bole. It differs from a tree by its low stature (generally less than 10 m) and non-treelike form. A reporting break is made between Tall (greater than or equal to 2 m) and Low (less than 2 m) for wildlife management interpretation purposes. Other breaks may be used if preferred, as height data are estimated as a continuous variable.

Treed: a polygon is considered Treed if 10% or more of the polygon area, by crown cover, consists of tree species of any size.

Upland: a broad class that includes all non-wetland ecosystems that range from very xeric to hygric soil moisture regimes.

Vegetated: a polygon is considered Vegetated when the total cover of trees, shrubs, herbs, and bryoids (other than crustose lichens) covers at least 5% of the total surface area of the polygon.

Wetland: is defined as land having the water table at, near, or above the soil surface, or which is saturated for a long enough period to promote wetland or aquatic processes. These wetland processes are indicated by the presence of Organic or Gleysolic soils and hydrophytic vegetation. See Wetland definitions later in this section for a more complete description.

Non-Vegetated Land Definitions

Beach (Exposed Land): an area with sorted sediments reworked in recent time by wave action. It may be formed at the edge of fresh or salt water bodies.

Bedrock (Rock/Rubble): unfragmented, consolidated rock contiguous with the underlying material.

Buildings and Parking (Exposed Land): buildings and associated developments such as roads and parking areas.

Burned Area (Exposed Land): land showing evidence of recent burning, either natural or prescribed. Vegetation of less than 5% crown cover is present at the time of polygon description.

Cutbank (Exposed Land): part of a road corridor created upslope of the road surface by excavation into the hillside.

Exposed Land: contains all other forms of exposed land identified by a range of 16 subclasses: Beach; Buildings and Parking; Burned Area; Cutbank; Exposed Soil; Gravel Pit; Landing; Moraine; Mudflat Sediment; Other; Pond or Lake Sediments; Railway Surface; Reservoir Margin; River Sediments; Road Surface; Tailings.

Exposed Soil (Exposed Land): any exposed soil not covered by the other categories (e.g., areas of recent disturbance including mud slides, debris torrents, avalanches, or disturbances such as pipe line rights-of-way or cultivated fields) where vegetation cover is less than 5%.

Glacier (Snow/Ice): a mass of perennial snow and ice with definite lateral limits, typically flowing in a particular direction.

Gravel Pit (Exposed Land): an area exposed through removal of sand and gravel.

Lake: a naturally occurring static body of water more than two metres deep in some portion. The boundary for the lake is the natural high water mark.

Land: the portion of the landscape not covered by water (as defined below), based on the percentage area cover.

Landing (Exposed Land): a compacted area adjacent to a road used for sorting and loading logs.

Lava Bed: an area where molten rock has flowed from a volcano or fissure and cooled and solidified to form rock.

Moraine (Exposed Land): an area of debris transported and deposited by a glacier.

Mudflat Sediment (Exposed Land): flat plain-like areas associated with lakes, ponds, rivers, or streams, dominated by fine-textured sediments. They can be associated with freshwater or estuarine sources.

Non-Vegetated: A polygon is considered Non-Vegetated when the total cover of trees, shrubs, herbs, and bryoids covers less than 5% of the total surface area of the polygon. Bodies of water are to be classified as Non-Vegetated.

Other (Exposed Land): a Non-Vegetated polygon where none of the other exposed land categories can be reliably chosen.

Pond or Lake Sediments (Exposed Land): exposed sediments related to dried-up lakes or ponds.

Railway Surface (Exposed Land): a roadbed with fixed rails; may contain single or multiple rail lines.

Reservoir: an artificial basin affected by impoundment of water behind a human fabricated structure such as a dam, berm, dyke, or wall.

Reservoir Margin (Exposed Land): land exposed by a drained or fluctuating reservoir. It is found above “normal” water levels, and may consist of a range of substrates including gravel, cobbles, fine sediments, or bedrock.

River/Stream: a watercourse formed when water flows between continuous, definable banks. Flow may be intermittent or perennial, but does not include ephemeral flow where a channel with no definable banks is present. Gravel bars are part of a stream, while islands within a stream that have definable banks are not.

River Sediments (Exposed Land): silt, gravel, and sand bars associated with former river channels and present river edges.

Road Surface (Exposed Land): an area cleared and compacted for the purpose of transporting goods and services by vehicles. Older roads that are used infrequently or not at all may cease to be classified as non-vegetated.

Rock/Rubble: bedrock or fragmented rock broken away from the bedrock surface and moved into its present position by gravity or ice. Extensive deposits are found in and adjacent to alpine areas and are associated with steep rock walls and exposed ridges. Canyons and cliff areas also contain these deposits.

Rubble, Talus, Blockfield (Rock/Rubble): fragmented rock, broken away from the bedrock surface, and moved into its present position by gravity or ice.

Rubby Mine Spoils (Rock/Rubble): discarded overburden or waste rock moved to extract ore during a mining operation.

Salt Water: a naturally occurring body of water containing salt or generally considered to be salty.

Snow Cover (Snow/Ice): snow or ice that is not part of a glacier, but is found during summer months on the landscape.

Tailings (Exposed Land): an area containing the solid waste material produced by the mining and milling of ore.

Water: a naturally occurring, static body of water, two or more metres deep in some portion, or a watercourse formed when water flows between continuous, definable banks. These flows may be intermittent or perennial; but do not include ephemeral flows where a channel with no definable banks is present. Islands within a stream with definable banks are not part of the stream; gravel bars are part of the stream. Interpretation is based on the percentage area covered.

Wetland Definitions

This section is taken from Fraser et al. (1995). The wetland classification was under review at the time of this report.

Wetland: Land having a water table at, near, or above the soil surface, or which is saturated for a long enough period to promote wetland or aquatic processes. These wetland processes are indicated by the presence of Organic or Gleysolic soils and hydrophytic vegetation. Sites with subhydric soil moisture regime and wetter are generally considered to be wetlands; sites with deeper waters are aquatic ecosystems. Wetlands must have one of the following four attributes (adapted from Cowardin et al. 1979):

1. At least periodically, the land supports predominantly hydrophytic plant species.
2. The substrate is predominantly poorly drained subhydric or wetter soil. Soils may be organic or mineral; in mineral soils, gleying occurs within the top 30 cm.
3. The substrate is nonsoil and is saturated with water covered by shallow water at some time during the growing season.
4. A water body less than two metres in depth.

Wetlands can be bogs, swamps, marshes, fens, hot springs and hot pools, alkali ponds, shrub carrs, swamps, shallow (less than 2 m) open water, and includes both forested and non-forested ecosystems. As an example, the wetland realm can be subdivided into a number of classes.

Bogs: a peat-dominated class of wetland. They are wetlands covered or filled with poorly to moderately decomposed Sphagnum-derived peats. They are nutrient poor. Soils are usually Fibrisols, Mesisols, or Humisols. In the Fort Nelson Lowlands, bogs can have Organic Cryosolic soils.

Swamps: wooded wetlands dominated by 25% or greater cover of trees or tall shrubs and characterized by periodic flooding and nearly permanent subsurface water flow through various mixtures of mineral sediments and peat. Swamps, like fens, are rich in minerals and nutrients, but the characteristic water movement through swamps tends to make them better aerated than fens. Swamp waters thus have sufficient levels of dissolved oxygen to support either tall shrubs or trees.

Marshes: wetlands that are permanently or seasonally inundated with nutrient-rich water, and support extensive cover of emergent herbaceous vegetation rooting in a mineral-rich substrate. The water level of marshes varies seasonally, and from marsh to marsh. Marshes that dry by late summer expose matted vegetation and unvegetated mudflats or sandflats, but saturation persists near the surface. The substrate ranges from dominantly mineral materials to shallow, well-decomposed peat, derived primarily from marsh vegetation. The substrate is strongly influenced by water chemistry, which in turn reflects basin geology and regional climate.

Fens: wetlands composed of accumulations of well to poorly decomposed, non-sphagnum peats. Most fens have more than 40 cm of peat accumulation. Fen waters come mostly from groundwater and runoff from adjacent mineral uplands. As a result, fens are less acid and more mineral-rich than are bogs. Fen peat is well to moderately decomposed. Associated soils are Mesisols and Humisols. Fen vegetation can be dominated by grasses, sedges, rushes, low shrubs, or trees, and often underlain by mosses.

Wet Meadows: seasonally inundated wetlands, dominated by grasses, sedges, or rushes. They generally occur on mineral soils and have little or no peat accumulation. Tree cover is less than 10%.

Shrub Carrs: wetlands that are seasonally flooded, but dry out at the soil surface during the growing season. They occur on mineral soils that are typically gleyed within the top 30 cm.

Shallow Open Water: permanent, shallow (less than 2 m midsummer levels), standing water that lacks extensive emergent plant cover. Vegetation can be absent or emergent plants can cover up to 10% of the surface. Shallow Open Waters often include various submerged and floating aquatic macrophytes. Submerged aquatic plants are common. Shallow Open Water is also found around the edges of many lakes.

