# ECOLOGICAL REGIONS OF THE NORTHWEST TERRITORIES

# CORDILLERA

ECOSYSTEM CLASSIFICATION GROUP

2010

Northwest Territories Environment and Natural Resources

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**Department of Environment and Natural Resources**
**Government of the Northwest Territories**
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*About the cover:* The small digital images in the inset boxes are enlarged with captions on page 32 (*Tundra Cordillera HS Ecoregion*), page 42 (*Taiga Cordillera HS Ecoregion*), 56 (*Taiga Cordillera LS Ecoregion*), page 106 (*Boreal Cordillera HB Ecoregion*) and page 146 (*Boreal Cordillera MB Ecoregion*). Aerial images: Dave Downing, Timberline Natural Resource Group. Ground images, main cover image and plant images: Bob Decker, Government of the Northwest Territories.

*Document images:* Except where otherwise credited, aerial images in the document were taken by Dave Downing, Timberline Natural Resource Group, and ground-level images were taken by Bob Decker, Government of the Northwest Territories.

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# Preface

Rugged mountain ranges cover over 25 percent of the North American continent and extend nearly 5000 km from Alaska to Mexico, forming the western spine of North America and Central America. The mountains have a continent-wide influence on climates and markedly affect precipitation and temperature. The interplay of climate, topography, hydrology and geology within montane landscapes creates diverse and unique ecosystems and some of the world's most inspiring vistas. The mountains within the Northwest Territories, collectively referenced within this report as the "Cordillera", are the northeastern anchor of the continental mountain chain. Forming a rough semicircle of high plateaus and jagged peaks along the western Territorial border and extending west into the Yukon, they influence the climate and hydrology of the Taiga Plains to the east and harbour an exceptional assemblage of boreal and subarctic mountain landscapes and ecosystems.

Mountain landscapes clearly show how climate, geology, and topography affect ecosystem development; for example, north slopes and south slopes support different plant communities and soil types, and mixed-wood forests give way to conifer woodlands and then to tundra as elevations and latitude increase. *Abiotic factors* such as latitude, elevation and parent materials control temperature, moisture, light and nutrient levels, all of which determine the type of plant communities and soils that can develop. *Biotic factors* (e.g., competition between species that influences the degree to which a plant can grow and reproduce) are also important. The influence of biotic and abiotic factors is determined by the interaction of atmospheric and terrain elements – climate, topography, parent materials and biotic elements – over decades and centuries, as described by Major (1951) and Jenny (1941) for vegetation and soils, respectively. Vegetation and terrain patterns can be delineated and represented as abstract ecological map units and described at various scales.

At the global scale, the *Biome* or *Vegetation Zone* is recognized (Walter 1979, Scott 1995, Commission for Environmental Cooperation 1997). At the national scale in Canada, *Ecozones, Ecoregions* and *Ecodistricts* are described (Ecological Stratification Working Group 1995). The Northwest Territories has modified the Canadian national scale and classification framework to match the multi-level continental ecosystem classification framework – *Ecological Regions of North America* – developed by the Commission for Environmental Cooperation in 1997. The Canadian and continental systems are outlined in Section 1 of this report.

The value of regional ecosystem classification systems as a foundation for sustainable resource management has been recognized since the 1960s in Canada. Ecosystem classifications provide a means of presenting and understanding biophysical patterns and processes in a geographic context and provide a common basis for communication. The Government of the Northwest Territories has used the national ecosystem classification framework since 1996 as the basis for identifying candidate protected areas, forest management planning, wildlife habitat management and environmental impact assessment and mitigation. In 2004, in response to increasing development pressures in the Mackenzie River Corridor, the delineation and description of the 1996 Taiga Plains Ecozone was examined by a third-party reviewer to assess its utility. Subsequently, a series of workshops in 2004 – 2006 and an intensive survey of the entire Taiga Plains in 2005 led to significant changes to the 1996 map, and a revised map and report were produced in early 2007. This report was revised and reprinted in 2009 (Ecosystem Classification Group 2007 (revised 2009)).

Similar revisions were undertaken in 2006 for the 1996 Taiga Shield Ecozone bordering the Taiga Plains to the east (Ecosystem Classification Group 2008), and again in 2007 through 2010 for the 1996 Taiga Cordillera and Boreal Cordillera Ecozones bordering the Taiga Plains to the west (this report). Initial planning for the Cordillera survey involved a geographic information system-based review of several spatial data sources including Landsat imagery, digital elevation models, hydrology, permafrost, bedrock and surficial geology, soils and interpolated climate models. This information facilitated the review of landscapes and existing mapped ecosystem units from a number of different perspectives and from this review, provisional ecosystem units were developed.

Air and ground assessment of the provisional units was an integral part of the revision process. In the summer of 2007, an intensive helicopter survey was undertaken throughout the entire Cordillera and included the main mountain ranges (the Mackenzie and Selwyn Mountains) and the northern Richardson Mountains. Over 18,000 km of transects were flown and a detailed and large-scale record of landscape features was captured in over 17,000 geographically referenced digital images accompanied by text comments. Site, vegetation and soil information was also collected from 40 detailed and reconnaissance ground plots. All photos were reviewed again in 2008 and more detailed comments were added. Both the photographs and themes derived from the comments proved to be indispensable for the revision process that involved ecosystem classification experts from the governments of the Northwest Territories and Yukon, Agriculture and Agri-Foods Canada and Timberline Natural Resource Group.

This report and the accompanying maps (Appendix 3) provide ecological descriptions of ecoregions within the Cordillera. Better spatial information and an understanding of climate and landscape patterns and processes gained through intensive aerial surveys have resulted in the recognition of 36 Level IV[1] ecoregions within the Cordillera, compared to four described by the Ecological Stratification Working Group in 1995.

The report integrates currently available information about climatic, physiographic, vegetation, soil and wildlife attributes to characterize each of the ecoregions within the Cordillera in a format that is suited to both technical and non-technical users. For this purpose, it has been organized into four sections.

- Section 1 defines the *Ecological Regions of North America* ecosystem classification framework as applied to the Cordillera and its relationship to the national classification system that is applied across much of Canada. The climatic and physiographic factors that exert major influences on landscapes are also discussed.
- Section 2 provides further details on the methods employed in the review and refinement of the 1996 Canadian Ecological Framework to better represent landscape patterns and to describe these patterns within the continental framework.
- Section 3 describes the Cordillera. Within this section:
    - Section 3.1 provides an overview of Section 3 contents;
    - Section 3.2 provides an overview of the entire Cordillera and each of three Level II Ecoregions within it;
    - Section 3.3 summarizes how Level III and Level IV Ecoregions are described and the sources of information used in the descriptions;
    - Section 3.4 describes the Level III Tundra Cordillera High Subarctic Ecoregion and two Level IV ecoregions within it;
    - Section 3.5 describes the Level III Taiga Cordillera High Subarctic Ecoregion and three Level IV ecoregions within it;
    - Section 3.6 describes the Level III Taiga Cordillera Low Subarctic Ecoregion and 12 Level IV ecoregions within it;
    - Section 3.7 describes the Level III Boreal Cordillera High Boreal Ecoregion and 10 Level IV ecoregions within it; and
    - Section 3.8 describes the Level III Boreal Cordillera Mid-Boreal Ecoregion and nine Level IV ecoregions within it.
- Section 4 describes the mammals and birds found in the various ecoregions of the Cordillera.

The report concludes with a list of cited references, common and scientific names of plants mentioned in the text (Appendix 1), a summary of changes from the 1996 published version of Ecozones and Ecoregions for the Cordillera to the current version (Appendix 2), a page-size map and legend for the Cordillera (Appendix 3), a description of the modelling approach applied to some Level III ecoregion boundary determinations (Appendix 4) and a glossary of useful terms (Appendix 5). A larger foldout map of the Cordillera Ecosystem Classification is provided in a map pocket at the back of printed copies of this report.

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[1] Level I, Level II, Level III and Level IV ecoregion definitions are provided in Section 1.

# Table of Contents

# Table of Contents (continued)

# Table of Contents (continued)

# Table of Contents (concluded)



# List of Figures

# List of Figures (continued)

# List of Figures (concluded)



# List of Tables

# Section 1: Concepts, Climates, and Landscapes

## 1.1 Introduction

Section 1 explains the system that classifies the Northwest Territories into ecologically meaningful units based on climate, physiography and vegetation patterns. Section 1.2 provides an overview of the North American continental ecosystem classification system, a comparison to the related Canadian framework, and its application to the Northwest Territories. Section 1.3 reviews mapping concepts, including the practical aspects of applying the ecosystem classification scheme to the Northwest Territories. Section 1.4 explains how climatically distinct regional land areas are delineated (Level III ecoregions, defined in Section 1.3.3). Section 1.5 explains how these regional areas are divided into units characterized by vegetation and physiography (Level IV ecoregions, defined in Section 1.3.4), how units are named, and how they are described.

## 1.2 Classification Framework

The recognition that climate and landforms influence biotic processes differently from place to place and at all scales encouraged the development of an integrated climate and landform-based ecosystem classification approach in Canada; this system has been under development since the 1960s. The Subcommittee on Biophysical Land Classification (Lacate 1969) developed the first nationally applied multi-level definition of landscapes using these criteria. The Canada Committee on Ecological Land Classification (CCELC) was formed in 1976; the Ecoregions Working Group was established shortly afterwards with a mandate to develop the concept and hierarchy for the *Ecoclimatic Regions of Canada* (Ecoregions Working Group 1989). The CCELC further defined classification elements and the methods for mapping them (Wiken and Ironside 1977); CCELC developed a multi-level classification framework, shown in Table 1 (Marshall *et al*. 1996; Commission for Environmental Cooperation 1997).

From 1996 to early 2006, this national scheme was used to delineate and describe ecosystem units within the Northwest Territories (Ecological Stratification Working Group 1995; Downing *et al*. 2006). Discussions with other experts in Canada and the United States in 2006 indicated the value of integrating the Northwest Territories ecological classification framework with the continental *Ecological Regions of North America*[2], and ecosystems of the Taiga Plains and the Taiga Shield were subsequently described as units within that classification.

Like the Canadian system, the North American continental framework is a multilevel, nested system for delineating and describing ecosystems; the Government of the Northwest Territories uses this information for planning and reporting purposes. Currently, the top four levels of the continental framework as applied to the Cordillera are Level I ecoregions, Level II ecoregions, Level III ecoregions and Level IV ecoregions.

## 1.3 Mapping Concepts and Landscape Descriptions

The classification scheme adopted for the Northwest Territories shows how landscapes are logically divided into units that reflect the ecological relationships between climate, topography, parent materials and biota. The approach starts with the largest landscape complex (Level I global to continental scale). Level II, III and IV ecoregions are nested within these, and are recognized as discrete units by vegetation and landform patterns at increasingly large scales. Level III and Level IV ecoregions cover areas of hundreds to thousands of square kilometres and encompass considerable complexity.

The spatial delineation and description of any of these units depends on the mapper's concept of what constitutes an ecologically meaningful pattern and the information available to support this conclusion. The mapping process is therefore inherently subjective, and mapped units and their descriptions are based on the best empirical information available at the time, a reasonable compromise between differing viewpoints, and the acknowledgement that map units are abstract representations of real-world landscapes. For example, boundaries between Level I, II and III ecoregions are shown as sharp lines on a map or in a GIS database, but are not always so well defined in nature. Clearly visible features such as the topographic differences between the generally level landscapes of the Taiga Plains and the plateaus and ridges of the Cordillera are readily observed and mapped. Where regional climatic differences are the boundary criterion, boundaries between map units are more correctly viewed as broad transition zones perhaps tens of kilometres in width.

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[2] Further information available at the Commission for Environmental Cooperation website: http://www.cec.org/files/pdf/BIODIVERSITY/eco-eng_EN.pdf and http://www.epa.gov/wed/pages/ecoregions/ecoregions.htm

**Table 1.** Northwest Territories ecosystem classification framework as applied to the Cordillera, compared to the National Ecological Framework for Canada (1995).

| Northwest Territories/Continental Ecosystem Classification | National Ecological Framework for Canada (1995) equivalent | Description |
|---|---|---|
| **Level I Ecoregion** *(Tundra, Taiga, Northwestern Forested Mountains)* | **Ecoclimatic Province** (The highest level defined by Ecoregions Working Group 1989, not a part of the 1995 National Ecological Framework) | *Global – Continental:* Scale 1:50,000,000. Equivalent to global biomes. Used as the first level of stratification for international planning and management initiatives. |
| **Level II Ecoregion** *(Tundra Cordillera; Taiga Cordillera; Boreal Cordillera)* | **Ecozone** | *Territorial – National*: Scale 1:30,000,000. Subdivision of global biomes. Used for national state-of-environment tracking. |
| **Level III Ecoregion** *(High Subarctic; Low Subarctic; High Boreal;Mid-Boreal, each with one or two phases defined by elevation (alpine, subalpine, boreal)* | **Ecoprovince** (Canada Committee on Ecological Land Classification) or **Ecoclimatic Region** (Ecoregions Working Group 1989) | *Regional*: For the Northwest Territories (Cordillera), Level III ecoregions are defined by regional climatic differences within Level II ecoregions and approximate Ecoclimatic Regions defined in *Ecoclimatic Regions of Canada* (Ecoregions Working Group 1989). Scale 1:2,000,000 – 1:10,000,000. |
| **Level IV Ecoregion** (36 in Cordillera, nested within each of three Level II and four Level III ecoregions above) | **Ecoregion** | *Regional*: Broad recurring vegetation and landform patterns within a regional climatic framework. For the Northwest Territories, physiographic characteristics (e.g., plains, hill systems, mountain ranges) and geographic features (e.g., major rivers and valleys) are employed to subdivide Level III ecoregions into Level IV ecoregions. Scale 1:250,000 – 1:1,500,000. |
| No current equivalent in North American continental system | **Ecodistrict** | *Subregional:* Subdivisions of an ecoregion based on distinctive landform differences. Ecodistricts, ecoregions and ecozones are defined for all provinces and territories in Canada in the national system. For the Northwest Territories, the ecodistrict might be equivalent to one Soil Landscape (SLC) polygon (refer to Section 1.3.5 for discussion), or might include two or more SLC polygons. Scale 1:50,000 – 1:250,000. |
| | **Ecosection** | *Subregional:* More specific delineation of recurring landform and vegetation patterns, usually with reference to major community type groups or soil subgroups. They are typically represented as complexes and may be used for regional and subregional integrated resource planning. An SLC polygon with vegetation attributes linked to physical characteristics could be regarded as an ecosection. Scale 1:20,000 – 1:50,000. |
| | **Ecosite** | *Local:* Scale 1:20,000 – 1:50,000. May be mapped at the operational level ("ecosites", "site series") for example, forest resources inventory. |
| | **Ecoelement** | *Local:* Scale <1:10,000. Usually a single vegetation type on a single soil type and site, but could be complexed in boreal landscapes. They are delineated where very detailed information is required (e.g., detailed pre-harvest assessments, special features delineation). |

Some mapped ecosystem units in the Cordillera are small eastern extensions of much larger units in the Yukon that have been defined by Yukon ecosystem classification specialists. Accordingly, some Cordillera map unit boundaries have been adjusted to match Yukon boundaries and descriptions of these units are based on descriptions of the adjacent Yukon units.

The ecosystem classification framework is an explicit and logical system based on the application of consistent rules for mapping, naming and describing units. The criteria for mapping ecosystem units at several scales are provided in Sections 1.4 and 1.5, and are further explained in Section 3.

### 1.3.1 Level I Ecoregions

North America includes 15 broad, Level I ecological regions (ecoregions) that provide the backdrop to the ecological mosaic of the continent, and provide context at global or intercontinental scales (Commission for Environmental Cooperation 1997). These ecoregions are similar in scale and scope to the global *biomes* (e.g., Walter 1979) and are mapped at a scale of about 1: 50,000,000.

Three Level I ecoregions span the Northwest Territories, and all are represented in the Cordillera. The *Tundra* occurs north of tree line; in the Cordillera, the Richardson Mountains occupy a thin strip west of the Mackenzie Delta and along the Yukon border that marks the eastern limits of a mountainous component, the Brooks Range, or *Tundra Cordillera*. The *Taiga* includes the area north of the Northwestern Forested Mountains boundary to the northern limits of the main mountain ranges, west of Norman Wells. The *Northwestern Forested Mountains* extends from Alaska to New Mexico; in the Northwest Territories it includes the southernmost quarter of the main mountain ranges with its northern limits at 63º N along the Yukon - Northwest Territories border, angling south to 62º N in the Nahanni Range west of Fort Simpson.

### 1.3.2 Level II Ecoregions

Level II ecoregions are useful for national and sub-continental overviews of physiography, wildlife, and land use (Commission for Environmental Cooperation 1997). They are more or less equivalent to the Canadian *ecozone*, defined as "areas of the earth's surface representative of large and very generalized ecological units characterized by interactive and adjusting abiotic and biotic factors … the ecozone defines, on a sub-continental scale, the broad mosaics formed by the interaction of macro-scale climate, human activity, vegetation, soils, geological, and physiographic features of the country." (Ecological Stratification Working Group 1995). They are nested within Level I ecoregions and are represented at a scale of 1:5,000,000 to 1:10,000,000. There are currently 20 Level II ecoregions within Canada and eight Level II ecoregions within the Northwest Territories. At the scales of mapping at each level of the ecoregion hierarchy, the smallest mapping unit is about two square centimetres; this is usually the smallest area that reasonably represents a significant difference between adjacent mapped polygons.

Level II ecoregions of the Northwest Territories include a broad range of climatic and physiographic conditions. Boundaries are recognized by major changes in physiography (e.g., the well-defined bedrock boundary between the Taiga Plains and the Taiga Shield, or the transition to mountainous terrain that marks the boundary between the Taiga Plains and Cordillera). Boundaries are also recognized by regional climate changes (e.g., the change from cold continental climates in the Taiga Plains to very cold polar climates in the Southern Arctic and Tundra).

The Cordillera includes three Level II ecoregions, each of which is a component of the three Level I ecoregions discussed in Section 1.3.1. The *Tundra Cordillera*[3] barely extends into the Northwest Territories west of the Mackenzie Delta and is part of the Tundra. The *Taiga Cordillera* occurs mainly in the Northwest Territories and Yukon and is part of the Taiga. The *Boreal Cordillera*, which extends from northern British Columbia through the Yukon to Alaska, is part of the Northwestern Forested Mountains. Figure 1 shows the three Level II ecoregions for the Cordillera and the neighbouring Level II Taiga Plains, Taiga Shield and mainland Southern Arctic Ecoregions; Section 3.2 provides details.

### 1.3.3 Level III Ecoregions

Level III ecoregions are approximately equivalent to the Canadian *ecoprovince* (Ecological Stratification Working Group 1995) or *ecoclimatic region* (Ecoregions Working Group 1989). In this document, Level III ecoregions are characterized by regional climatic differences, approximately as defined at the ecoclimatic region level in *Ecoclimatic Regions of Canada* (Ecoregions Working Group 1989). The criteria for recognizing Level III ecoregions are provided in Section 1.4 along with a discussion of how the national model was modified to ensure a reasonable representation of Cordilleran climates in the Northwest Territories. Figure 2 shows how Level III ecoregions are distributed across much of the mainland Northwest Territories.

[3] For the purposes of this report and unity in the nomenclature used throughout the Northwest Territories Cordillera, the Level II Brooks Range Tundra is called the Level II Tundra Cordillera throughout this report; it is however represented as the Brooks Range Tundra on the continental ecoregions map.

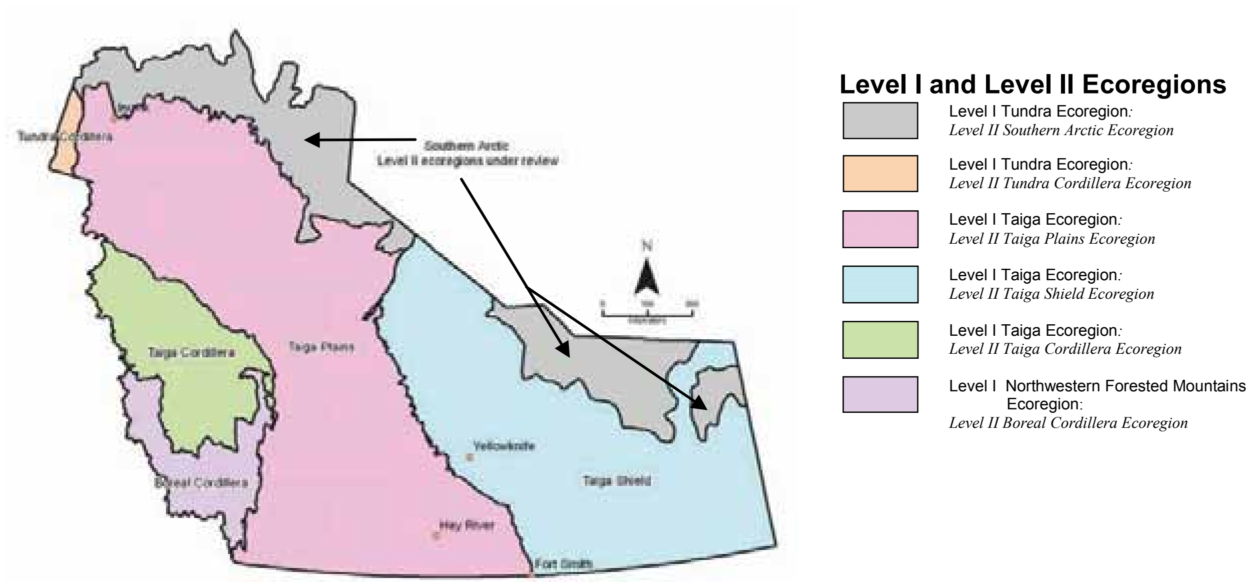


**Figure 1.** Level I Ecoregions define the largest landscape units in the Northwest Territories (Tundra, Taiga and Northwestern Forested Mountains) Level II Ecoregions are subdivisions of the Level I Ecoregions, and include the Cordillera(Tundra, Taiga, Boreal), Taiga Plains, Taiga Shield, and Southern Arctic Ecoregions. Cordilleran Level II Ecoregions are further discussed in Section 3.2 of this report.

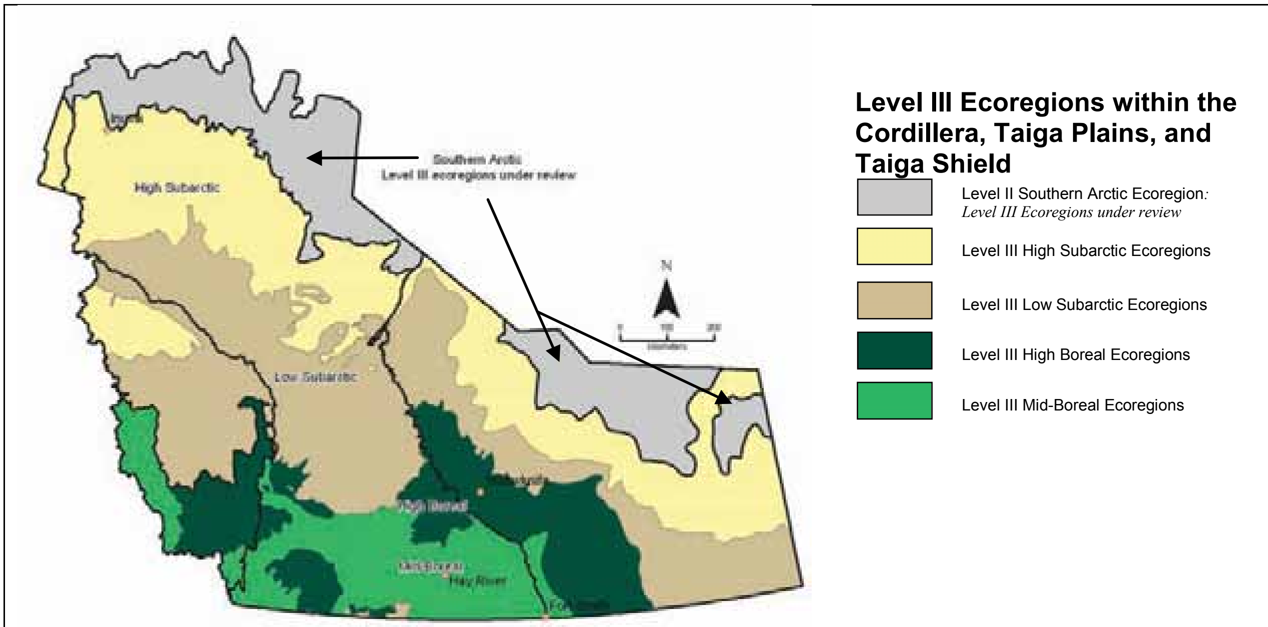


**Figure 2.** Level III ecoregions show the distribution of regional climates across the Level II Cordillera, Taiga Plains and Taiga Shield Ecoregions, and are nested within these three Level II ecoregions (delineated by heavy black lines). Details about the mapping criteria used to define Cordilleran Level III ecoregions are presented in Section 1.4 of this report; descriptions of each ecoregion are provided at the beginning of Sections 3.4 through 3.8.

Two Level III ecoregions, the *High Subarctic* and the *Low Subarctic*, represent the regional climatic regimes of the Taiga Cordillera Ecoregion. The High Subarctic also represents the climate influencing the Tundra Cordillera Ecoregion. The Level III *High Boreal* and *Mid-Boreal* define the regional climatic regime of the Boreal Cordillera Ecoregion within the Northwest Territories and southeastern Yukon. Level III ecoregions provide a logical framework within which Level IV ecoregions having similar physiographic characteristics and climatic regimes can be discussed. They are represented at map scales of 1:2,000,000 to 1:5,000,000; there are currently 72 Level III ecoregions in Canada and 18 Level III ecoregions in the Northwest Territories. The climatic, vegetation and landscape features that were used to delineate and define the Northwest Territories Level III ecoregions are discussed in Section 1.4.

### 1.3.4 Level IV Ecoregions

Level IV ecoregions are subdivisions of, and are nested within, the Level II and Level III ecoregions. They are characterized by distinctive regional ecological factors, including climate, physiography, vegetation, soil, water and fauna (Marshall *et al.* 1996). Level IV ecoregions have been variously defined, depending on the landscape and the classification objectives, as "total landscape ecoregions" (physiography–vegetation), "habitat ecoregions" (wildlife habitat–vegetation–physiography), "soil ecoregions" (soil–vegetation) or "ecoclimatic ecoregions" (ecologically effective macroclimate as expressed by vegetation) (Ecoregions Working Group 1989).

Climate, physiography, vegetation and soils all define Level III and Level IV ecoregions to the extent that available information allows. Long-term annual climate data records are very sparse from the mountains of the Northwest Territories and the Yukon, but there is sufficient climate-related terrain and vegetation information to reasonably delineate and describe Level III and Level IV ecoregions. Information sources include: existing surficial and bedrock geology maps; good-quality satellite imagery; terrain models; geo-referenced digital photographs; observed relationships between climate and climate surrogates such as permafrost-affected upland and wetland features; forest cover density and composition; and plant species distribution. Level IV ecoregions are usually represented at a scale of 1:250,000 to 1:1,500,000.

The Cordillera includes 36 Level IV Ecoregions. Two occur within the Tundra Cordillera, 15 within the Taiga Cordillera, and 19 within the Boreal Cordillera. Figure 3 shows the currently mapped Level IV ecoregions across much of the mainland Northwest Territories; the inset box shows the level of detail displayed at this level of classification.

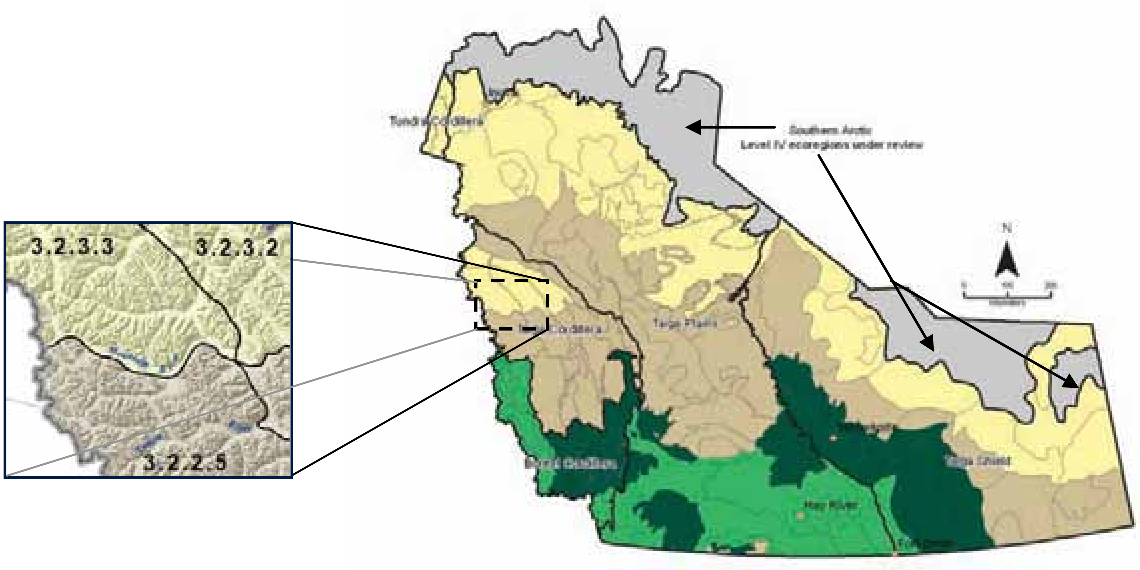


**Figure 3.** Level IV ecoregions are nested within Level II and Level III ecoregions and are differentiated on the basis of bedrock geology, landform, hydrology, and vegetation. The inset box shows part of three Level IV ecoregions within the Level II Taiga Cordillera Ecoregion. Units 3.2.3.2 and 3.2.3.3 occur within the Level III Taiga Cordillera High Subarctic Ecoregion and unit 3.2.2.5 occurs within the Level III Taiga Cordillera Low Subarctic Ecoregion. Details about the mapping criteria used to define Cordilleran Level IV ecoregions are presented in Section 1.5; descriptions of individual Level IV ecoregions are provided in Sections 3.4 through 3.8. A map of Cordilleran Level III and Level IV ecoregions is presented in Appendix 3.

### 1.3.5 Further Divisions of Level IV Ecoregions

Two additional classification levels form part of the 1996 ecosystem classification framework of the Northwest Territories. The *ecodistrict* is a finer physiographic subdivision of the Level IV ecoregion. Ecodistricts may also include one or more smaller units. "*Soil Landscapes of Canada (SLC) polygons*" are described by a standard set of attributes such as surface form, slope class, general texture and soil type, water table depth, permafrost and lake area. SLC polygons may contain one or more distinct soil landscape components and may also contain small but highly contrasting inclusion components. The location of these components within the polygon is not defined.

The ecodistrict and the SLC level of classification are neither detailed in this report nor presented on the map because ecoregions are only mapped to a regional Level IV scale. The 1996 ecodistrict units delineated by the Ecological Stratification Working Group (1995) are useful because they reveal general climatic trends through interpolated models developed by Agriculture and Agri-Foods Canada (1997), discussed further in Section 1.4. The 1996 SLC map units delineated and described by the Ecological Stratification Working Group (1995) as the largest-scale classification levels also provide information that is used to augment the description of parent geologic materials, soils and wetland/upland proportions within each Level IV ecoregion. The ecodistrict and SLC levels of classification are usually represented at scales of about 1:50,000 to 1:250,000.

### 1.3.6 Long-term Value of the Cordillera Ecosystem Classification

The 2010 Cordillera ecosystem classification is a reasonable approximation of Northwest Territories biophysical patterns in the mountains and foothills given the climatic and biophysical information currently available. It is based partly on present-day evidence of past climatic trends that are not necessarily representative of future trends (refer to Section 1.4.2). It is likely that current ecological classification concepts will change in response to new information, climate change, improved analytical techniques, and revised viewpoints on how national and global classifications ought to be presented. This document and the accompanying map will serve both as a framework for current resource management and as a benchmark against which future ecosystem changes can be assessed.

## 1.4 How Level III Ecoregions are Defined

The Cordillera includes four Level III ecoregions with different regional climates – the very cold High Subarctic (HS) Ecoregion, the cold Low Subarctic (LS) Ecoregion, and the milder High Boreal (HB) and Mid-Boreal (MB) Ecoregions. Long-term climate records from the Northwest Territories or Yukon mountains are too sparse to adequately model and map climate trends upon which to base Level III ecoregion delineations. Climatic information is deficient across the Northwest Territories, and Level III ecoregions in the Taiga Plains and Taiga Shield were defined with reference to certain landscape and vegetation features that were considered as useful surrogates for regional climatic patterns (Ecosystem Classification Group 2008, 2007 (revised 2009)). Similarly, landscape and vegetation features are also useful for defining the four Level III ecoregions within the Cordillera.

*Ecoclimatic Regions of Canada* (Ecoregions Working Group 1989) provided the initial model for Level III ecoregion delineations in the Northwest Territories. Modifications needed to make the initial model applicable to the Cordillera are discussed in Section 1.4.1. The principal montane climate and terrain factors that interact to produce Level III ecoregions are summarized in Section 1.4.2.[4] Vegetation and landform features used to delineate Level III ecoregions are discussed in Section 1.4.3.

### 1.4.1 Relationship to Ecoregions Defined in *Ecoclimatic Regions of Canada*

Regional climatic patterns of the Taiga Plains and Taiga Shield were based directly on the ecoclimatic region models presented in *Ecoclimatic Regions of Canada* (Ecoregions Working Group 1989). Permafrost features, forest cover characteristics and other climate-related indicators provided in that report matched well with field observations made from 2005 and 2006 in support of the Taiga Plains and Taiga Shield revisions. Because all four original 1989 ecoclimatic regions (Level III ecoregions) shared by the Taiga Plains and Taiga Shield encompass large areas within the Northwest Territories, their descriptions adequately reflect regional conditions and only minor modifications were needed.

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[4] Appendix 3 includes a map of Level II, Level III and Level IV ecoregions in the Cordillera.

In contrast, montane ecoclimatic regions described in *Ecoclimatic Regions of Canada* (Ecoregions Working Group 1989) are not well represented in the Northwest Territories. The Mid-Cordilleran ecoclimatic region stops just short of the Northwest Territories-Yukon boundary to the south, and both the Northern Cordilleran and Northern Subarctic Cordilleran ecoclimatic regions extend only short distances into the Northwest Territories from the Yukon. Furthermore, the descriptions of northern montane ecoclimatic regions provided in *Ecoclimatic Regions of Canada* (Ecoregions Working Group 1989) fit poorly with field observations made during the 2007 field program.

The four Level III ecoregions assigned to the Taiga Plains and Taiga Shield – the High Subarctic, Low Subarctic, High Boreal and Mid-Boreal Ecoregions – have characteristics that are reasonably well related to those for average sites in the Cordillera. These assignments were applied to the Cordillera and are slightly modified to encompass the elevational climatic variations from valley bottoms to mountain peaks. Their definitions as applied to the Cordillera and a brief summary of the differences between the revised version and the original 1989 version are presented in Table 2. The definition of each Level III ecoregion in Table 2 is based on differentiating climate, soil, and vegetation characteristics. Figures 4 through 7 present a general climatic picture of the Cordillera. Illustrations of representative terrain and vegetation features that characterize climates within each Level III ecoregion are shown in Figures 8 through 19. Each Level III ecoregion is described in more detail in later sections of this report. Characteristics of the High Subarctic (HS) Ecoregion for the most northerly component of the Cordillera are presented in Section 3.4 (Tundra Cordillera). Characteristics of the HS and the Low Subarctic (LS) Ecoregions for the main Cordilleran area (Taiga Cordillera) are presented in Sections 3.5 and 3.6 respectively. Features of the High Boreal (HB) and Mid-Boreal (MB) Ecoregions are presented for the Boreal Cordillera in Sections 3.7 and 3.8 respectively.

## 1.4.2 Climatic Factors Influencing Level III Ecoregions

Climate can be defined as the cumulative long-term effects of weather, involving the processes of heat and moisture exchange between the earth and atmosphere. Climate is affected by several factors. These factors interact to produce regional climates (Level III ecoregions) that are reflected in landform and vegetation patterns.

Climates of the Cordillera are determined by both regional factors (Section 1.4.2.1) and by local factors (Section 1.4.2.2) that significantly modify regional climatic influences. Climate change over time has been and will continue to be a controlling influence on regional to local ecosystems (Section 1.4.2.3).

### 1.4.2.1 Factors influencing regional climate

*Latitude*

As latitude decreases, the incident angle of the sun's rays increase. For example, at mid-day on December 21 at Inuvik (68°21' N) the sun does not rise at all. On the same day at Norman Wells (66°11'N) the sun is only 0.4 degrees above the horizon and at Fort Liard (60°13'N), the sun is 6.3 degrees above the horizon. Figure 4 shows this relationship schematically at these three locations on June 21 and December 21. A decrease in sun angle produces a corresponding decrease in the amount of solar energy, which is further reduced by the longer passage the sun's rays must take through the atmosphere at higher (more northerly) latitudes. Slope and aspect variations in the mountains strongly influence solar energy (Section 1.4.2.2).

Figure 5 shows the increase in average daily global solar radiation (the amount of radiation incident at the top of the atmosphere[5]) with decreasing latitude, modeled from Ecodistrict Climate Normals provided by Agriculture and Agri-Food Canada (1997). The amount of incident solar radiation also influences the annual temperature of an area; Figure 6 shows how mean annual temperature also increases with decreasing latitude. Because warm air holds more moisture, precipitation also increases at lower latitudes; as well, the high mountains along the western border force Pacific systems to drop rain and snow (Figure 7 and Section 1.4.2.2).

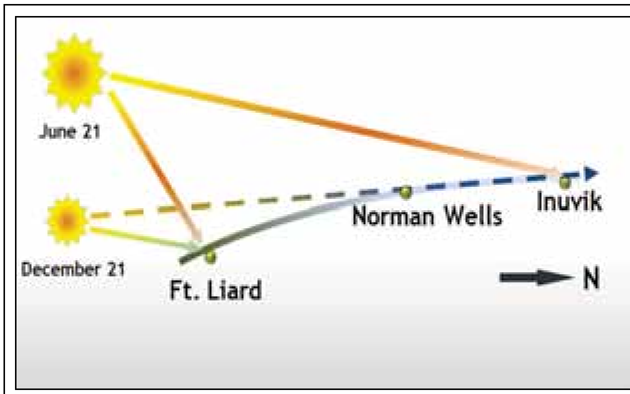


**Figure 4**. Schematic portrayal of sun angles at different locations at the winter and summer solstice.

[5] This amount exceeds the solar radiation incident at the ground surface for various reasons, including particulate matter and clouds in the atmosphere, and the albedo of incident surfaces.

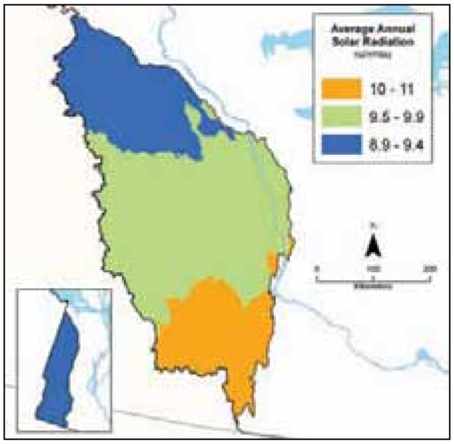


**Figure 5**. Increasing average annual solar radiation in the Cordillera with decreasing latitude (southward) (units are mJ/m$^2$/day). Source data: Agriculture and Agri-Food Canada (1997). The inset map in this figure and Figures 6 and 7 shows the northern Tundra Cordillera Ecoregion adjacent to the Mackenzie Delta.

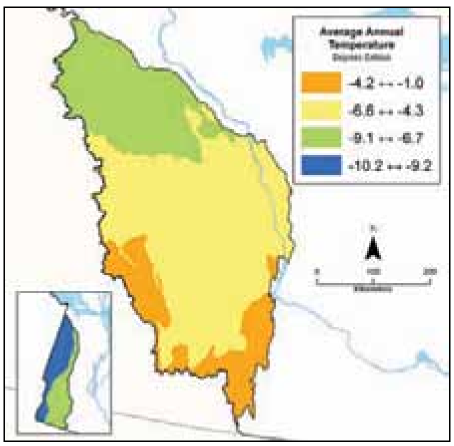


**Figure 6**. Increasing average annual temperature in the Cordillera with decreasing latitude (units are degrees Celsius). Source data: Agriculture and Agri-Food Canada (1997).

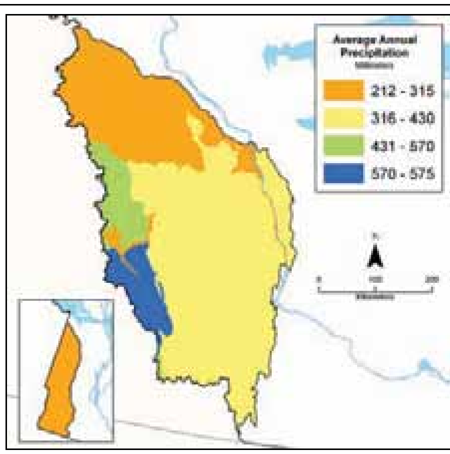


**Figure 7**. Increasing average annual precipitation in the Cordillera with decreasing latitude and proximity to the Yukon border (units are mm of precipitation). Source data: Agriculture and Agri-Food Canada (1997).

*Regional and global circulation patterns*

General north-to-south circulation patterns in the atmosphere redistribute heat, without which arctic and subarctic regions would experience a net annual energy loss. They also redistribute moisture. Upper air flow is determined by two features: an upper low that is usually over the central Arctic Islands during the summer and that intensifies and moves to the northern Foxe Basin during the winter; and the Aleutian Low/Pacific High (Klock *et al.* 2000). Northern and eastern regions of the Cordillera (Franklin Range, the front ranges of the Mackenzie Mountains west of Norman Wells and the far northern Richardson Mountains) are usually influenced by cold, dry Arctic air masses, whereas the southern parts of the Cordillera are more strongly influenced by warm, moist Pacific air masses (Bryson 1966). The central portions of the Cordillera are likely influenced by both major patterns, producing an intermediate climate.

- Winter patterns: A north-westerly upper air flow holds cold Arctic high pressure systems across the Northwest Territories and often drives these systems south into the Prairies (Klock *et al.* 2000); these cold, dry systems probably influence the northern and eastern regions of the Cordillera (Franklin Range, Mackenzie Valley, front ranges of the Mackenzie Mountains, and British-Richardson Mountains). The southern and western regions of the Cordillera are influenced by vigorous low-pressure systems from the Gulf of Alaska that track across northern British Columbia wrapping cloud and snowfall into the southeast Yukon and the southwest Northwest Territories (Klock *et al.* 2000).
- Summer patterns: The upper flow pattern is weaker than in winter and averages west-northwest. Embedded upper troughs and daytime heating produce convective activity, and thunderstorms often form over the east slopes of the Mackenzie Mountains. The Richardson Mountains and the northern front ranges of the Mackenzie Mountains are influenced by abundant low-level moisture resulting from melting sea ice, and upslope airflows produce persistent low level cloud and fog. In the southern Cordillera, Pacific storm systems bearing mild, moist air track eastward along the southern Yukon and Northwest Territories borders, and significant precipitation events occur (Klock *et al.* 2000).

### 1.4.2.2 Factors influencing local climate

*Topography*

Climate models (Agriculture and Agri-Food Canada 1997, Wahl 2004) show a general decrease in mean annual precipitation with increasing latitude (Figure 7), and a marked increase in rainfall and snowfall along the Northwest Territories-Yukon border, where high mountain ranges force moist Pacific systems upward. As the air rises and cools, its water holding capacity drops and precipitation occurs. The largest icefields and glaciers occur in the southwestern high-elevation Ragged Ranges, where average temperatures are cold year-round and snowfall is highest. To the east, these ranges produce a rain shadow and drier conditions prevail in the interior mountains.

Within these larger patterns, mountainous terrain produces extreme local and subregional climatic variability. As elevations increase, average temperatures fall, average wind speeds rise and precipitation on windward slopes increases. These trends are reflected by vegetation zones such as forested valley bottoms, sparsely treed upper valley slopes, and treeless tundra or barren rock at the highest elevations. North-facing slopes receive less sun exposure than south-facing slopes and this tendency increases with latitude. Permafrost features and late-seasonal snow patches are more common on shady northerly slopes than on sunny south-facing slopes, and a shorter growing season is reflected by lower tree lines on north-facing slopes than on south-facing slopes.

*Albedo*

Albedo is the ratio of the amount of solar radiation reflected by a body to the amount incident on it, commonly expressed as a percentage (Klock *et al.* 2000). Coniferous forest cover has a low albedo, and reflects about nine percent of incident sunlight (Eugster *et al.* 2000), whereas snow and ice cover reflect considerably more incident sunlight. Extensive ice-covered areas (e.g., the glaciers and icefields of the southwestern mountains) increase albedo, as does cloud cover which can be persistent over the mountains during the summer months especially to the south and west. Slope and aspect strongly influence the incidence of solar radiation. Southerly slopes intercept more solar radiation than northerly slopes that retain reflective snow cover for longer periods in the spring and early summer.

#### 1.4.2.3 Climate change

Northern environments are highly sensitive to climate change (Eugster *et al.* 2000). Duk-Rodkin *et al.* (2004) provide extensive evidence for markedly different climates in the Northwest Territories and Yukon over the last three million years. Zoltai (1995) presents evidence indicating that permafrost zones were considerably further north 6,000 years ago in the Holocene Warm Period than they are at the present time. Woo *et al*. (1992) suggest that mean annual surface temperatures may increase by 4$^{o}$C in Northern Canada in future; Tarnocai *et al*. (2004) indicate that the depth of thaw penetration into permafrost is sensitive to past temperature change and has responded measurably to recent major climatic events.

Northern climates and ecosystems have historically been highly changeable and will undoubtedly continue to be so. This ecosystem classification should be viewed as the present-day representation of a dynamic Arctic – Cordilleran system and a useful benchmark against which to compare future environmental states.

### 1.4.3. Landscape Features Used to Delineate Level III Ecoregions

Level III ecoregions are defined by permafrost and vegetation characteristics that indicate climatic influences (Table 2), along with basic GIS-derived information such as total land and water area and elevation ranges. Regional geomorphic features are also useful descriptors.

The landscape characteristics most useful for differentiating Level III ecoregions in the Cordillera are topographic features from digital elevation models and National Topographic Series maps, landscape and vegetation patterns visible on Landsat images, oblique aerial landscape views on geographically referenced digital photographs and GIS themes prepared from these photographs (refer to Section 2 for a discussion of methods). Permafrost and vegetation characteristics were used to arrive at a reasonable approximation of Level III ecoregion boundaries.

Some of the features useful for determining the approximate boundaries between Level III ecoregions are shown in Figures 8 through 19 and are explained in the figure captions. Permafrost characteristics include peat plateaus, polygonal peat plateaus, patterned ground (nonsorted circles and earth hummocks), runnels, veneer bogs, solifluction features, and retrogressive flow slides where thawing permafrost has caused slope failures[6]. These features occur throughout the Cordillera, but are more frequently associated with the colder Level III Low Subarctic and High Subarctic Ecoregions.

Vegetation characteristics include canopy composition (e.g., jack pine or lodgepole pine forest, alpine fir woodlands, mixed trembling aspen – white spruce forest, spruce – lichen woodlands) and canopy closure (e.g., open woodlands, closed canopy forests).

The occurrence of aspen stands on southerly slopes and jack pine[7] regeneration on burns is indicative of a transition from subarctic to milder boreal climates. Lodgepole pine and alpine fir are limited to the southern third of the Cordillera, where average annual temperatures are higher, and their northern and eastern extents are used to define the northern and eastern boundaries of the High Boreal and Mid-Boreal Level III Ecoregions.

Plant species that are typically associated with mild, moist climates of the Pacific Cordillera (e.g., arrow-leaved

[6] The above-listed permafrost features are defined in the glossary of terms (Appendix 5).

[7] The production of viable jack pine seeds is significantly influenced by climate at the northern limits of the species range, and at least three growing seasons with sufficiently high temperatures are required for the successful maturation of viable jack pine seeds (Despland and Houle 1997). Jack pine and lodgepole pine are closely related and can hybridize, and the northern limits of lodgepole pine in the Northwest Territories are probably, like those of jackpine, determined by growing season temperatures.

groundsel, false hellebore, alpine valerian) occur along the western border of the Cordillera where high ranges intercept Pacific moisture; the distribution of these species helps to define the Mid-Boreal Level III Ecoregion. General changes in tundra appearance from yellowish-green sparsely vegetated tundra in the northeast to bright green well-vegetated tundra in the southwest also reflect transitions to milder, moister conditions. Widely spaced, stunted conifer woodlands with a shrub and lichen understory indicate the relative severity of subarctic and high subalpine climates in the northern and eastern two-thirds of the Cordillera, and are characteristic of the Low Subarctic and High Subarctic Ecoregions.

Tree line, the latitude or elevation above which trees do not occur because the growing season is too short for reproduction and establishment, was indirectly used to define the boundary between the Level III High Subarctic Ecoregion and the Level III Low Subarctic Ecoregion. There is a statistically significant and reasonably strong relationship between tree line elevations on south-facing slopes and both latitude and longitude, based on 84 elevations collected at representative locations on southerly slopes. Tree line elevations decline to the north and east, with the highest observed elevations in the southwest quarter of the Cordillera and the lowest elevations in the Richardson Mountains in the far north. Appendix 4 presents a discussion of the tree line analysis and its application to Level III boundary definition.

## 1.5 How Level IV Ecoregions are Defined

Level IV ecoregions are the highest detailed mapped units presented in this report. They are recognized and named according to a combination of features, discussed in Section 1.5.1. Section 1.5.2 provides an overview and explanation of vegetation and geomorphic patterns that are common to many of the Cordilleran Level IV ecoregions.

### 1.5.1 Landscape and Climate Features Used to Name Level IV Ecoregions

Level IV ecoregions are consistently named with reference to three descriptive components: geographic location, dominant landscape feature, and ecoclimate/elevation.

*Geographic location*

The ecoregion's name is defined by a feature of local or regional significance, and in the Cordillera generally by a named feature on National Topographic Series maps, such as Canyon Ranges, Painted Mountains, or Sunblood Range.

*Dominant landscape feature*

Six major landscape elements constitute the second component of ecoregion names in the Cordillera and these are defined by their form, position relative to other elements, topographic variability, parent materials and hydrologic processes, all of which modify the effects of regional climates. Landscape elements are described in alphabetical order below.

- *Foothills* are low hills at the base of mountains. For purposes of delineation in the Northwest Territories, an arbitrary elevation range of 200-800 m ASL is used and is reasonably well correlated with breaks in slope between the valleys and the foothills and between the foothills and the mountains. Incised stream channels, uneven topography that creates variable microenvironments, and steeper slopes than the surrounding lowlands and plains are typical. Wetlands and ponds are less common than on the surrounding lower terrain.
- *Mountains* are areas that display large differences in relief, usually over 600 m. Bedrock exposures, steep slopes and deeply incised parallel river channels are characteristic, climatic zonation occurs as a result of elevation changes, and microenvironments are highly variable. A *range* is a row or chain of mountains separated from other mountain ranges by passes or rivers; a *ridge* is an elongate crest or a linear series of crests.
- *Plains* are extensive, typically level to hummocky areas that can occur at low to high elevations, the latter as part of inter-montane plateaus (e.g., the "Plains of Abraham" west of Norman Wells).
- *Plateaus* are extensive upland areas at a higher elevation than their surroundings, often underlain by horizontally-oriented bedrock strata. Plateaus in the Cordillera may take the form of extensive flat-topped mountains and they can also be deeply incised or eroded, sometimes resulting in sharply ridged terrain with remnant plateau islands.
- *Upland* is a general term for an area that is higher than the surrounding area, sometimes several hundred metres higher, that are not plateaus. Uplands usually have undulating to hummocky terrain, a higher proportion of moderately well- to well-drained sites than lowlands or plains, and a lower proportion of wetlands. Drainage patterns tend to be dendritic (resembling tree roots).
- *Valleys* include any low-lying area bounded by plateaus, mountains, foothills or plains and traversed by a river.

**Table 2.** Climate and landscape characteristics of four Level III Ecoregions within the Cordillera of the Northwest Territories.

| **Distinguishing Characteristic** | **Level III Ecoregion** | | | |
|---|---|---|---|---|
| | *Tundra Cordillera and Taiga Cordillera – High Subarctic (HS) Ecoregions* | *Taiga Cordillera – Low Subarctic (LS) Ecoregion* | *Boreal Cordillera – High Boreal (HB) Ecoregion* | *Boreal Cordillera – Mid-Boreal (MB) Ecoregion* |
| *Temperature regime* [1,2] | Very short, cold summers; frost probably occurs in every month; extremely cold and long winters, mean annual temperature minus 9°C to minus 10 °C. | Short, cool summers, very cold winters, mean annual temperature minus 4 °C to minus 8 °C. | Short, cool summers, very cold winters; mean annual temperature minus 4 °C to minus 5 °C. | Short, wet summers; very cold and snowy winters; mean annual temperature minus 4°C to minus 6 °C. |
| *Precipitation patterns* [1,2] | Average annual precipitation 210-290 mm, 60-70% of precipitation falls from May-September. | Average annual precipitation 280-350 mm; 60-70% of precipitation falls from May-September. | Average annual precipitation 340-400 mm; 60-70% of precipitation falls from May-September. | Average annual precipitation 400-600 mm; about 50% as rain or snow from May-September, and 50% as snow from October-April. |
| *Relative insolation* [1] | 9-9.5 $mJ/m^2$/day. | 9.5-10.5 $mJ/m^2$/day. | 10.0-10.5 $mJ/m^2$/day. | 9.5-10.0 $mJ/m^2$/day. |
| *Characteristic permafrost features, peatlands, and soils* [3] | Continuous permafrost. Patterned ground, nonsorted circles, and runnels are the most common permafrost forms and occur mainly in the larger valleys. Polygonal peat plateaus occur on subdued terrain at lower elevations and are rare in mountain valleys. Retrogressive flow slides are common in saturated fine-textured materials. Permafrost depth is about 30 cm in subalpine areas. Cryosols are the dominant soils, with Brunisols on coarse-textured materials and Regosols or non-soils (bedrock) in alpine areas. | Continuous to discontinuous permafrost Peat plateaus, runnels and veneer bogs are common at lower elevations and on gentle to moderate terrain in the plains and foothills north and east of the mountains; polygonal peat plateaus occur on similar terrain mainly north of the Keele River. | Continuous to discontinuous permafrost. Peat plateaus, runnels and veneer bogs are uncommon and mainly occur along the border with the Low Subarctic Ecoregion. Solifluction is common on mountain slopes with fine-textured materials. Cryosols and Brunisols, Regosols or non-soils (bedrock) occur in alpine areas. | Continuous to discontinuous permafrost. Glaciers and icefields at high elevations; solifluction on some slopes indicates the presence of permafrost at depth. Peat palsas are common on the Natla Plateau. |
| ***Characteristic forest cover*** [3] | Open, usually stunted spruce woodlands are dominant in subalpine areas. At the northern boundary with the Low Arctic ecoclimatic region (defined by tree line), trees occur in small stands only along lakeshores, lower slopes, eskers and gullies. At the boundary between subalpine and alpine areas, trees grow sparsely on southerly slopes. Jack pine and trembling aspen are absent. | Open spruce woodlands with lichen and shrub understories are dominant in subalpine areas. Aspen occurs mainly in the southeastern part of this Ecoregion on low-elevation terrain and on south-facing low elevation valley slopes to the north. Jack pine occurs mainly in the Mackenzie Valley. | Lodgepole pine is characteristic of the Mid-Boreal and High Boreal Ecoregion. Alpine fir occurs in scattered stands at higher elevations near tree line. Dense vigorous aspen, mixed-wood and spruce forests and sedge-dominated wetlands are common on lower valley slopes and valley floors. | Alpine fir and plant species with a Pacific-Cordilleran distribution occur in the Mid-Boreal Ecoregion. Aspen, mixed-wood and spruce forests and sedge-dominated wetlands are common on lower valley slopes and valley floors. Lodgepole pine was observed in 2007 along the South Nahanni River valley, the Flat River, and in the Liard Ranges. |
| *Differences from Ecoclimatic Regions of Canada (1989)* | The 1989 High Subarctic Ecoclimatic Region extends well south of the High Subarctic Ecoregion that is mapped in this report. | The Low Subarctic Ecoregion includes parts of the 1989 Subhumid High Boreal, Low Subarctic, High Subarctic, Northern Cordilleran, and Northern Subarctic Cordilleran Ecoclimatic Regions. | The High Boreal Ecoregion includes parts of the 1989 Subhumid High Boreal, Low Subarctic, High Subarctic, and Northern Cordilleran Ecoclimatic Regions. | The Mid-Boreal Ecoregion was classified as part of the 1989 Northern Cordilleran Ecoclimatic Region. |

[1] Data generalized from *Canadian Ecodistrict Climate Normals* (Agriculture and Agri-Food Canada 1997).
[2] Descriptive information obtained from *Ecoclimatic Regions of Canada* (Ecoregions Working Group 1989) and *Ecoregions of the Yukon Territory* (Wahl 2004).
[3] Information obtained from 2007 field program ground and aerial observations (refer to Section 2 of this report).

**Figure 8**. Treeless Arctic plateaus and plains lie north of the Tundra Cordillera, where there are scattered trees in the valleys. Patterned ground indicative of permafrost is in the right foreground; the pond-studded and treeless expanse of the Mackenzie Delta lies in the background.
(*Location:* Richardson Plateau HS*as* Ecoregion)

**Figure 9**. High Subarctic climates in the valley bottoms of the northern Canyon Ranges restrict tree growth and result in very open, stunted spruce – shrub – lichen woodlands.
(*Location:* Canyon Ranges HS*as* Ecoregion)

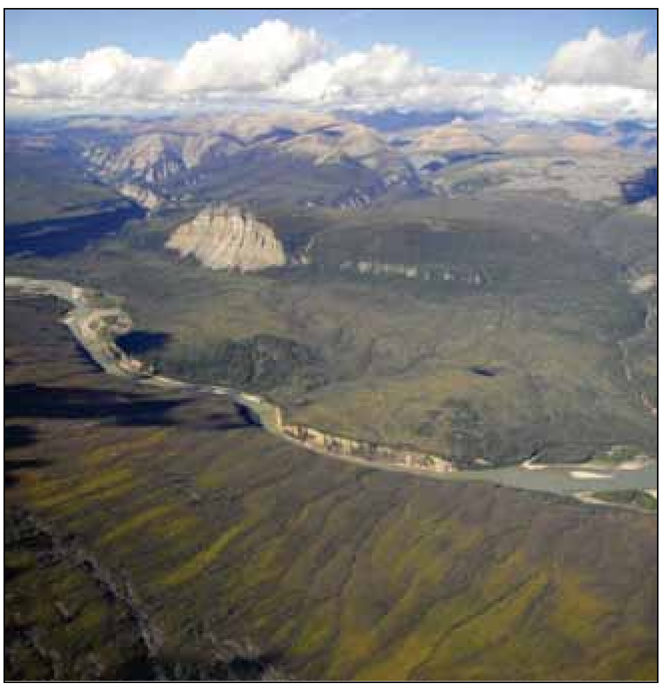

**Figure 10**. The striking striped patterns on lower north-facing slopes to the left of the river in this image are called runnels and are characteristic of permanently frozen ground in the Taiga Cordillera HS and Taiga Cordillera LS Ecoregions. They form in saturated and permanently frozen soils; the light green stripes are sedge tussock fens, and the dark stripes are wet spruce woodlands.
(*Location:* Canyon Ranges HS*as* Ecoregion)

**Figure 11**. Patterned ground is formed by frost action and occurs in places where permafrost is currently present or has been until recently. It is common in the Tundra Cordillera HS and Taiga Cordillera HS Ecoregions, but it also occurs in high-elevation parts of the Taiga Cordillera LS and Boreal Cordillera HB Ecoregions where temperatures remain cold year-round. Each polygon in the image is several metres across.
(*Location:* Thundercloud Range LS*as* Ecoregion)

**Figure 12**. Peat plateaus and polygonal peat plateaus are permafrost-affected areas of wet organic terrain that occur on level to gently sloping areas. Peat plateaus (greenish white areas with golden-brown inclusions in the foreground) are common on low-relief terrain throughout the LS and HS ecoregions of the Cordillera; polygonal peat plateaus (whitish-green patches with polygonal patterns above the lake) are more common in the HS.
(*Location:* Arctic Red Upland LS*b* Ecoregion)

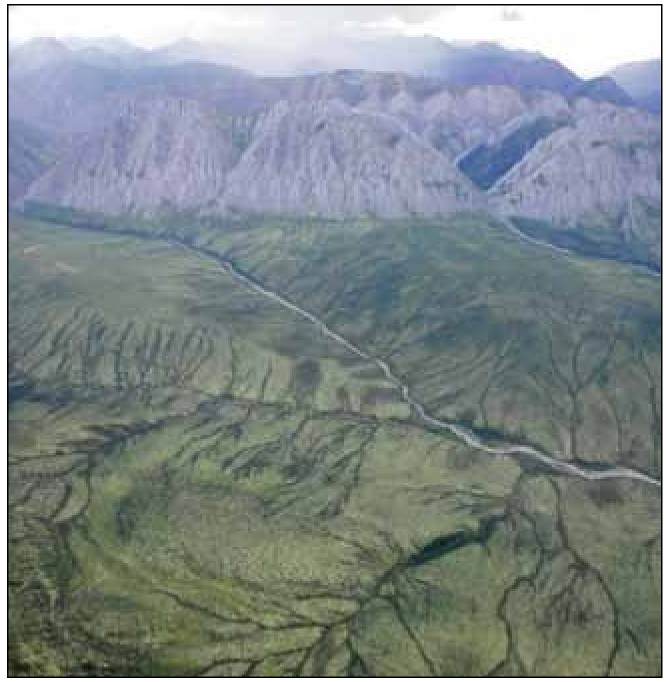

**Figure 13**. Veneer bogs appear as whitish-green areas on the image, and occur on gently sloping terrain underlain by generally discontinuous permafrost. Drainage is mainly subsurface, but is channelled by erosion gullies that appear in the image as sinuous dark green drainages; peat thickness is generally less than 1.5 m. Veneer bogs are locally extensive in the foothills and plateaus of the Level III Taiga Cordillera LS and Boreal Cordillera HB Ecoregions.
(*Location:* Painted Mountains LS*sa* Ecoregion)

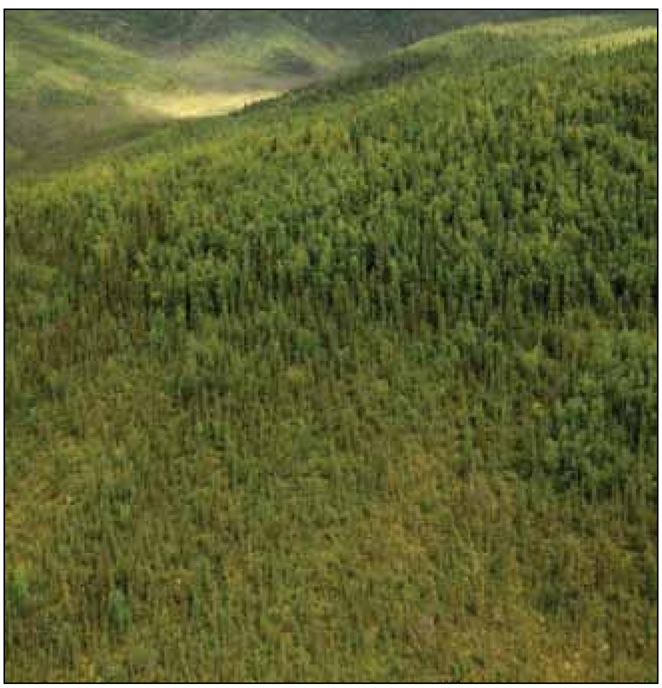

**Figure 14**. Mixed-wood spruce and birch stands are characteristic of well-drained lower elevationLow Subarctic sites in rolling terrain, with wet black spruce – shrub – lichen stands in seepage areas on lower slopes.
(*Location:* Mackenzie Foothills LS*bs* Ecoregion)

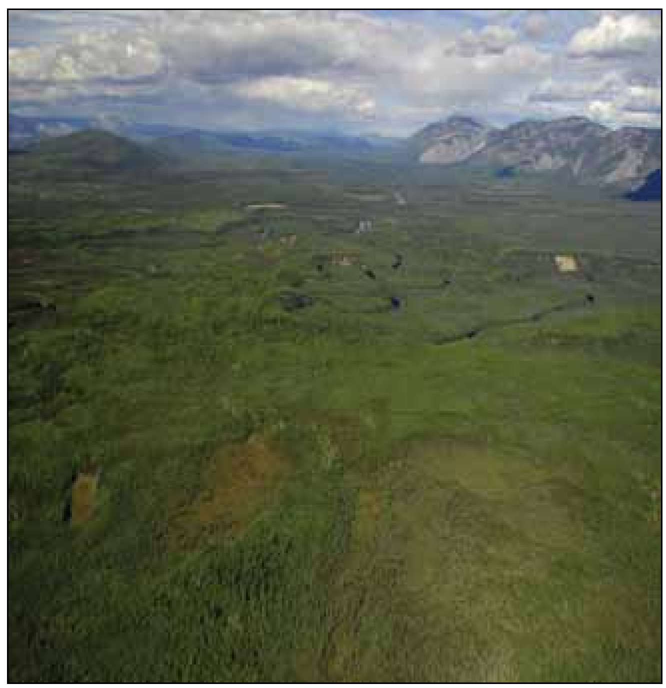

**Figure 15**. This north-facing view of the Tetcela River valley shows light-green lodgepole pine stands in the foreground and midground, brownish peat plateaus, tall spruce forests along the river banks, and mixed darker green spruce – trembling aspen forests throughout. These communities are characteristic of lowlands in the Boreal Cordillera HB Ecoregion.
(*Location:* Nahanni-Tetcela Valley HB*b* Ecoregion)

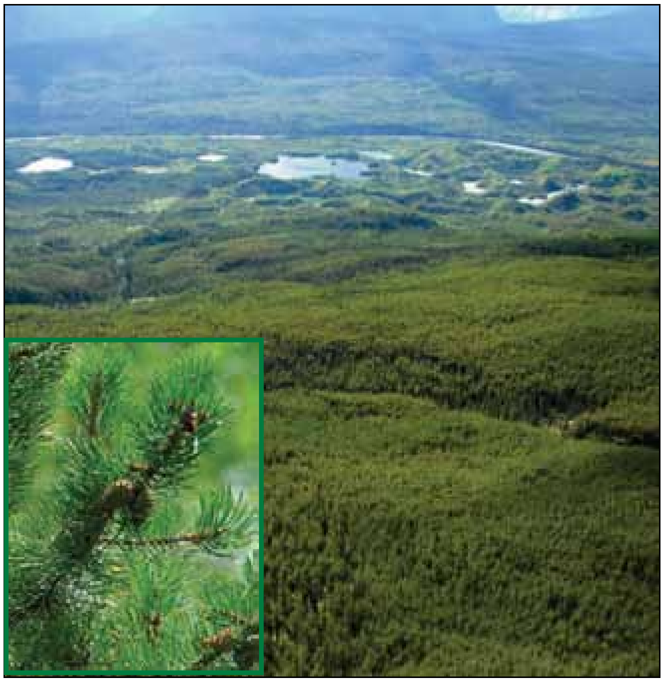

**Figure 16**. Lodgepole pine is indicative of climates characteristic of the Boreal Cordillera HB and Boreal Cordillera MB Ecoregions and in the Northwest Territories occurs at higher elevations and lower latitudes than the closely related jack pine. The light green tones in the foreground and midground are pine stands. The inset shows the long paired needles and prickly cones characteristic of lodgepole pine.
(*Location:* Ragged Range Valley MB*bs* Ecoregion)

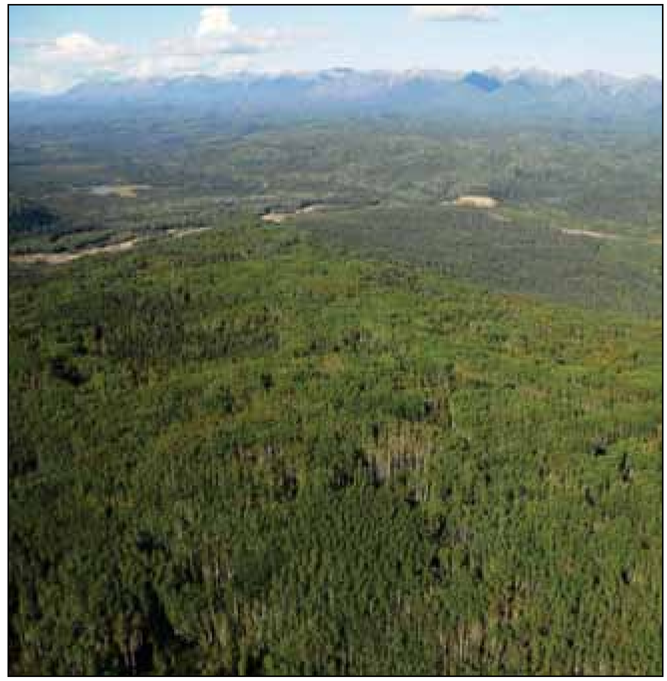

**Figure 17**. Dense, vigorous white spruce, trembling aspen and mixed-wood stands grow on alluvial terraces and till deposits on valley floors and lower slopes in the Boreal Cordillera MB Ecoregion. Wetlands are common (light green patches in the upper left background) and typically include shore fens and floating fens.
(*Location:* Liard Range MB*bs* Ecoregion)

**Figure 18**. Alpine fir and other Pacific-Cordilleran species such as false hellebore (inset) occur in areas with high summer rainfall and heavy winter snows in the Boreal Cordillera MB Ecoregion.
(*Location:* Sapper Ranges MB*as* Ecoregion)

**Figure 19**. Icefields and glaciers are common in the southwestern part of the Boreal Cordillera MB Ecoregion, where high mountains intercept Pacific moisture.
(*Location:* Ragged Range MB*as* Ecoregion)

### *Ecoclimate and elevation*

The ecoregion name includes the ecoclimate, expressed as a two-letter code following the naming conventions outlined in Ecoclimatic Regions of Canada (Ecoregions Working Group 1989) and modified with reference to local topographic and climatic variations as explained below. This component indicates the Level III ecoregion within which the Level IV ecoregion occurs.

It is important to note that in the Cordillera the vegetation, wetland and permafrost features of valley bottoms and lower slopes are the most consistent indicators of regional climate. Local climatic factors (colder temperatures, higher precipitation) acting at higher elevations mask the influence and evidence of regional climate features. Therefore, Level IV ecoregions are assigned to Level III climatically defined ecoregions mainly on the basis of their valley bottom and lower slope characteristics. For example, the Level IV Ragged Range MB*as* Ecoregion (Section 3.8.5) has extensive icefields, glaciers and bare rock at higher elevations, but it is the lush valley bottom vegetation (mixed-wood forests and wetlands) that indicates assignment to a Mid-Boreal climatic ecoregion. The Level IV Northern Backbone Ranges HS*as* Ecoregion (Section 3.5.3) similarly has glaciers and bare rock at higher elevations, but the valley bottoms have vegetation characteristic of High Subarctic climates (open spruce woodlands).

The lower case italicized letters in these two examples represent the climatic variations created by local topography within the regional climate of a Level III ecoregion. There are three phases[8], two of which are usually associated with each Level IV ecoregion.

- The *alpine* climate phase ("*a*") occurs at elevations above tree line, and is characterized by treeless tundra, barren rock and colluvium, or ice.
- The *subalpine* climate phase ("*s*") occurs below the alpine phase, occupying higher-elevation valley bottoms and valley sides up to tree line, and is characterized by relatively open conifer woodlands mixed with sedge and shrub tundra.
- The *boreal* climate phase ("*b*") occurs in lower-elevation valley bottoms and on lower-elevation ridges, hills, and plateaus. Denser coniferous woodlands and forests, mixed-wood stands, and deciduous forests are typical, and wetlands tend to be relatively common.

The order of the phases indicates their relative importance within a named unit. For example, units of the Low Subarctic Ecoregion can be designated as LS*as*, indicating the predominance of high-elevation tundra or exposed bedrock, or LS*sa*, indicating the higher relative proportion of subalpine woodlands compared to alpine tundra and exposed bedrock.

As examples, the Canyon Ranges HS*as* Ecoregion includes the plateaus and ridges of the front ranges west of Norman Wells influenced by a High Subarctic climate and dominated by alpine vegetation or exposed nonvegetated bedrock, with subalpine forests and tundra at lower elevations. The Ragged Range MB*as* Ecoregion includes the rugged granite peaks of the extreme southwest influenced by a Mid-Boreal climate. Glaciers and icefields are common, high precipitation contributes to relatively vigorous tundra growth and valley bottom forest development, and plant species that are found further south and west in the mountains of British Columbia and the Yukon occur here and nowhere else in the Northwest Territories.

Figure 20 illustrates the relationship between elevation and climate phase within the Level III Mid-Boreal Ecoregion. The Logan Mountains MB*as* Ecoregion in the midground and background includes alpine and subalpine phases on the peaks and slopes; the Ragged Range Valley MB*bs* Ecoregion in the foreground includes boreal phase ecosystems within the low-elevation Flat River valley.

[8] The phase concept is adapted from the British Columbia Biogeoclimatic Ecosystem Classification; the phase accommodates the variation resulting from local relief in the regional climate. (Definition accessed May 2009 from: http://www.for.gov.bc.ca/hre/becweb/system/how/index.html,)

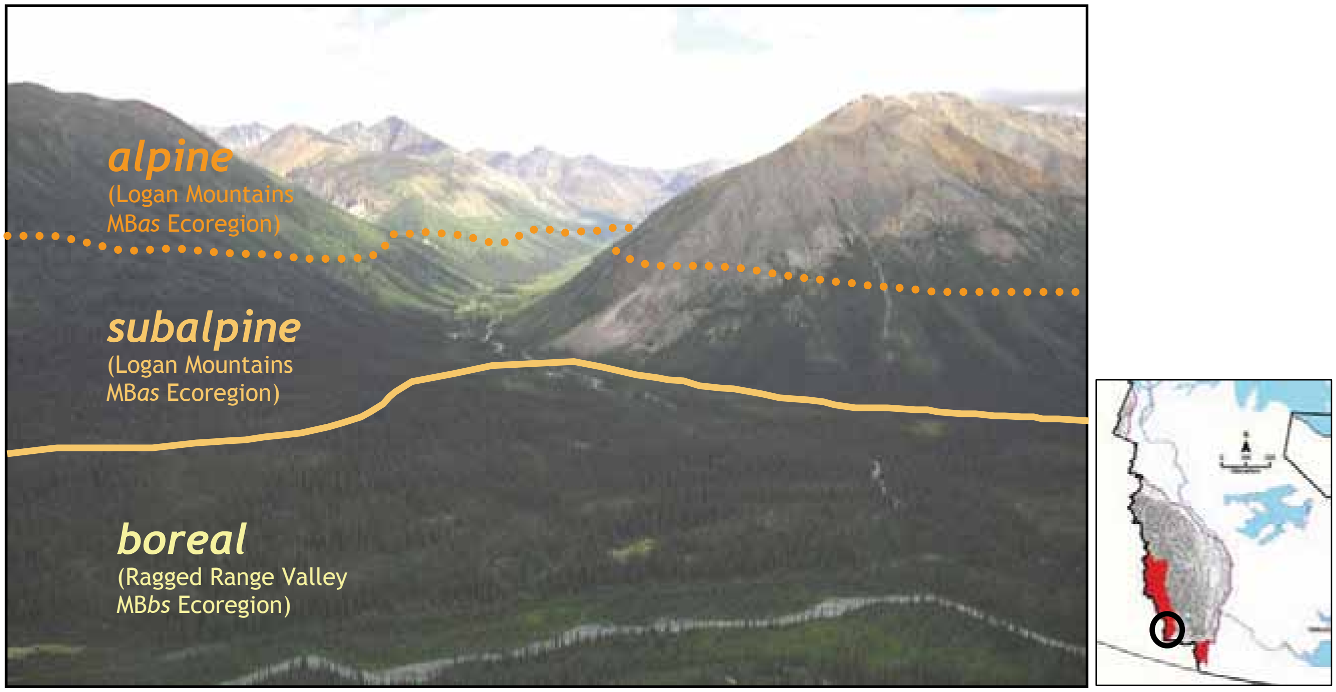


**Figure 20.** In the southwest corner of the Cordillera near Tungsten and the Northwest Territories – Yukon border (circled on inset map), the low-elevation Flat River valley (foreground) supports dark-toned boreal forests and bright green wetlands and constitutes part of the boreal phase for the Ragged Range Valley MB*bs* Ecoregion. In the Logan Mountains MB*as* Ecoregion, the mid-elevation subalpine phase is characterized by white spruce and alpine fir forests and alder shrublands on lower slopes, changing to more open spruce and fir woodlands at higher elevations with subalpine herb and shrub communities; its upper limit is determined by tree line. Stunted trees occur in sheltered places and warm exposures at higher elevations in the alpine phase, but shrubby and herbaceous alpine tundra (light green tones) dominates where there is sufficient moisture. Lichens are the main non-vascular plant cover with scattered pockets of dwarf shrubs and herbs in the upper-elevation reaches of the alpine phase (brown and gray tones). Glaciers and icefields are common in this area as well.

### 1.5.2 Common Landform and Vegetation Patterns in Level IV Ecoregions

#### 1.5.2.1 Recognizing Level IV ecoregions

Landform, soil and vegetation characteristics differentiate one Level IV ecoregion from another. The *reference site* is the landform – soil – vegetation combination that concisely describes the central concept of a Level IV ecoregion. It is conventionally regarded as a site with "deep, well- to moderately well-drained, medium-textured soils, with neither a lack nor an excess of soil nutrients or moisture, and neither exposed nor protected from climatic extremes" (Strong and Leggat 1992; Ecoregions Working Group 1989).

Sites meeting these criteria are considered to reflect the regional climate. For example, in the Central Mackenzie Valley HB*b* Ecoregion, a reference site for the low elevation boreal climate phase (see Section 1.5.1) would be associated with trembling aspen and mixed trembling aspen – white spruce stands on deep, moderately fine-textured soils of average moisture and nutrient status at lower elevations.

The mountainous Level IV ecoregions of the Cordillera are influenced by different factors depending on geographic location and topography, and this definition of reference site rarely fits well with the most commonly occurring vegetation – landform – soil combinations. There is almost always more than one reference site because of marked elevational variations within ecoregions that produce distinct local climates.

A more inclusive definition of reference sites for Level IV ecoregions in the Cordillera is *"the vegetation, soil and landform combinations that are dominant within an ecoregion and that characterize its major climatic phases"*. There will usually be at least two such combinations determined by elevation in the Cordillera. For example, reference sites in the Ragged Range MB*as* Ecoregion would include icefields, glaciers and barren rock with patchy tundra in *alpine* areas above tree line, bouldery talus slopes with open forest and tundra on lower-elevation *subalpine slopes*, and gravelly to silty braided river terraces with conifer forests and a few wetlands in *subalpine valley bottoms*. The landform and vegetation characteristics of these reference sites link the Level IV ecoregion to the regional climate, and these ecological relationships are presented in the overview and summary statements and in the general description of each Level IV ecoregion in Section 3.

### 1.5.2.2 Features that define Level IV ecoregions

Landforms common to many Level IV ecoregions across the Cordillera include glacial till veneers and blankets, glaciolacustrine deposits, fluvial and glaciofluvial terraces, alluvial fans, braided rivers, meandering rivers, colluvial fans and slopes, solifluction terrain, and bedrock formations (limestones, sandstones, shales, and igneous rocks in various forms from sharp ridges to broad plateaus). The plant communities associated with these landforms are partly determined by regional climate as discussed in Section 1.4, and partly by local landform characteristics, the more influential of which are listed below.

- The steepness of terrain associated with these landforms, their elevation relative to other areas and the direction in which they face has an important effect on temperature, moisture, and light as outlined in Section 1.4.2.2 and a corresponding influence on vegetation development.
- The parent materials associated with these landforms determine the rate of infiltration and drainage and the water-holding capacity of soils. Bouldery colluvium derived from the breakdown of limestones and sandstones holds little or no water, whereas fine-textured loamy and clayey soils derived from the weathering of shales can retain large amounts of water.
- Slope position and regional to local groundwater and surface water flow patterns determine soil moisture and the distribution of features such as springs in discharge areas and seepage areas on lower slopes.
- Slope stability has a major influence on vegetation development. Active colluvial fans or landslides result from physical and chemical weathering of bedrock and glacial deposits, and permafrost thawing can lead to slope failures on small to large scales. Unstable slopes retard the development of some plant communities such as forests and tundra, and provide new substrates for the development of others, such as early-successional annual species and lichens.
- Permafrost terrain such as patterned ground, solifluction lobes and stripes, sorted and non-sorted circles, peat plateaus and polygonal peat plateaus support vegetation that is adapted to cold, wet and nutrient-poor soils.

Plant communities common to many Level IV ecoregions throughout the Cordillera include:

- lichen crusts on boulders and bedrock faces;
- lichen-dominated tundra on dry upper slopes;
- shrub-dominated tundra on dry to wet upper slopes;
- open conifer woodland – tundra communities at higher latitudes and higher elevations;
- sedge-cottongrass tussock fens on wet seepage slopes, often underlain by permafrost;
- spruce – shrub – lichen woodlands on well drained slopes;
- spruce – shrub – lichen woodlands on moist to wet seepage slopes;
- spruce – shrub – herb – moss forests on alluvial terraces and fans;
- lodgepole pine, jack pine or hybrid lodgepole pine – jack pine communities in the southern part of the Cordillera;
- mixed conifer – deciduous forests on alluvial terraces and fans and on well- to imperfectly-drained slopes and valley bottoms;
- dwarf birch, willow, green alder and paper birch regeneration on recent burns;
- sedge and shrub fens in valley bottoms.

These plant communities vary in appearance and composition according to regional climate. For example, shrub-dominated tundra in the moist, relatively mild Ragged Range MB*as* Ecoregion is characterized by a dense and tall bright green cover of species such as willows and alders, whereas shrub-dominated tundra in the cold, relatively dry Canyon Ranges HS*as* Ecoregion is characterized by a sparse brownish-green mat of low-growing species such as dwarf willows, Arctic bearberry, northern Labrador tea, and mountain-heather.

Figures 21 to 32 illustrate several of the landform and vegetation features that are used to characterize Level IV ecoregions.

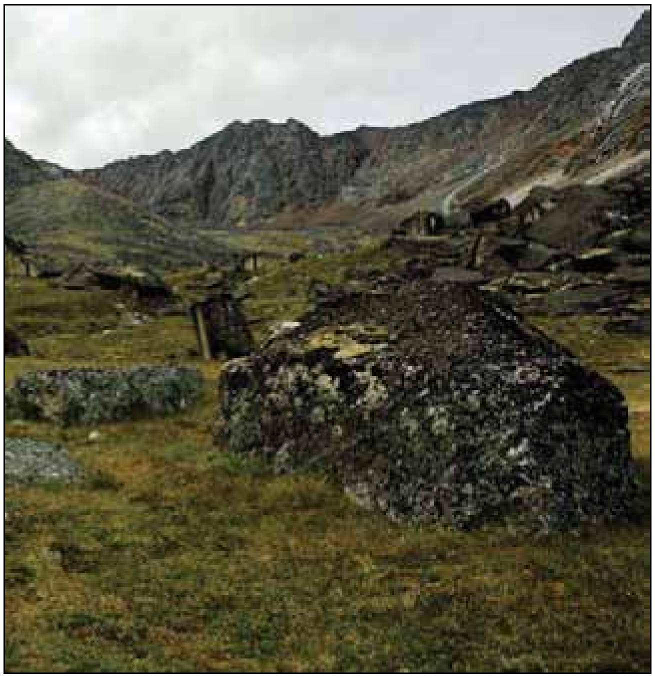

**Figure 21**. Black and green lichen crusts on bedrock and scattered patches of tundra in sheltered moist locales are characteristic of high elevations.
(*Location:* Ragged Range MB*as* Ecoregion)

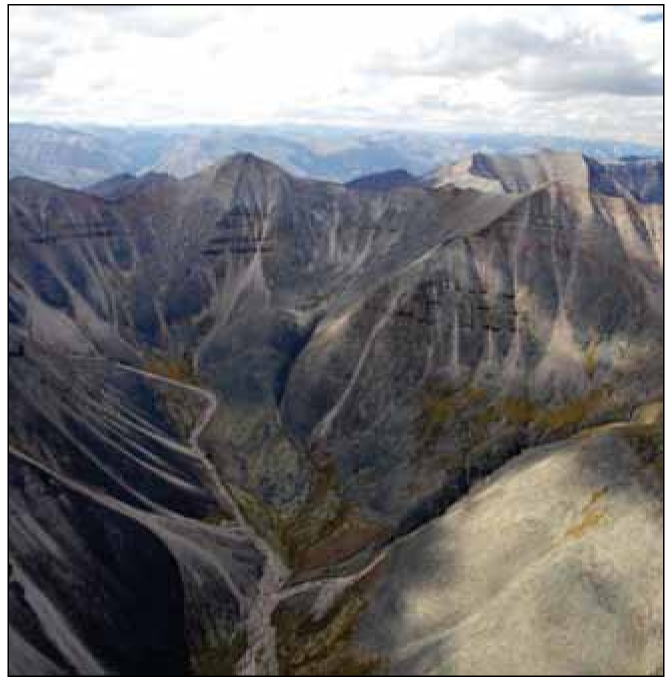

**Figure 22**. The active downslope movement of boulders and the lack of fine-textured materials prevents plant establishment except in valley bottoms and on more stable slopes between fan-shaped erosional deposits.
(*Location:* Shattered Range HS*as* Ecoregion)

**Figure 23**. Low-growing, sparse yellowish-green sedge and shrub tundra is common on gentle seepage slopes underlain by permafrost in the cold, dry Level III Taiga Cordillera HS Ecoregion.
(*Location:* Shattered Range HS*as* Ecoregion)

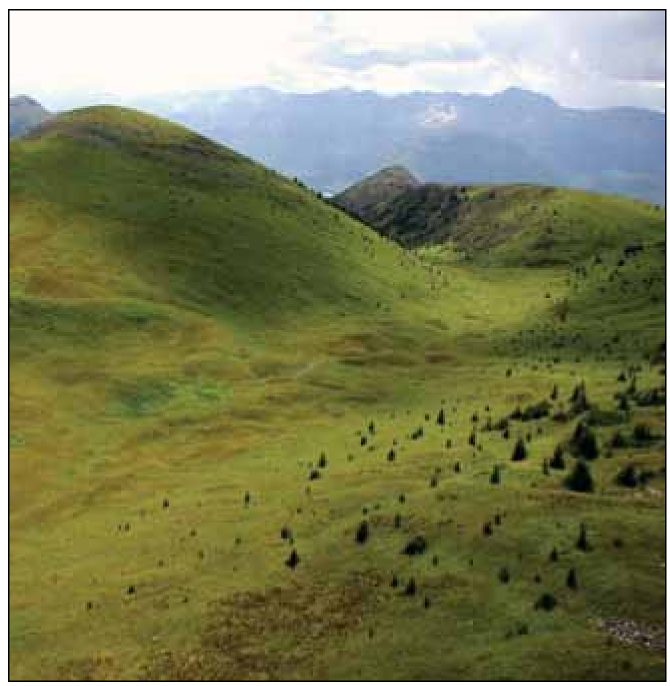

**Figure 24**. Lush, bright green herb and shrub tundra and alpine fir woodlands grow on slopes receiving seepage and heavy year-round precipitation in the relatively mild and moist Boreal Cordillera MB Ecoregion.
(*Location:* Southern Sapper Ranges MB*as* Ecoregion)

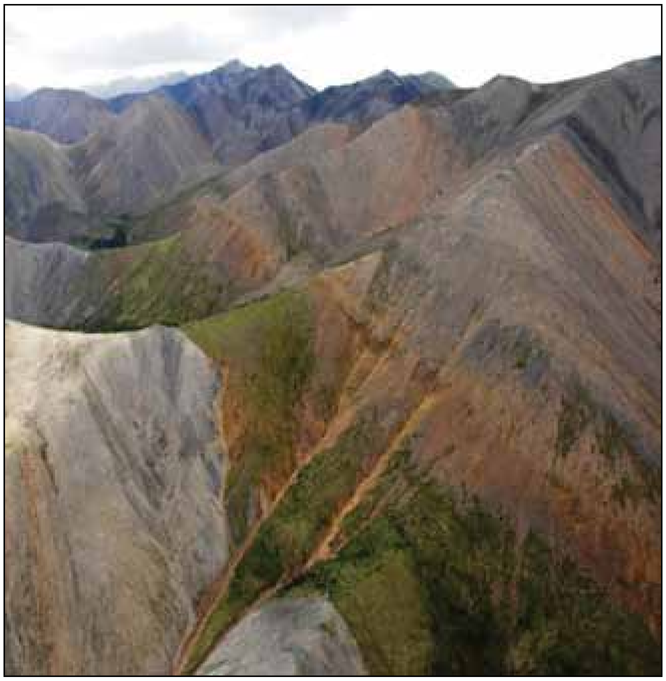

**Figure 25**. The vegetated bands in this image are woodland and tundra communities that have developed on fine materials resulting from the breakdown of shales. Resistant limestone and sandstone strata on either side provide few sites for plants to take root, and support lichen crusts; mosses and vascular plants grow in small sandy to clayey pockets.
(*Location:* Painted Mountains LS*sa* Ecoregion)

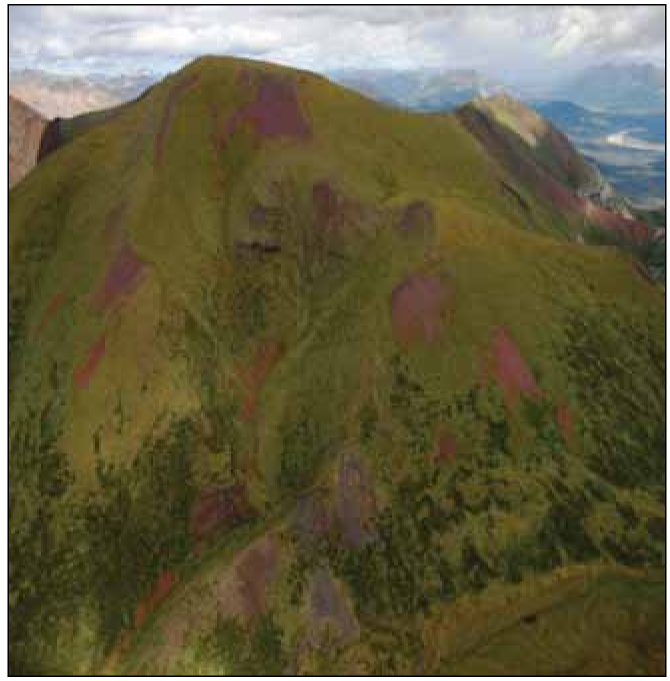

**Figure 26**. Purple shales support a nearly continuous tundra cover, and where they occur, Dall's sheep are often found. Black to dark gray shales also support a nearly continuous tundra cover, but shales of other colours generally are less well vegetated, suggesting that purplish and black shales might provide better moisture and nutrient supplies and perhaps warmer surface temperatures than other shale types.
(*Location:* Southern Backbone Ranges LS*sa* Ecoregion)

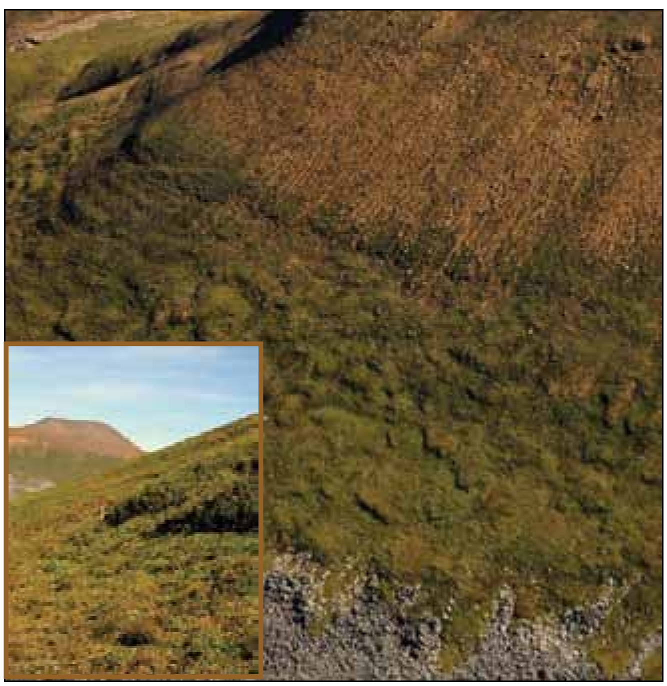

**Figure 27**. Solifluction lobes in tundra indicate the presence of wet, fine-textured materials that thaw in summer and flow slowly downslope over an underlying permafrost layer. These features occur more frequently on colder north-facing slopes where the thawed surface soils are less likely to dry out. The inset shows the tip of a solifluction lobe that is about 1 m high.
(*Location:* Canyon Ranges HS*as* Ecoregion)

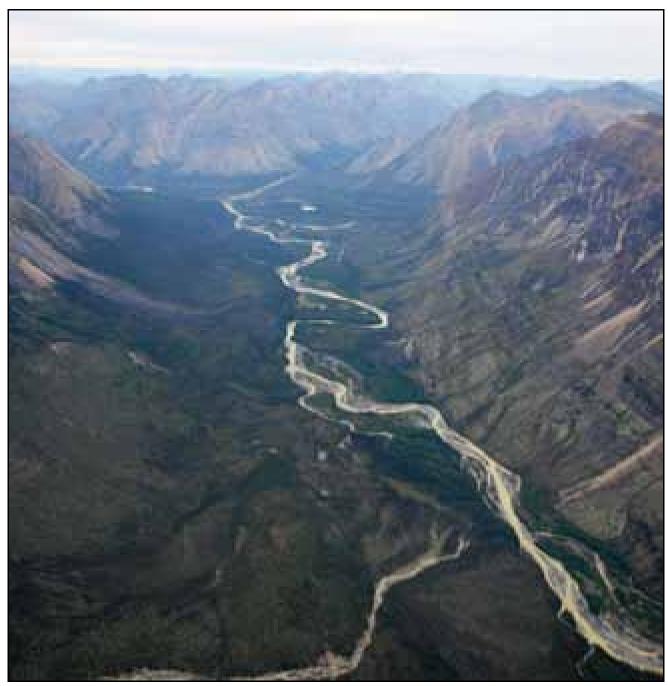

**Figure 28**. This southeast view down the glacially scoured Twitya River valley shows open light-coloured spruce – shrub – lichen woodlands on the north facing lower slopes to the right of the river, denser dark-toned spruce – shrub woodlands on the south facing slopes to the left of the river, and spruce forests and shrublands on the alluvial terraces beside the river.
(*Location:* Sayunei-Sekwi Ranges LS*as* Ecoregion)

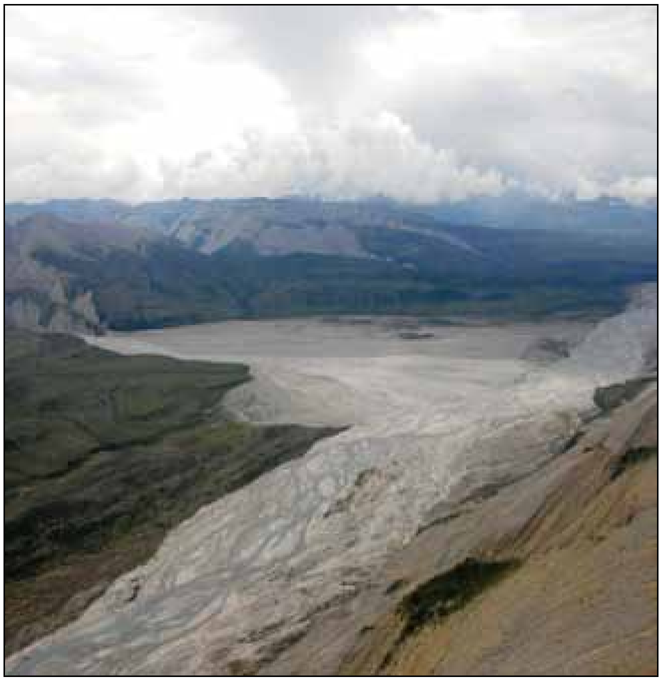

**Figure 29.** Braided river channels develop in areas with an abundant supply of sediment, a high stream channel gradient, and marked seasonal variations in water supply. Rapid erosion of the surrounding mountains contributes very coarse gravels and boulders, producing the broad, dry and mostly barren braided river channels that frequently dominate dry valleys in the rain shadow of higher mountains to the west.
(*Location:* Root River, Painted Mountains LS*sa* Ecoregion)

**Figure 30**. Not all braided river channels are barren. Shrub communities and deciduous, mixed-wood and coniferous forests establish where the water table is close to the surface and pockets of finer materials are deposited, generally on lower-gradient river reaches, in locales where damaging ice-jams and flooding are infrequent, and in areas that receive more moisture, such as the South Nahanni River.
(*Location:* Ragged Range Valley MB*bs* Ecoregion)

**Figure 31**. Recent Cordilleran and Continental glaciation has carved U-shaped valleys with a variety of glaciofluvial, glaciolacustrine and till deposits on the valley floor and sides. This image shows pothole lakes in an old glaciofluvial terrace along the South Nahanni River.
(*Location:* Ragged Range Valley MB*bs* Ecoregion.

**Figure 32**. Some areas remained ice-free during the last glacial advance as indicated by *tors* (pillars of erosion-resistant rock) such as this sandstone tower that would have been sheared away if ice had flowed over it.
(*Location:* Shattered Range HS*as* Ecoregion)