Fraser Headwaters
Proposed Conservation Plan

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Acknowledgements

The Silva Forest Foundation and Fraser Headwaters Alliance acknowledge that the Fraser Headwaters forms a part of the traditional territories of the Lheidli T'enneh and Secwepemc First Nations. We hope that constructive partnerships can be formed between these First Nations and the Fraser Headwaters Alliance to develop and implement ecosystem-based planning throughout the Fraser Headwaters.

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1. Introduction

> *Earth spaces are endangered. Because of their evolutionary creativity, Earth spaces are more important over the long run than the species abstracted from them. Without this insight, conservationists will keep slipping back into the language of saving organisms and their habitats, leaving the door open to those who argue that the solution is more and better arks. To plan the preservation of "biodiversity" at the land-water ecoscape level is to preserve more than that term initially suggested. It is to preserve the world.*
>
> J. Stan Rowe (1997)

1.1 Project Overview

Figure 1: The Fraser River, shown here at Dunster, is the source of life for the many aquatic and terrestrial species that live along its 1370 km length. Maintaining full ecosystem functioning here in the headwaters is critical to ensuring the health of the entire Fraser River ecosystem.

High in the Rocky Mountains of Mt. Robson Provincial Park, trickles of glacier-fed water flow together to form the humble beginnings of the mighty Fraser River. These waters will flow approximately 1370 km over widely varied terrain, from the rugged Rocky Mountain Trench through the gently rolling Interior Plateau and into the Fraser Valley on the lower mainland before finally pouring into the ocean at Vancouver.

The Fraser River watershed is a complex system that provides many ecosystem services, including clean drinking water for its many human inhabitants, spawning grounds for salmon, and critical habitat for many other species. The health of the river is dependent on the health of the ecosystems through which it flows—mountains, forests and plains. The Fraser Headwaters, the birthplace of the river, is the most important part of the watershed; what happens here will affect all ecosystems downstream.

In 1999, the Fraser Headwaters Alliance began working with the Silva Forest Foundation to complete a landscape-level ecosystem-based plan for a 1.3 million hectare area in the headwaters of the Fraser River.

The project was undertaken on behalf of the Fraser Headwaters Alliance, a non-profit grassroots conservation organization based in the Robson Valley, whose mission is to preserve and restore the ecological integrity and natural beauty of the Fraser Headwaters region.

The project is part of ongoing work to develop and implement ecosystem-based planning at the landscape, watershed, and stand levels for the entire Fraser Headwaters. Previous projects include watershed-level plans for the Raush River and Horsey Creek watersheds (Silva Forest Foundation 1997 and 1999). The purpose of both this and previous projects is to provide practical information to local residents and groups who wish to protect, maintain, restore, and plan for the ecologically sustainable use of the ecosystems that form the Fraser Headwaters.

The entire Fraser Headwaters ecosystem-based plan is subject to respect for, and accommodation of Aboriginal title and rights, including a just and honorable resolution of the land question. As such, meaningful consultation on this project is required with all affected First Nations. Meaningful consultation needs to provide an active, participatory role for all affected First Nations, leading to informed consent for the plan.

This report contains a description of the *Fraser Headwaters Proposed Conservation Plan*, and is accompanied by a set of seven full size maps at a scale of 1:200 000.This chapter, the introduction, briefly explains the process of ecosystem-based planning and how it is applied at multiple scales[1]. The chapter concludes with a list of the objectives of the project and an outline of the material covered within the rest of the report.

1.2 Ecosystem-Based Planning at Multiple Spatial Scales

The *Fraser Headwaters Proposed Conservation Plan* was designed using an ecosystem-based approach. Ecosystem-based planning is based upon the principle that economies are subsets of human cultures and societies, which in turn are subsets of ecosystems (Figure 2). Human societies and economies are dependent upon the natural diversity and integrity of the ecosystems of which they are a part. Therefore, if our activities protect the functioning of ecosystems, we will protect human cultures, and if we protect human cultures, we will protect and sustain our economies.

An ecosystem-based approach thus protects ecosystem functioning at all spatial scales through time as the first priority, and then seeks to sustain, within ecological limits, a diversity of human uses across the landscape. In other words, an ecosystem-based approach focuses first on what to leave and then on what can be taken without damage to ecosystem functioning.

The ecosystem-based philosophy and methodology applies at all scales from the microscopic to the global. Ecosystems are a continuum through time and space. Some processes occur over small areas and time periods, such as the death of an individual tree,

[1] The process of ecosystem-based planning is described in greater detail in the document *An ecosystem-based approach to forest use: definition and scientific rationale*, which can be downloaded from the Silva Forest Foundation website at www.silvafor.org.

or the spring flow of a tiny seasonal creek. Other processes take place over much larger temporal and spatial extents: the annual migration of many bird species between tropic and temperate zones; the slow shift in global climate patterns (although the pace of this particular phenomenon appears to be increasing rapidly in response to human activity).

Processes at all scales are interconnected. While the death of a single tree may seem irrelevant at a continental scale, that tree creates the structure necessary to maintain high quality habitat for many species of plants and animals; the collective death of many individual trees, therefore, is crucial to maintaining ecological composition, structure and functioning at the landscape level. Similarly, maintaining high quality bird habitat here in Canada will not succeed in conserving bird species if all of the wintering grounds in the tropics are deforested.

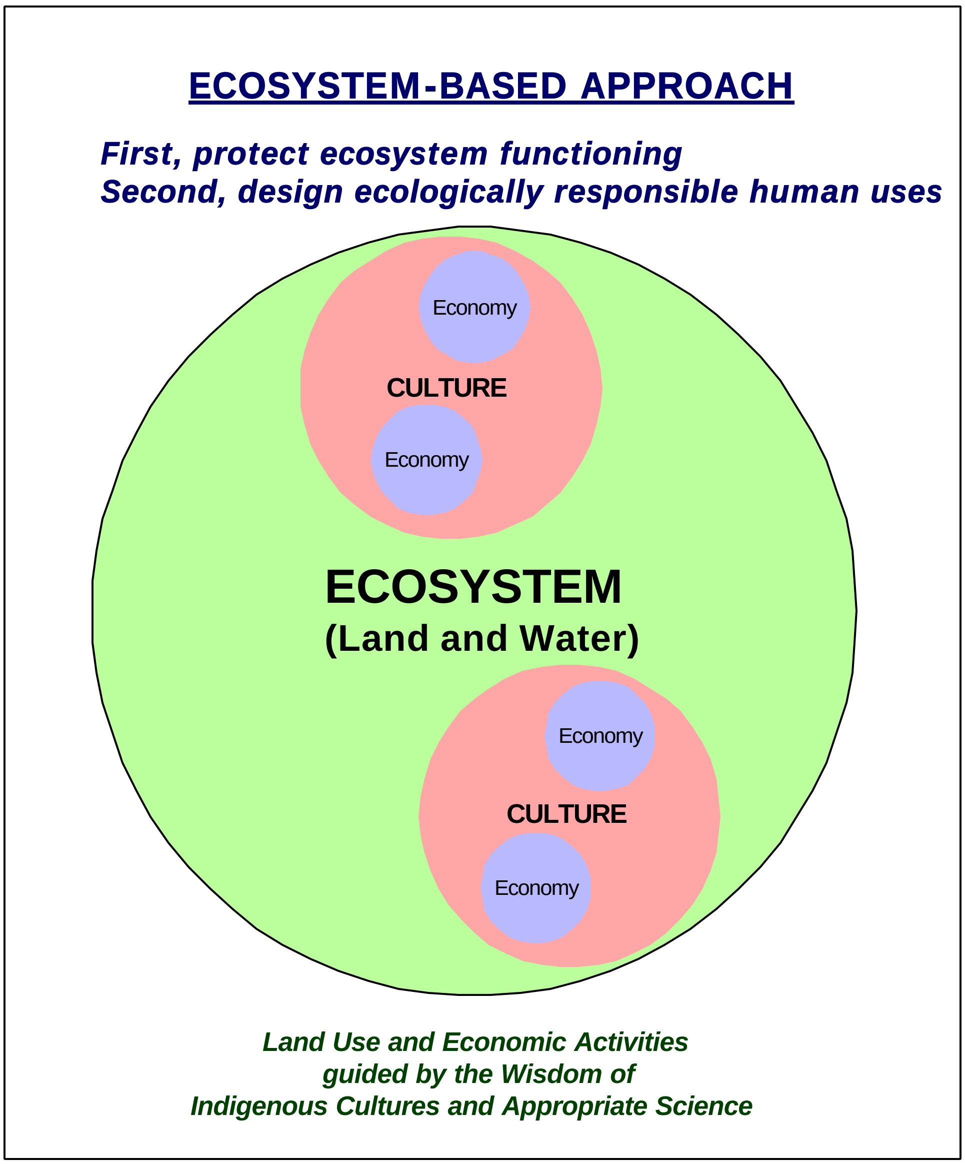

Figure 2: An ecosystem-based approach to planning

To maintain ecological integrity over large areas, therefore, ecosystem-based planning must be conducted at multiple scales to ensure that none of the details are missed. The philosophy and approach to planning remains the same at all scales; only the level of detail changes. Processes and structures not visible over larger landscapes become the target of focus in smaller areas. In practice, the Silva Forest Foundation carries out ecosystem-based planning at three spatial scales: landscape, watershed, and stand (Figure 3).

The *Fraser Headwaters Proposed Conservation Plan* is a landscape level plan. The word "landscape" is usually used in the English language to mean "scenery." Here, we are using the word in its technical sense: "a mosaic where the mix of local ecosystems or local land uses is repeated in similar form over a kilometers-wide area" (Forman 1995). The Fraser Headwaters landscape mosaic consists of a series of high elevation, rugged, narrow valleys that feed into a lower elevation central wide valley (the Rocky Mountain Trench). The ecology of each of these tributary watersheds (the rivers and creeks that feed into the Fraser River) is similar because they share many biophysical characteristics.

At a landscape level, ecosystem-based analysis focuses on patterns and processes that occur over large areas. The analysis of landscape diversity, for example, shows how ecosystem or forest types are distributed across the landscape, and highlights areas of particularly high diversity as candidate areas for conservation. Detailed analysis of small areas is neither possible nor appropriate at this scale. The analysis is primarily a computer modeling exercise that relies on existing digital data.

Ecosystem-based planning begins with an analysis of the character and condition of a given landscape.

The *character* of a landscape refers to how ecosystems work: how the structures and composition present in the landscape interact with climate and geology to govern ecosystem functioning. The character of a landscape determines the composition and structures that must be protected in order to maintain ecosystem functioning. Determination of the character of a landscape typically includes spatial analysis of unique habitats and ecosystems (such as old growth forests), ecologically sensitive areas, and representative ecosystems.

The *condition* of a landscape describes how human uses have modified ecosystem functioning. Human impacts generally occur as discrete events in time at the patch or stand level. However, over time, the impacts of discrete human uses at the stand or patch level combine or accumulate to lead to cumulative effects at the landscape level. The condition of a landscape is typically assessed by mapping human activities and the zone of influence for these disturbances.

The analysis of the character and condition of a landscape help to define the *ecological limits* of ecosystems to human use. Ecosystem productivity, resilience, and recovery can be limited by factors such as very wet or very dry areas, cold temperatures, heavy snowpacks, steep slopes, and thin soils. The maps depicting character and condition help to highlight where these ecological limits occur.

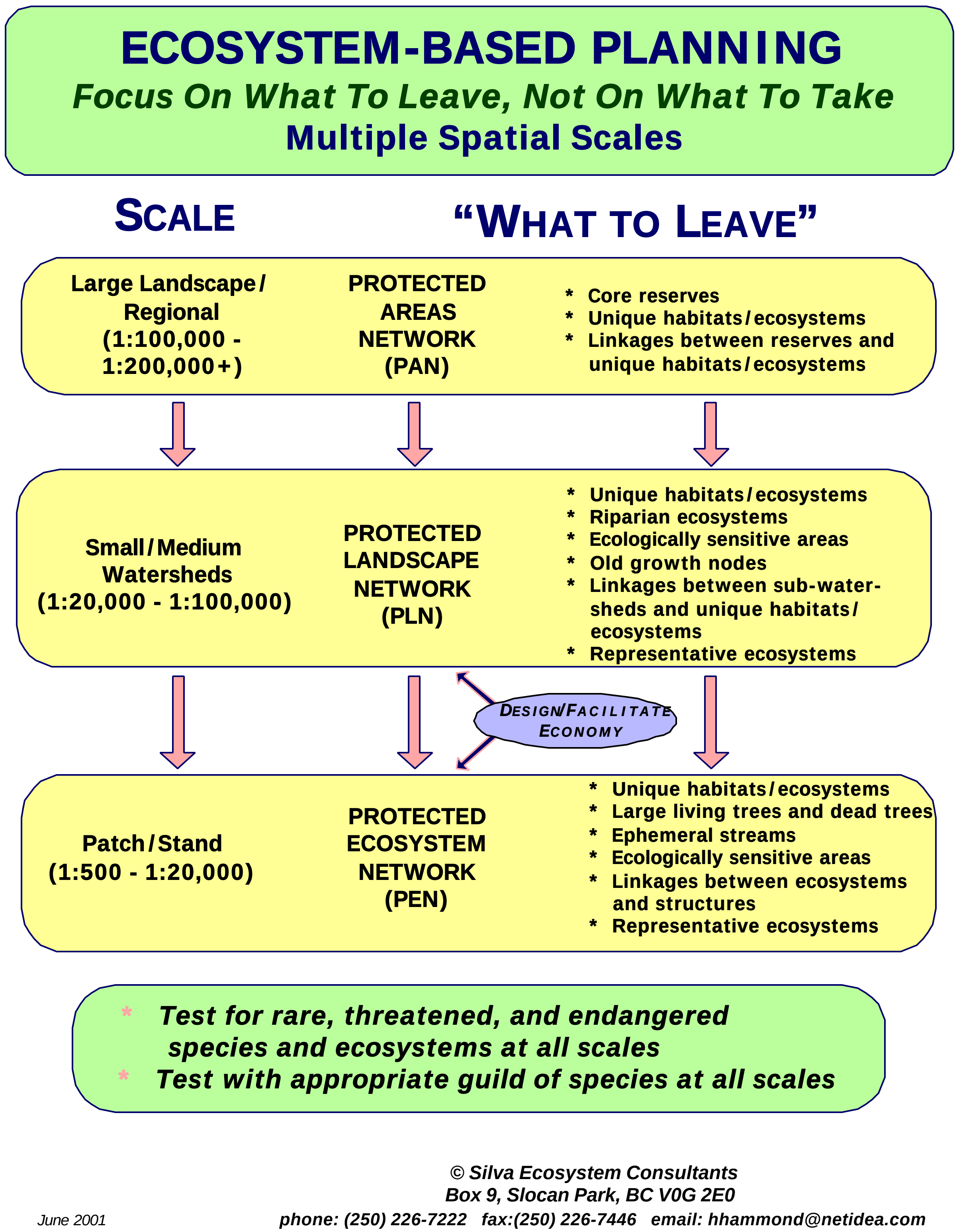

Figure 3: Ecosystem-based planning at multiple spatial scales

Once the character, condition and ecological limits of a landscape have been identified, the next step in the process of ecosystem-based planning is to identify protected networks. These protected networks are designed to protect, maintain, and where necessary, restore fully functioning ecosystems. They form the framework within which various ecologically responsible human activities may occur.

The final product of a landscape level plan is the Protected Areas Network (PAN). Based on the character and condition of the landscape (which includes the analysis of patterns such as landscape diversity, ecological risk, old growth forests, and human disturbance) the PAN focuses on identifying both core reserves and large linkages between and within adjoining landscapes. For the Fraser Headwaters, this means ensuring that there are linkages through the study area that join the provincial parks that border the study area in both the Rocky and Columbia Mountains. Core reserves in a PAN are typically the size of individual watersheds or the drainage basins of small rivers.

This proposed *Fraser Headwaters Conservation Plan* recommends the design for a PAN. However, this proposed plan currently does not include the other elements of a complete ecosystem-based plan, as described below.

Once planning has been completed at the landscape level, the analysis can proceed to the watershed level. A watershed is the drainage basin for a particular river or stream. The size of the basin changes depending on the size of the watercourse, but typically at this level of planning we are considering watersheds of about 100 000 ha (1000 km^2).

At the watershed level, ecosystem-based planning focuses on identifying unique habitats and ecosystems, ecologically sensitive areas, and riparian ecosystems. Airphoto interpretation becomes a very valuable tool at this scale and allows a more detailed interpretation of finer grained features.

The goal of the watershed level analysis is to delineate a Protected Landscape Network (PLN), similar to the PAN but designed at a finer resolution. In addition to unique habitats, ecologically sensitive areas, and riparian ecosystems, the PLN includes old growth nodes and cross-valley corridors. Old growth nodes are similar to the core reserves identified at the landscape level, but smaller in size. Cross-valley corridors fulfill the same role at the watershed level as do landscape linkages at the landscape level, but again vary in size. The two levels of planning are therefore complementary.

Once a PLN has been designed for a watershed, wholistic forest use zoning is then carried out in areas outside the PLN. The goal of zoning is to design an ecologically sustainable human economy that fits within the limits of ecosystems. In establishing forest use zones, the most sensitive and easily damaged human uses are accommodated before allocating areas for more aggressive human uses. In order of the establishment, typical forest use zones include: culture, areas that are culturally or historically important to local people; ecologically sensitive, small sensitive areas not identified or protected in the Protected Landscape Network; fish and wildlife habitat; tourism; hunting, fishing, and trapping; and timber management.

In those areas that have been zoned for wholistic timber management, ecosystem-based planning is carried out with yet more detail. Much more emphasis is placed at this stage on field work as many of the features that need to be taken into account are simply not visible from remotely sensed data (that is, digital data or airphotos). Analysis focuses on identifying unique habitats and ecosystems, large living trees and dead trees, ephemeral (seasonal) streams, and small ecologically sensitive areas, such as tiny wetlands. Where core reserves and old growth nodes were identified at the landscape and watershed levels respectively, at the stand level, full cycle trees are one of the ecological components that are protected. The final outcome of ecosystem-based planning at the stand level is the Protected Ecosystem Network (PEN).

Carried out from the landscape through to the stand level, ecosystem-based planning results in a Protected Areas Network (landscape), Protected Landscape Network (watershed), and Protected Ecosystem Network (stand). Taken together, these networks protect, maintain, and where necessary restore full ecosystem functioning.

A question is often raised about how ecosystem-based planning compares with species-based conservation design. Where an ecosystem-based approach considers the character and condition of the entire system, a species-based approach selects one or more wildlife species as surrogates for that system (Soule and Terborgh 1999). Species chosen often include those that require large home ranges and relatively undisturbed conditions ("umbrella species" such as grizzly bears) or those that play a key role in regulating ecosystem functioning ("keystone species" such as wolves) (Carroll *et al.* no date). The method typically involves modeling the habitat requirements of the chosen species, and then protecting adequate amounts of this habitat to ensure population viability. By ensuring that viable populations of these species are maintained, it is hypothesized that the needs of other species will also be fulfilled.

From our perspective, the ecosystem-based approach is a more inclusive method of planning. Ecosystems include species, and an ecosystem-based plan uses a range or "guild" of species to test the final design of the PAN or PLN. The data required to carry out ecosystem-based plans are often more readily available than those necessary to model the habitat requirements of individual species.

Inherent within the process of ecosystem-based planning is the provision for human needs. It is a wholistic approach that provides networks of protection within which human uses are nested. The species-based approach is more often premised on an allocation model, like the current parks system, where the focus is on setting land aside rather than determining how sustainable human economies can be designed to fit within the limits of ecosystems. A balanced approach, therefore, leads with an ecosystem-based plan, and incorporates species data where available to ensure that the needs of a range of indicator species are indeed being met.

The *Fraser Headwaters Proposed Conservation Plan* represents the first step in the ecosystem-based planning process in the Fraser Headwaters. While one of the goals of the project is to identify large core reserves and landscape-level linkages, this does not mean that those areas not identified as such are fully available for consumptive human uses. As outlined above, further planning is required at the watershed and stand levels in order to determine how such uses can be accommodated within the limits of ecosystems. Two watershed-level plans have previously been completed for the Raush and Horsey

Creek watersheds[2] (Silva Forest Foundation 1997 and 1999). Further planning still needs to be completed elsewhere in the area.

1.3 Project Objectives and Report Outline

The overall goals of the project are two-fold:

1. **To analyze the character and condition of the study area**. This analysis includes a consideration of:
    - landscape diversity – the pattern of forest types across the landscape
    - ecological risk – the location and distribution of ecologically sensitive ecosystems
    - antique and old growth forests – the location and distribution of candidate antique and old growth forests
    - human disturbance – the extent of human activities across the landscape, including past and planned logging, roads, cleared land, and private land
2. **To design a Protected Areas Network (PAN), based on the character and condition of the study area.**

The results of the final project include both this report and a set of 7 large (poster-sized) maps that accompany this report. The map folio includes:

- *Map 1: The Fraser Headwaters (base map)*
- *Map 2: Landscape Diversity*
- *Map 3a: Ecological Risk in Summary*
- *Map 3b: Ecological Risk in Detail*
- *Map 4: Antique and Old Growth Forests*
- *Map 5: Human Disturbance*
- *Map 6: Proposed Protected Areas Network*

Maps 5 and 6 were produced in both paper and mylar (clear overlay) versions.

The report is divided into five chapters, of which this introduction is the first.

Chapter 2 introduces the Fraser Headwaters study area. It begins with a description of where the study area is located and why it was chosen. This is followed by a summary of the biological and physical characteristics of the area as well as a brief consideration of the human history of the region.

Chapter 3 describes the methods used to complete the project, including the acquisition of data, field sampling, and the analytical techniques used to create each map.

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[2] An example of how the Fraser Headwaters Protected Areas Network and Horsey Creek Protected Landscape Network complement one another is shown on the large folio version of Map 6: Proposed Protected Areas Network, that accompanies this report.

Chapter 4 details the results and interpretations of the four analytical maps in the mapset: Landscape Diversity, Ecological Risk, Antique and Old Growth Forests, and Human Disturbance.

Chapter 5 describes the proposed Protected Areas Network, which synthesizes information from all the proceeding analysis and maps. This chapter includes a discussion of existing protected areas in the region, as well as a rationale for the new Proposed Full Protection areas and Proposed Conservation Emphasis areas.

Finally, Chapter 6 provides both a brief conclusion and recommendations for ways to move forward toward the ultimate goal of implementing ecosystem-based planning at multiple spatial scales throughout the Fraser Headwaters.

2. The Fraser Headwaters Study Area

This chapter contains a description of the Fraser Headwaters study area, including

- an explanation of where the Fraser Headwaters is located and how the boundaries of the study area were determined (Section 2.1);
- a description of the physical environment, including geology and climate (Section 2.2);
- a description of the biological environment and ecological patterns and processes found within the area, including vegetation and disturbance regimes (Section 2.3);
- a description of wildlife found in the study area, with particular attention to mountain caribou (Section 2.4); and
- the history of human occupation from Indigenous Peoples to current residents (Section 2.5).

Map 1: The Fraser Headwaters on page 13 is the base map for this project, and provides an orientation to the location, features, and character of the Fraser Headwaters. The map highlights the basic physiography of the region, as well as locations of towns, highways, roads, and water features. Map colours were assigned based on the elevation of a given point on the map, so that the yellow/orange colours occur at the lowest elevations, the greens at mid to upper elevations, and grey and white at the highest elevations. The three-dimensional quality of the map shows the topography or lay of the land within the study area. Further description of the methods used to produce the map are found in Chapter 3.

2.1 Study Area Location and Rationale

The Fraser River originates in Mount Robson Provincial Park, in the Rocky Mountains of central interior British Columbia (B.C.), adjacent to the B.C.-Alberta border (Figure 4). The river flows northwest through the Rocky Mountain Trench, flanked to the east and west by the rugged Rocky and Columbia Mountains respectively, then turns south through the more gentle rolling country of the Interior Plateau, and finally west through the rugged Coast Mountains before meeting the ocean at the Strait of Georgia at Vancouver. In total, the Fraser River flows a distance of 1370 km. The Fraser River drainage basin is the second largest in B.C. (after the Mackenzie River basin), covering a total area of 231 313 km^2 (Holland 1976)

The study area chosen for this project encompasses the headwaters of the Fraser River drainage basin, Mount Robson Provincial Park, and a portion of Kakwa Provincial Park. The study area runs approximately parallel to the Rocky Mountain Trench, stretching from Valemount in the southeast to Sinclair Mills in the northwest, and from the height of land in the Rockies down across the Rocky Mountain Trench and up to the height of land in the Columbia mountains.

The study area covers approximately 1.3 million hectares (13 000 km^2), and ranges in elevation from 608m to 3516m.

The study area is surrounded by a number of large protected areas: Mount Robson and Willmore Wilderness Provincial Parks, Jasper National Park, and Kakwa Provincial Park to the northeast, and Bowron Lake, Cariboo Mountains, and Wells Gray Provincial Parks to the southwest (see *Map 6: Proposed Protected Areas Network* for locations of parks).

The boundaries of the Fraser Headwaters study area were delineated in a number of ways:

- In the Rocky and Columbia mountains, the boundary follows the height of land (the watershed boundary), except where small inclusions were made to connect the study area to the surrounding large protected areas. (Large protected areas within the Fraser Headwaters were eliminated from the study area.)
- Along the Rocky Mountain Trench, the southern limit of the study area falls just south of the town of Valemount. This boundary represents a watershed divide; waters to the south of this line flow into the Columbia River basin.
- At the northern end of the study area, a somewhat arbitrary boundary was delineated. The Fraser River continues beyond this point, so few natural boundaries to the drainage basin exist across the Rocky Mountain Trench. We chose therefore to follow the boundaries of the Hungary Creek watershed and to include as much of Bearpaw Ridge as possible.
- The boundary across the Torpy and McGregor Rivers follows the boundary of the McGregor Model Forest (Tree Farm License 30), and is thus institutional rather than ecological in nature. Although forest cover data are available for the Model Forest, they are in a considerably different format than the data covering the rest of the study area. It was therefore decided to exclude the McGregor Model Forest, because the effort required to convert the data so that it would be comparable would be too time-consuming, if even possible at all. As such, the study area boundary in that region is perhaps less than ideal from an ecological perspective.

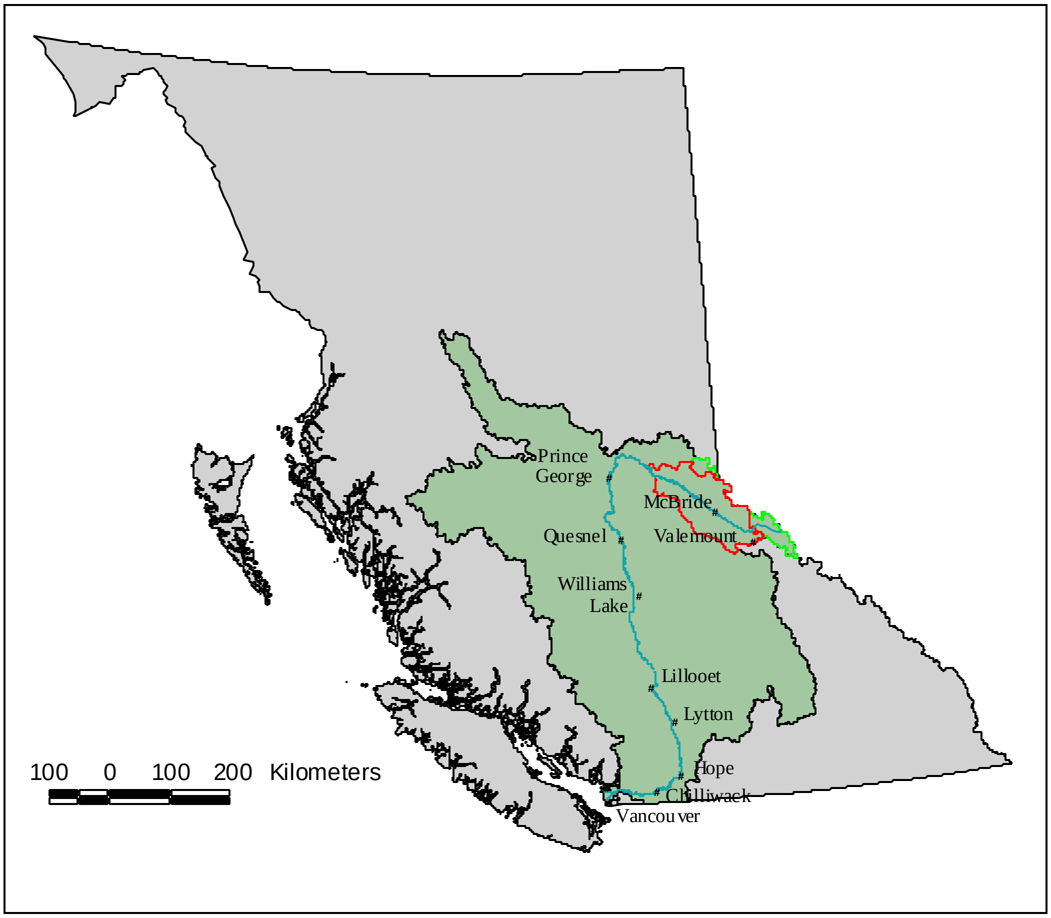

Figure 4: Location of the Fraser River drainage basin (in green) and the Fraser Headwaters study area (outlined in red) within British Columbia.

[remove this page and replace with 11x17 fold-out map]

Map 1: The Fraser Headwaters

Although the study area includes most of the Fraser Headwaters, there are a few notable exceptions. Perhaps the most obvious exclusion is that of Mount Robson Provincial Park—where the Fraser River originates. The primary digital data used for this project, forest cover data, is compiled by the Ministry of Forests for the purposes of timber management. Thus, date for large protected areas is not usually available. Moreover, the area has already been accorded protected status, so a comprehensive analysis of ecological risk seemed redundant. Recognizing that the park does play an important role in contributing to the ecological integrity and connectivity of the upper Fraser, however, we did attempt to evaluate its conservation value (see Section 5.2.1).

A portion of Kakwa Provincial Park also falls within the Fraser Headwaters and was excluded from the study area for similar reasons.

Several small pieces of land that do not fall within the Fraser Headwaters were included within the study area for reasons of connectivity. Betty Wendle Creek and Cariboo River, for example, adjacent to Bowron Lake Provincial Park on the southwestern boundary of the study area, are not part of the Fraser Headwaters. Leaving them out of the study area, however, would have created a small gap between the study area and Bowron Lake[3]. Because one of the goals of this project was to ensure connectivity between the surrounding large protected areas, it seemed important to include these potential linkages.

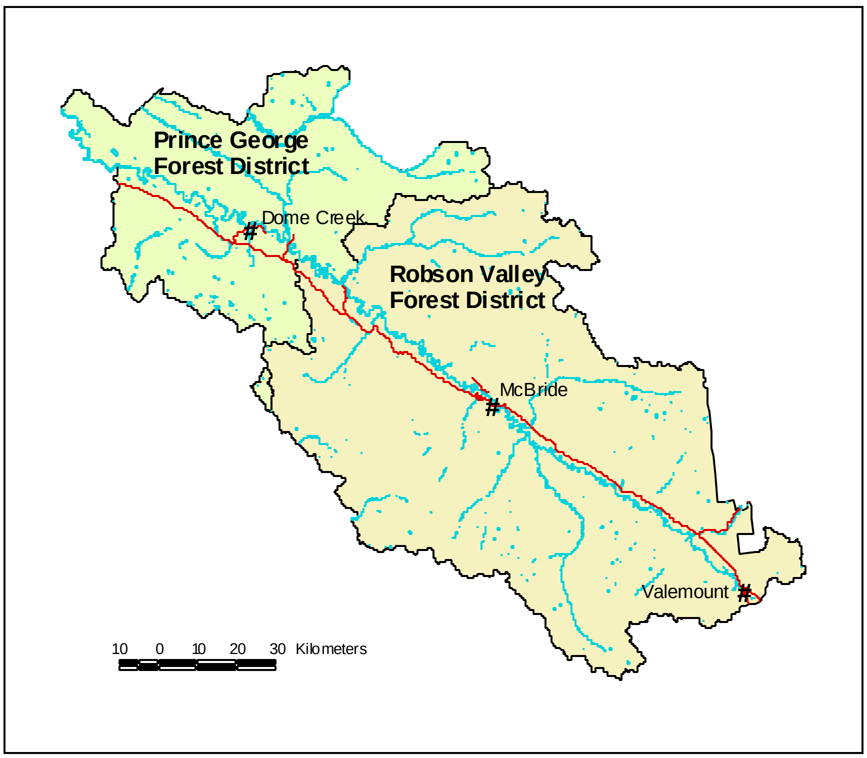

Figure 5: Ministry of Forests forest districts within the Fraser Headwaters study area.

From an administrative perspective, approximately 70% of the study area falls within the Robson Valley forest district and the remaining 30% within the Prince George forest district (Figure 5). Both of these districts are within the Prince George forest region.

[3] During the process of this project, Betty Wendle Creek, Wolverine Creek, and a portion of the Cariboo River were officially added to Bowron Lake Provincial Park as a result of the local Land and Resource Management Plan.

2.2 The Physical Environment

2.2.1 Geology

The Fraser Headwaters is dominated by the Rocky Mountain Trench and the high mountains that surround it on either side.

The Rocky Mountain Trench is a steep sided valley that extends all the way from the Canada-U.S. border to Liard River in northern B.C. Visible from the moon, the trench is one of the great lines on the planet. It is a major break in the earth's crust and has been present for at least 45 million years (Gadd 1986). The walls of the trench disappear only once, just north of the study area. Here, where the Fraser River meets the McGregor River and turns west and south, the landscape begins to open, and the trench merges with the Interior Plateau. The Rocky Mountain Trench resumes on the other side of the McGregor River and continues its journey uninterrupted to northern B.C. (Holland 1976).

Figure 6: The Fraser Headwaters is dominated by the high rugged terrain of the Rocky and Columbia mountains that surround the Rocky Mountain Trench. Ecological limits are many on this landscape. One-third of the study area lies above treeline in the alpine tundra. Cold air from high elevation glaciers and snow fields funnels through steep side valleys and into the trench, affecting vegetation growth all along its path. Steep slopes and thin soils, widespread in the area, also affect forest growth and regeneration.

The Rocky Mountain Trench is surrounded to the north by the Rocky Mountains and to the south by the Cariboo (Columbia) Mountains. Both ranges are rugged and deeply incised, carved over time by the force of ice.

Much of the landscape lies at high elevations. Approximately one-third of the study area is alpine tundra, the region beyond tree-line where tree growth is limited by harsh climate. Large glaciers and snow fields still remain in many places at high elevations. Cold air is funneled from these ice and snow fields through the narrow side valleys and down into the Rocky Mountain Trench. This cold air limits forest growth and regeneration. It has a major influence on ecological patterns and processes within the side valleys and a more moderate influence in the trench.

In geological terms, the region is quite young. The steep topography has not yet settled; it is still in an active stabilizing condition. Talus slopes, for example, are a common feature, especially in the Rocky Mountain region of the study area (Ryder 1978). "Oversteepened" slopes are also common, especially in side valleys, and are susceptible to natural landslides. Landslides in this kind of terrain increase in frequency as a result of human modifications; landslides on a clearcut, for example, are two to nine times more frequent than landslides in an uncut forest (Hammond 1991). Steep slopes thus present one of the major ecological limits in the region, and are one of the main variables in the analysis of ecological risk undertaken in this project (see Section 4.2).

The Fraser Headwaters landscape was glaciated until about 12000 years ago in the trench, and as recently as 4000 years ago in the side valleys. The sediments left behind by these glaciers include till (a mixture of ground up rock and mud left in the wake of retreating glaciers) and glaciolucustrine silt (the particles that settle out of the lakes that formed as the glaciers retreated) (Gadd 1986, Ryder 1978). The valley bottom in the Rocky Mountain Trench is dominated by glaciolacustrine and glaciofluvial deposits as well as fluvial sediments (those associated with river features) formed during the Holocene (11000 years ago to the present day). These are primarily fine sediments that are reasonably stable and quite productive. The sides of the trench are lined by kame terraces (also known as lateral moraines or glacio-fluvial terraces): steeper-sided features with relatively flat tops (Figure 7). Kame terraces are typically less productive due to a lack of moisture. Downslope drainage follows the underlying contours of the bedrock geology deep below the terraces, which are essentially heaps of deposits pasted to the sides of the mountain. Vegetation along the top and edges of the terrace cannot easily access this moisture and are therefore dependent solely on rain and snowfall.

Figure 7: Kame terraces (glaciofluvial terraces) are a common geological feature along the sides of the Rocky Mountain Trench. As the glaciers melted, flowing waters ran off the glaciers to the sides, carrying a bedload of gravel, sand, and silt released from the melting ice. These mounds of materials built up over time along the edges of the valley side walls. They are seen below the steep slopes of the mountains and above the rolling forests of the valley bottom. Kame terraces are often moisture limited. Water drainage from higher elevations follows along the slope of the underlying bedrock, deep below the kame terraces, thus limiting moisture on the terraces to that which falls in the form of precipitation.

Because of the relatively recent retreat of the glaciers, soil development in the Fraser Headwaters, especially in the side valleys, has been limited. Soils are created primarily through two processes: chemical and physical weathering of the mineral matter left in the wake of the glaciers, and organic decomposition. A very general rule of thumb is that it takes 1000 years for the development of one inch of soil. Young, often thin soils present a major ecological limit to forest development and growth, restricting both water storage and the rooting depth of vegetation.

2.2.2 Climate

The climate throughout the area is characterized by cold winter temperatures and relatively high annual precipitation. The northwestern end of the study area tends to be cooler and moister; climate becomes slightly warmer and significantly drier progressively toward the southeastern portion of the study area. This climate trend through the Fraser Headwaters is reflected in the vegetation: the oldest forests (antique forests) are found at the northwestern end of the study area, while the forests of the southeast tend to be younger, drier, and more susceptible to fire.

Dome Creek, located in the northwest portion of the study area, receives an average of 839 mm of precipitation annually[4]. Daily mean temperatures range from 14.7°C in July, the warmest month, to –12.1°C in December, the coldest month (Figure 8) (Environment Canada 1980). The average frost-free period in Dome Creek is 72 days (Environment Canada 1982).

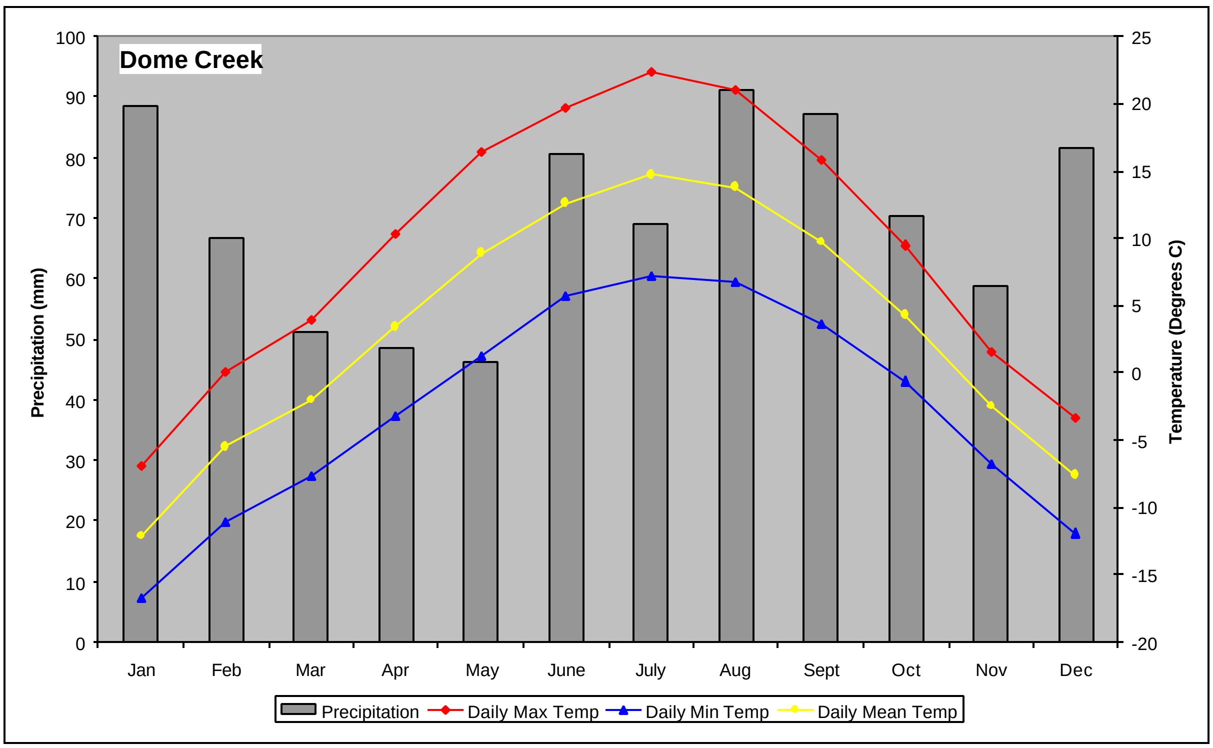

Figure 8: Annual precipitation and temperature trends at Dome Creek (Environment Canada 1980).

[4] See Figure 5 for locations of Dome Creek and Valemount.

At Valemount, in the southern portion of the study area, total annual precipitation is 503mm, significantly less than at Dome Creek. Daily mean temperatures range from 15.8°C in July to –11.0°C in December (Figure 9) (Environment Canada 1980). The average frost-free period is 76 days.

Much of the annual precipitation falls in the form of snow, especially at higher elevations. That said, the summer months do experience ample rainfall, especially in the northwestern portion of the Fraser Headwaters. It is this characteristic in part that has led to the development of the antique forests north of McBride. Unlike coastal rainforests, which

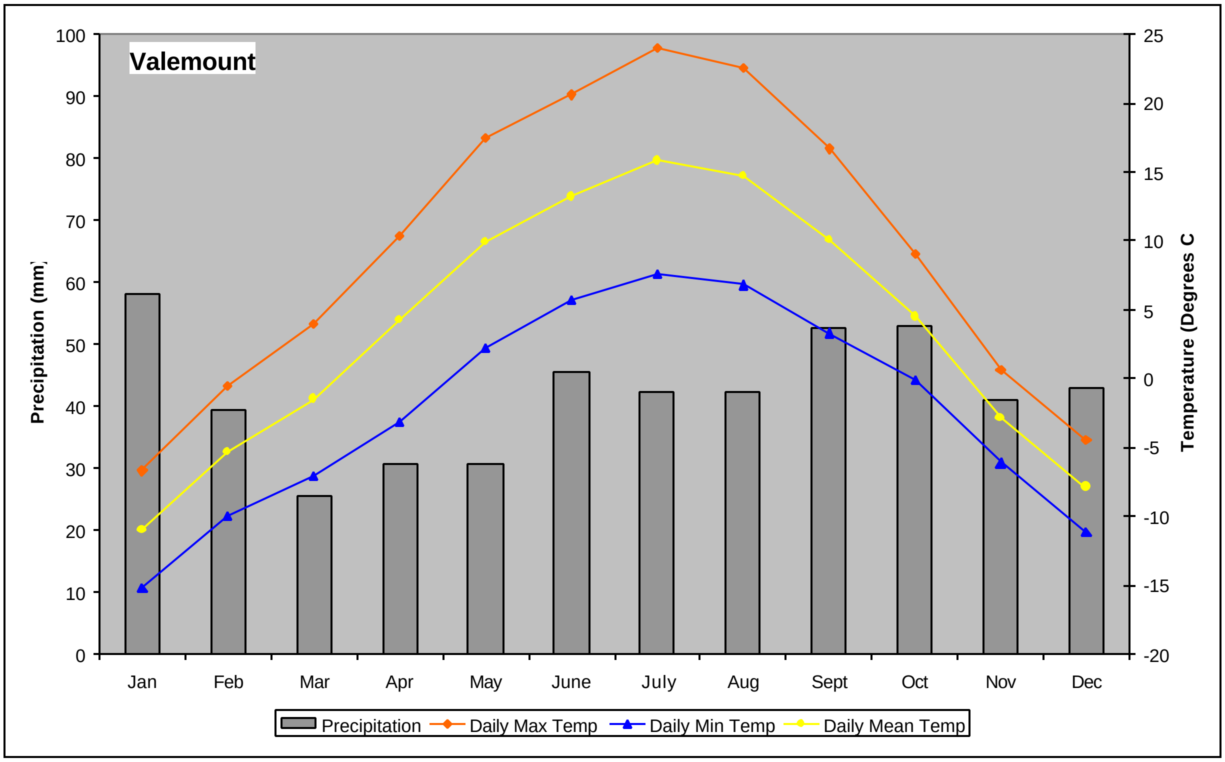

Figure 9: Annual precipitation and temperature trends at Valemount (Environment Canada 1980).

receive more precipitation in the winter than summer, antique forests experience precipitation throughout the year. These high levels of humidity have led to the high biodiversity characteristic of these stands.

2.3 The Biological Environment

2.3.1 Major Vegetation Types

The Biogeoclimatic Ecosystem Classification (BEC) system, first developed by Dr. V.J. Krajina, is a broad system of vegetation classification in use throughout British Columbia (MacKinnon *et al.* 1992). The system is hierarchical, starting at the top with a number of broad biogeoclimatic zones that are then broken down into progressively more specific subzones, variants, and finally site series.

A zone represents a general geographic area that shares similar vegetation, soils, and climate (Jones and Annas 1978). Subzones and variants are characterized by the climax plants that would be likely to develop over a period of time on an average site within the area. These average or "zonal" plant communities reflect different climatic conditions within the BEC zones. Variants are then broken into site series, usually based on the nutrient and moisture characteristics of a given site (MacKinnon *et al.* 1992). In B.C. comprehensive mapping to sub-zone (and sometimes variant) is available for the whole province; site series information is usually collected by researchers in the field where necessary.

The varied topography in the Fraser Headwaters has led to a high diversity of BEC zones and subzones in the region. This is turn translates into a high variety of different habitat types that can support a wide range of different animal and plant species.

Four major BEC zones are found within the study area (Figure 10, Figure 11 and Table 1) (B.C. Ministry of Forests 1996; Meidinger *et al.* 1988). The Sub-Boreal Spruce (SBS) and Interior Cedar - Hemlock (ICH) zones are located at lower elevations; these are the most productive ecosystem types and make up 11% and 18% of the total study area respectively. The Engelmann Spruce - Subalpine Fir (ESSF) zone occupies 39% of the area and occurs at mid and upper elevations. Forests found at these higher altitudes tend to be less diverse and productive. Finally, the Alpine Tundra (AT) lies beyond treeline at the highest elevations, comprising 32% of the total area.

Each of the four BEC zones is composed of a number of subzones. In general, subzones within each zone follow a longitudinal climate gradient within the study area. The northern end of the study area is considerably wetter and cooler than the southern end, which is drier and somewhat warmer. These climatic differences affect both the productivity of ecosystems and the disturbance regimes that occur within them, and, therefore, the plant communities found in an area.

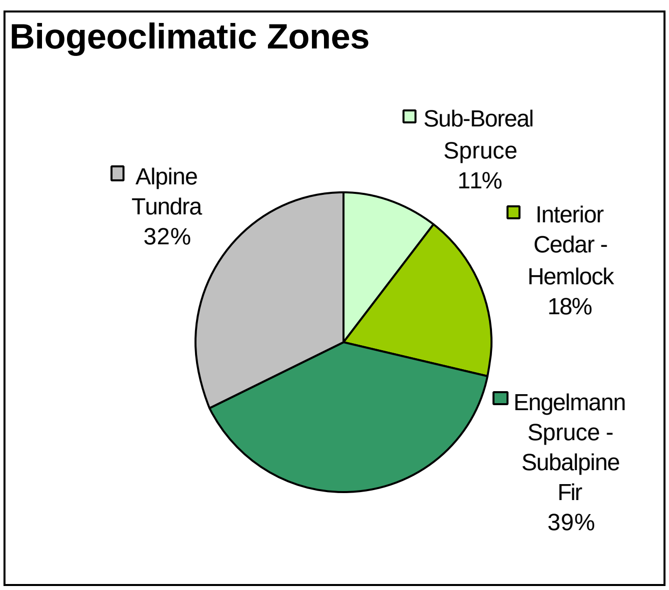

Figure 10: Biogeoclimatic zones found within the Fraser Headwaters studv area.

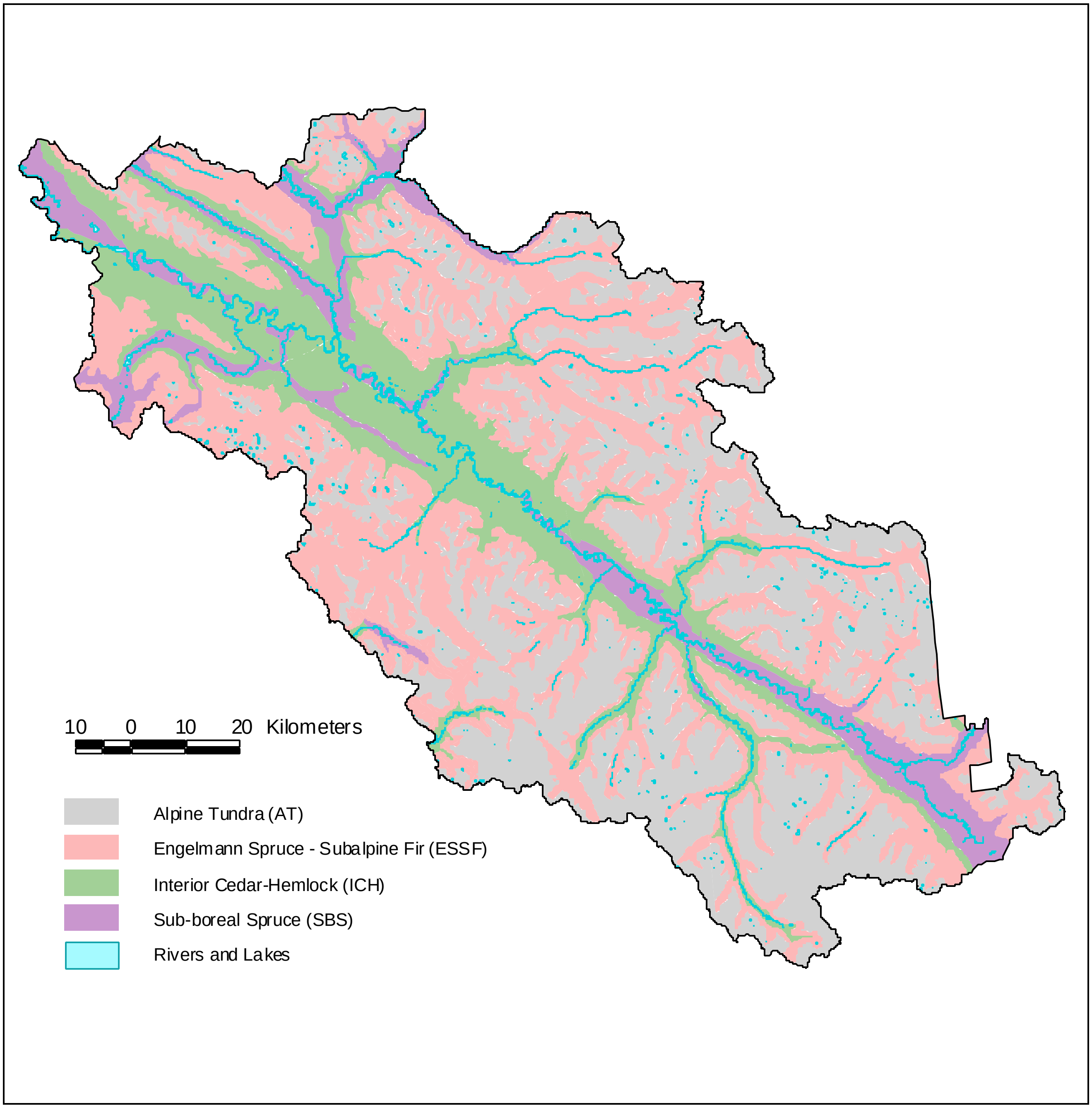

Figure 11: Biogeoclimatic Ecosystem Classification (BEC) zones within the Fraser Headwaters study area.

The influence of the cold climate and rugged topography is evident throughout the Fraser Headwaters. One-third of the study area lies beyond tree-line, and another third is composed of high elevation climate-limited subalpine forests. As explained previously, cold air from these high alpine areas funnels through the narrow side valleys into the Rocky Mountain Trench. As such, even low-elevation forests exhibit ecological sensitivity due to these cold air flows. The Sub-Boreal Spruce zone, for example, tends to occur in pockets of cold-air drainage below the ICH. Moreover, the biogeoclimatic zones, as shown in Table 1, are composed primarily of “cool” and “cold” subzone types. Vegetation growing under these conditions is subject to a number of limitations, including a short growing season; heavy snow-packs, especially at higher elevations; and nutrient-limited soils, due in part to slower rates of decomposition of organic matter.

The following sections include more detailed descriptions of each of the BEC zones and subzones found within the Fraser Headwaters. The BEC system reflects the variance in habitat types found within the region, as well as the conditions to which the flora and fauna are adapted. The challenge of ecosystem-based planning is to ensure both adequate representation and distribution of all BEC types across the landscape, as well as protection for those types that exhibit high ecological risk due to human activities.

Table 1: Biogeoclimatic Zones in the Fraser Headwaters Study Area

Biogeoclimatic Ecosystem Classification		
Zone and Subzone	**Area (ha)**	**Area (%)**
Alpine Tundra (AT)	415705	32.3
Engelmann Spruce - Subalpine Fir (ESSF)		
***moist mild* (mm)**	262861	20.4
***wet cold* (wc)**	12740	1.0
***wet cool* (wk)**	228947	17.8
Interior Cedar-Hemlock (ICH)		
***moist mild* (mm)**	55281	4.3
***wet cool* (wk)**	99268	7.7
***very wet cool* (vk)**	75828	5.9
Sub-Boreal Spruce (SBS)		
***dry hot* (dh)**	53575	4.2
***wet cool* (wk)**	2299	0.2
very wet cool (vk)	81484	6.3
TOTAL	1287988	100.0

Sub-Boreal Spruce (SBS)

Figure 12: The Sub-Boreal Spruce zone occurs at the lowest elevations, usually in pockets of cold air drainage. Visible here is a lodgepole pine forest within the SBS. Although relatively productive, forests in the SBS are the least abundant within the Fraser Headwaters. Moreover, because of their location at lower elevations, they have already been heavily impacted by human activities.

The Sub-Boreal Spruce (SBS) zone occurs at the lowest elevations within the study area, usually below the Interior Cedar – Hemlock in valley bottoms that receive cold air drainage (Meidinger *et al.* 1988) (Figure 11). Two main subzones are present in the study area. The SBSdh (dry hot) occurs in the south and makes up 4.2% of the study area, while the SBSvk (very wet cool) is found in the north and occupies 6.3% of the landscape. Very small amounts (0.2%) of SBSwk (wet cool) are located in the Betty Wendle Creek drainage (Table 1).

The dominant tree species in the SBS are hybrid white spruce (*Picea glauca* x *engelmannii*), subalpine fir (*Abies lasiocarpa*), Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*). Spruce and subalpine fir are especially abundant in the SBSvk in the north. The SBSdh, in the south, is a much drier and warmer subzone. Fire therefore occurs more frequently and forests are dominated by earlier successional species, such as Douglas-fir and lodgepole pine.

The SBS is the least common BEC zone in the Fraser Headwaters, occupying only 11% of the study area. As such, it is particularly important to ensure adequate representation of SBS subzones in the Protected Areas Network.

Interior Cedar - Hemlock (ICH)

The Interior Cedar - Hemlock zone contains the most productive forest stands within the study area. The ICH is located at lower to mid-slope elevations, usually above the SBS and below the ESSF (Figure 11). Three ICH subzones are present within the study area. Increasingly wetter and colder from south to north, they are: ICHmm (moist mild), ICHwk (wet cool), ICHvk (very wet cool).

As the name of the zone implies, forests within the ICH are dominated by western redcedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*). Smaller amounts of hybrid spruce and subalpine fir are also often present. Cottonwood (*Populus balsamifera ssp. trichocarpa*) is common on the floodplains surrounding the Fraser River. Younger stands are dominated by Douglas-fir, lodgepole pine, and trembling aspen (*Populus tremuloides*) (Meidinger *et al.* 1988).

Figure 13: The Interior Cedar - Hemlock forests are the most productive ecosystem type within the Fraser Headwaters. The oldest forests within this BEC zone, termed antique forests, are of global significance as storehouses of biological diversity. The unusually humid conditions in these forests have allowed the development of a rich assemblage of lichen species. Large numbers of fallen trees harbour high levels of micro-organisms, insects, and other species not commonly found in younger forests. Because of this rich concentration of diversity, antique forests act as centers of dispersion of biodiversity for the rest of the landscape.

The ICHmm, occupying 4.3% in the southern end of the study area, is the warmest and driest of the subzones. It has a large component of younger forest stands, mostly resulting from frequent fire events. This history of high fire frequency is due in part to the warmer and drier nature of the subzone, but is also a result of the large numbers of forest fires associated with settlement and railroad construction throughout the area in the early twentieth century (Wheeler 1979).

The ICHwk and ICHvk, which occupy 7.7% and 5.9% of the study area respectively, are dominated by much older forests. The wet cool climate associated with these subzones has resulted in rainforest conditions similar to those found in coastal British Columbia. Many of the stands are extremely productive, with large old trees, complex structure, and high quality habitat for many animal and plant species.

In the most humid spots, sheltered from the effects of fire and other disturbance agents, extremely old forest stands have developed. Termed “antique forests” by lichenologist Trevor Goward, these unique ecosystems show no signs of disturbance for many hundreds and perhaps thousands of years (Goward 1995). Antique forests function as a repository of biological diversity, a source of species that can recolonize neighbouring ecosystems following disturbance. Their value, moreover, transcends the local context. This particular combination of humidity and continentality (i.e. interior rainforest) may not be found anywhere else on the planet (Arsenault and Goward 2000). As such, it is even more important that we ensure the remnant patches of antique forest are fully protected, and that degraded antique ecosystems are restored where possible. Further description of antique forests can be found in Section 4.3.

Engelmann Spruce - Subalpine Fir (ESSF)

The Engelmann Spruce - Subalpine Fir (ESSF) zone is located in a band between the lower elevation forests (SBS and ICH) and treeline (Figure 11). Three ESSF subzones are present in the study area. From south to north, they are: ESSFmm (moist mild), ESSFwc (wet cold), and ESSFwk (wet cool). Both the ESSFmm and ESSFwk are well represented within the landscape, occupying 20.4% and 17.8% of the total study area respectively (Table 1). The ESSFwc is much less widespread and occurs in only 1.0% of the study area in the Hungary Creek region.

Subalpine fir and Engelmann spruce (*Picea engelmannii*) are the dominant species throughout the ESSF, with lodgepole pine occurring at lower elevations on drier sites.

Figure 14: Subalpine forests have a characteristically low canopy cover and clumped tree distribution. Snowpack is heavy in these forests, especially at higher elevations. Regeneration tends to occur in the snow-shade of other trees, resulting in the open canopy and clumped tree distribution visible in this photograph. Clearcutting eliminates the trees that provide these snowshades, making tree regeneration difficult, which can result in snow fields instead of forests.

Forest stands within the ESSF are multi-aged, developing and diversifying over hundreds of years as individual or small groups of trees die and are replaced by others. They differ from lower elevation forests in a number of important ways: colder average temperatures, shorter growing season, heavier snow-pack, lower nutrient availability, and overall slower growth rate of trees. Steep slopes and rocky outcroppings are common.

Much of the subalpine forest is old growth, and despite harsh climate and low nutrient availability, many of these stands have reasonably high timber volumes. Surveys of several subalpine stands in the Fraser Headwaters showed volumes ranging from 226 m^3/ha in the upper Forgetmenot Creek watershed to 458 m^3/ha in the upper Milk River watershed. To put this in perspective, timber volumes in lower elevation forests ranged from 376 m^3/ha in the lower Morkill River watershed to 992 m^3/ha in the lower Kiwa Creek watershed. The Timber Supply Review for the Robson Valley district (the document that determines the total timber availability on the landscape) suggests that for ground-based logging to be viable, stands must contain at least 140 m^3/ha (B.C. Ministry of Forests 2000). While not everybody agrees with an economic rationale based on minimum timber volumes alone to determine timber availability, from the Ministry’s perspective, subalpine stands are an important part of the timber landbase. This is increasingly the case as lower elevation old growth forests are eliminated through clearcut logging.

While some current timber volumes in subalpine forests may look attractive, the crucial issue is maintaining full ecosystem functioning in these sensitive ecosystems. There is significant uncertainty as to how well these forests will regenerate and grow following clearcutting. We have not been logging these forests long enough to have much evidence of how high elevation forests respond to clearcutting. The evidence currently available strongly suggests that these forests should not be clearcut (Vogt *et al.* 1989). Given the severe nutrient deficiencies of the soil and the harsh unforgiving climate, which limit tree growth; heavy winter snowpack, which hinders tree regeneration; and steep slopes, which are prone to soil erosion; among other characteristics, a precautionary approach to management seems only sensible.

Alpine Tundra (AT)

The Alpine Tundra makes up 32% of the Fraser Headwaters study area. It includes the treeless meadows, rocky slopes and ridges, snowfields and icefields beyond treeline at high elevations (Jones and Annas 1978) (Figure 11). Harsh climates prevail at these elevations, creating conditions ecologically similar to those found in the arctic. The number of frost-free days is small, snow accumulations are high, soils are thin, and wind is often a prevailing force.

Figure 15: The Alpine Tundra occupies one-third of the Fraser Headwaters study area. Cold air is funneled from these high elevation areas through the narrow valleys leading to the Rocky Mountain Trench. Characteristics of lower elevation ecosystems along the way show the effects of this cold air, including regeneration difficulties and often slower tree growth.

Trees are mostly unable to grow at these elevations, although stunted twisted specimens, called “krummholz,” sometimes cling in sheltered spots. Many plants have developed adaptations to counter the wind and cold. Despite its barren appearance, the alpine provides important habitat for many species of plants and animals. The threatened mountain caribou, for example, spend much of the summer high in the alpine. And any hiker who has ventured into the alpine in late July is familiar with the legendary beauty of an alpine meadow in flower.

Because of the harsh climatic conditions at high elevations, the alpine tundra is extremely sensitive to disturbance. It can take from decades to centuries for a disturbed site to return to its previous condition (B.C. Ministry of Forests 1988). Although the alpine tundra is not at risk due to resource extraction activities such as logging, other human activities such as recreational skiing, snowmobiling, and ATV use can damage these sensitive ecosystems.

2.3.2 Disturbance Regimes

Forests are inherently dynamic ecosystems. They are continually undergoing change, usually gradually, occasionally dramatically. The processes that initiate change come in many shapes and sizes: fire, wind and ice storms, spring floods, beaver dams, insects, root decay, and others. Some forest types are adapted to periodic severe disturbance. For example, lodgepole pine trees have special cones sealed with a resin that melts open in the heat of a fire, thus releasing seed en masse to trigger a new flush of regeneration. Many other forest types develop over long periods in the absence of large disturbance events. The cedar-hemlock forests within the Fraser Headwaters are an example of this. These forests are shaped by a steady progression of smaller disturbances such as the death of individual trees or small groups of trees due to wind, fungi, insect and animal damage.

All disturbance processes—large and small-scale—are an important part of a healthy functioning forest ecosystem. However, the most common disturbance in any forest is the death of individual trees or small groups of trees.

In the following sections, we describe two important disturbance processes: fire and insects. Fire is traditionally viewed as the major disturbance type in forest. ecosystems. While it is true that fire can play a large role in some forest types, most forest types are affected to an equal or greater degree by a series of less obvious disturbance events, such as insects. The importance of such events is often overlooked. The following sections describe how each process has shaped forest ecosystems historically, and how human management practices might be affecting these age-old processes.

2.3.2.1 Fire

Fire is frequently viewed as the major large-scale disturbance process on the landscape. Large fires are a dramatic event, a force of nature that is simultaneously fascinating and frightening. Perhaps because of these characteristics, people generally emphasize fire as the major disturbance agent, to the exclusion of other less dramatic but more common disturbance types. This is especially the case in many of the forests in the Fraser Headwaters, which are shaped primarily by a suite of continuous small disturbance events.

Fire is often portrayed as a catastrophic event that sweeps through a forest, killing the majority of trees. In reality, fire is a patchy visitor in forest ecosystems. Although fires may be intense, and burn the majority of trees in small areas, at a landscape level many fire “skips” remain untouched. The wettest and most sheltered of forest ecosystems may repeatedly escape fire in this way. At a stand level, seldom are all trees killed, leaving behind a legacy of both living and dead trees for the new ecological communities that will develop. These legacies provide the structure critical for wildlife habitat, and harbour the fungi, insects, and other micro-organisms critical to the continued healthy functioning of the forest. In contrast to the homogenizing effect often attributed to fire, fire in fact contributes to diversity. The result is a juxtaposition of older and younger forests on the landscape, creating the irregular patterns of forest structure that are so important for habitat diversity.

While fire is patchy wherever it occurs, some forest types do experience fire more frequently than others. In an attempt to characterize this, the Ministry of Forests has developed a system of Natural Disturbance Types (NDT), ranging from NDT1 (ecosystems with rare stand-initiating events) to NDT4 (ecosystems with frequent stand-maintaining fires) (B.C. Ministry of Environment, Lands and Parks 1995). Each BEC zone is assigned to one of these categories and timber prescriptions are to be designed with the characteristics of natural disturbances in mind.

The NDT system is valuable in highlighting the relative role that fire plays in different forest types. Before considering the NDT classifications of the forest types within the Fraser Headwaters, however, there are two problems with the way the NDT system has been developed and implemented that need to be raised.

First, the classification system emphasizes the role of fire in ecosystem dynamics, downplaying the complex structure and composition that results from the myriad other disturbance events that also play important roles in forest functioning. Secondly, the fire return interval, the mean period between successive fires, is often seriously underestimated. This is a cause for concern as timber managers are increasingly using historical fire regimes as a rationale for current timber management practices. While there are many problems with this approach in general (including the fundamental issue that fire and clearcutting produce completely different ecological results), of particular importance in this context is the difficulty in collecting reliable data on historical fire regimes. There is a certain tendency to overestimate the amount of fire on the landscape, and more historical fire is translated by some into support for higher amounts of logging. These issues are treated in greater depth below.

Table 2 shows how the BEC zones within the study area fit within the NDT classification system. The estimates of fire return intervals provided below should be considered minimums (that is, the period between successive fires was likely longer, and fire frequency therefore lower).

The southern part of the study area is generally warmer and drier than the northern part; as such, fire has played a more important role. The Sub-Boreal Spruce dry hot (SBSdh) variant, located at lower elevations south of McBride, is the only biogeoclimatic zone in the study area that has a history of relatively frequent high intensity fire (NDT3). The fire return interval within the SBSdh is at least 125 years (B.C. Ministry of Environment, Lands and Parks 1995), which means that, on average, a given patch of land will experience fire once every 125 years. This is an average number; certain particularly warm and dry areas will burn more frequently while other sheltered or more humid regions may burn very infrequently.

The Interior Cedar - Hemlock moist mild (ICHmm) and Engelmann Spruce - Subalpine Fir moist mild (ESSFmm) variants, also located in the southern part of the study area, are classified as ecosystems with infrequent stand-initiating events (NDT2). Average fire return intervals are at least 200 years (B.C. Ministry of Environment, Lands and Parks 1995), and much of the forest structure develops in response to a continuous series of smaller disturbance events. At lower elevations in the ICHmm, there is a higher proportion of young stands than would be expected given its ecological characteristics; these are likely the result of a high number of fires associated with railroad construction and settlement at the turn of the century (Meidinger *et al.* 1988).

Table 2: Natural Disturbance Types in the Fraser Headwaters Study Area. This information is drawn from the Biodiversity Guidebook, part of the Forest Practices Code of British Columbia (B.C. Ministry of Environment, Lands and Parks 1995). New studies suggest that the fire return intervals listed below may be seriously underestimated. For example, recent research undertaken just north of the study area suggests that return intervals range from 1200-6250 years for the SBSvk and 541-1429 years for the ESSFwk2/wc3 (Vasbinder 2001). As such, the fire return intervals listed below should be considered minimums.

Natural Disturbance Types			
BEC zone, subzone & variant	**Natural Disturbance Type**	**Characteristics**	**Fire return interval (years)**
SBSdh	3	Frequent stand initiating events. Wildfires range from small to very large in size. Landscape dominated by regenerating forests with mature forest remnants in those areas missed by fire. Insect outbreaks and root diseases are also fairly frequent.	125
SBSvk ICHmm ESSFmm1	2	Infrequent stand initiating events. Wildfires of moderate size. Landscape dominated by extensive areas of mature forest interspersed with patches of younger forest.	200
ICHwk3 ICHvk2 ESSFwc2 ESSFwc3 ESSFwk	1	Rare stand initiating events. Regeneration occurs mostly in small gaps created by death of individual trees. Fire, wind, and landslide disturbances occur rarely and are small in size. Landscape dominated by old growth forests.	250 (ICH) – 350 (ESSF)

In the northern part of the study area, at lower elevations, the Sub-Boreal Spruce very wet cool (SBSvk), is also listed as an ecosystem with rare stand-initiating events (NDT2) (B.C. Ministry of Environment, Lands and Parks 1995). However, recent research suggests that fire return intervals may be considerably higher than previously thought, ranging from 1200-6250 years (Vasbinder 2001). As such, the SBSvk would more appropriately be classified as experiencing high intensity fire only rarely (NDT1).

The other BEC zones in the northern part of the study area, ICHwk (wet cool), ICHvk (very wet cool), ESSFwc (wet cool), and ESSFvk (very wet cool), are classified as ecosystems that experience high intensity fire only rarely (NDT1) (B.C. Ministry of Environment, Lands and Parks 1995). Fire plays a much less important role in these forests, with many of the most sheltered sites having escaped fire for upwards of a thousand years (Goward 1995). Stand dynamics are driven by the deaths of individual or small groups of trees (B.C. Ministry of Forests 1996). A large percentage of these forests are old growth. Fire return intervals are at least 250 to 350 years, and recent research suggests that fire may be much less frequent than this, with average return intervals from 541-1429 years (Vasbinder 2001).

Both the Ministry of Forests and the timber industry maintain that clearcut logging practices mimic the role of natural disturbance (such as fire or insect damage) on the landscape. The premise of the argument is that natural disturbance be suppressed through firefighting, insect control, and so on, and that logging be carried out in its place. However, equating clearcut logging with natural disturbance has major flaws.

To begin with, natural disturbances may kill trees, but they do not remove the trees from the site. Dead standing trees and decaying fallen trees are critical structures for maintaining fish and wildlife habitat, soil fertility, and storage and filtration of water (Hammond 1991).Secondly, natural disturbances rarely kill all the trees. They tend to skip through the forest, leaving behind a patchy mosaic of dead and living trees. Areas of higher moisture or in sheltered topographic positions may burn only very rarely. Finally, major natural disturbances are typically infrequent and occur much more rarely than proposed logging rotations.

Table 2 suggests that the average fire return interval for most vegetation types within the study area ranges from 200 to 350 years. Moreover, recent studies suggest that these fire return intervals may be grossly underestimated, and that fire may in fact occur much less frequently (Vasbinder 2001). Under the current timber management regime, on the other hand, once old growth stands within the timber landbase have been logged, average harvest age will be 150 years. This is significantly shorter than even the shortest fire return intervals in much of the study area. While the NDT system is useful in highlighting ecological differences between forest types, it should not be used as a justification for conventional timber management practices.

2.3.2.2 Insects

Insects are a natural part of the forest ecosystem and exist at endemic levels (in low numbers) all the time. They are a very important disturbance agent in many types of forest, where they kill small numbers of trees, creating gaps that understory species can grow to fill. This process is important, for example, in facilitating the succession from subalpine fir to Engelmann spruce in high elevation forest stands in the Fraser Headwaters.

Occasionally, insect populations will undergo a transition from endemic levels to epidemic (outbreak) levels. The exact causes of this transition are not well known, but epidemics may occur when forest stands are weakened by disease or drought, or when weather conditions are particularly favourable towards the insects (Safranyik *et al.* 1999). The transition from endemic to epidemic populations in the mountain pine beetle, for example, is dependent on a complex mix of variables including stand conditions and climate, mixed with an element of chance.

Within the Fraser Headwaters study area, several insect species play major roles in shaping forest ecosystems: the hemlock looper, mountain pine beetle, balsam bark beetle, and spruce bark beetle. In recent years, hemlock looper epidemics have occurred in the low-elevation forests around Crescent Spur, and mountain pine beetle outbreaks have occurred in the upper-elevation forests in the Forgetmenot Creek, Holmes River, and other drainage basins. As is expected with disturbance events of this magnitude, significant numbers of trees in these areas have been killed.

The Ministry of Forests has responded to these events by encouraging timber companies to salvage log these areas. The philosophy behind this practice is to curb the spread of the insect outbreak, and thus minimize the “damage” to valuable timber resources. Such a philosophy only makes sense if we view insects as a “pest” or an unnatural disturbance that must be stopped. In fact, as outlined above, insects are a natural part of the forests and play a critical role in shaping the structure and functioning of these ecosystems. Insects are only a “pest” from the timber manager’s perspective, because they kill the “product” that he or she wants to market.

Ironically, studies are beginning to suggest that current industrial timber practices are actually contributing to an increase in the severity and extent of insect outbreaks. In eastern Canada, a number of anthropomorphic factors, including fire suppression and clearcutting, have been cited as primary contributors to an increase in severity and area affected by eastern spruce budworm, as well as an increase in the frequency of outbreaks (Lewis and Lindgren 2000). Western spruce budworm outbreaks in Oregon have become more frequent and more severe in response to a combination of fire suppression and selective harvesting of non-susceptible species (Lewis and Lindgren 2000).

In the Fraser Headwaters, it has been postulated that large clearcuts in the vicinity of the current hemlock looper infestation near Crescent Spur may have helped to trigger the outbreak. These clearcuts may be sufficiently large to cause a change in local microclimate in stands adjacent to clearcuts. Drying winds from clearcuts extend into adjacent uncut stands, as does sunlight, which contributes further to drying influences. These conditions likely increase water stress in adjacent stands, thereby reducing the resistance of individual trees to insect attack. Thus the very management practices that are intended to curb insect “pests” in the short term may contribute to more severe outbreaks in the long-term.

Fortunately, there are alternatives to the use of extensive salvage logging to limit insect outbreaks. For example, the most basic step in mountain pine beetle management is to break up large, continuous areas of beetle habitat into smaller management areas. This is done to quarantine beetle infestations and prevent or delay their spread over a large area, and to reduce the area susceptible to beetle attack at any one time. A mosaic pattern can be created through thinned stands, selectively logged blocks, and residual forests. Naturally occurring young stands, water, nonforest areas, old clearcuts, and old infestations can also be use in the mosaic to help geographically divide uniform pine types. A cutting pattern of this nature can have positive benefits of providing good road access to all the residual blocks to facilitate silviculture and monitoring and/or control of mountain pine beetle activity[5].

In healthy, fully functioning forests, a careful balance exists between trees, insects, and the environment. Our attitudes towards insects need to change; far from being “pests” that must be controlled, insects play a critical ecological role in the natural successional patterns of forest ecosystems.

2.4 Wildlife

The diverse topography and vegetation communities found within the Fraser Headwaters create highly diverse habitat types that provide fore diverse wildlife species adapted to these habitats.

More than 50 mammal species occur in the Fraser Headwaters. Large ungulate species include moose, white-tailed deer, mule deer, mountain goat, and mountain caribou. Black bears are common, and a smaller number of grizzly bears and wolverine also live in the area. Common small mammals include beaver, coyote, fox, mink, weasel, and red squirrels. Over two hundred species of birds have been recorded in the region.

The Fraser River and tributary watercourses support a variety of anadramous and freshwaters fish populations including salmon; rainbow, cutthroat, and bull trout; and mountain whitefish. The Fraser is the longest remaining salmon spawning river in British Columbia. Much of the Fraser River and most lower reaches of tributary streams have been designated as class “A” fish habitat. This designation is especially significant for salmon stocks, which face habitat degradation throughout their range.

A number of species within the Fraser Headwaters have been identified as endangered or threatened in the Robson Valley forest district according to the Conservation Data Centre (B.C. Conservation Data Centre 2001). Two species are red-listed[6]: the white sturgeon (Fraser River population) and the mountain caribou. The mountain caribou is of special concern due to its sensitivity to logging activities. Caribou ecology and behaviour is discussed in greater detail in the following section. Eleven species are blue-listed, including the grizzly bear, bighorn sheep, wolverine, fisher, American bittern and bull trout.

The number and distribution of many terrestrial wildlife species are limited by steep valley walls, heavy winter snow accumulations, and loss of habitat due to settlement, agricultural development, and logging activities. Restoration and maintenance of both habitat and movement corridors will be critical to the long-term persistence of these species within the study area. Protection and maintenance of riparian ecosystems, instream habitat, side-

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[5] Further information on the biology and management of mountain pine beetle can be found in *Mountain Pine Beetle Literature Review* by T. Bradley, Silva Ecosystem Consultants, Ltd. The document can be obtained from www.silvafor.org.

[6] Red-listed species are considered to be extinct, endangered, or threatened in B.C.. Endangered means facing imminent extinction; threatened means the species is likely to become endangered in current conditions persists. Blue-listed species are considered to be at risk and therefore sensitive to human disturbance.

channels, and natural streamflows is necessary to sustain resident fish populations within the Fraser Headwaters.

Figure 16: Mountain caribou are officially listed as a threatened species within the Fraser Headwaters. Heavily dependent on arboreal lichens found in old growth forests, their populations are dwindling in response to logging of old growth forests, increased hunting mortality due to increased access on logging roads, and increased predation by wolves.

The mountain caribou, *Rangifer tarandus caribou*, is of special concern within the Fraser Headwaters because of its sensitivity to logging activities. The southern mountain population of the species, which occurs in the southern parts of British Columbia and Alberta, is listed as "threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Threatened is defined by COSEWIC as "likely to become endangered if limiting factors are not reversed" (Environment Canada 2001). "Endangered," in turn, is defined as "a species facing imminent extirpation or extinction."

Mountain caribou range over large areas. Like many other caribou, they feed primarily on lichens. Unlike other caribou, however, they rely primarily on arboreal lichens as opposed to terrestrial lichens (Stevenson 1994). During early winter, caribou frequently browse, especially on low evergreen shrubs. As snowpacks increase, they depend increasingly on arboreal lichens. Such lichens are most abundant in old growth forests, and are rarely abundant enough to be a dependable food source in forest areas less than 100 years old (Stevenson 1994). By late winter, caribou typically feed in high elevation open-canopied stands, where the settled snowpack gives them the added height necessary to reach lichens on the lower branches of the trees (Stevenson *et al.* 1994).

Within the Fraser Headwaters, caribou most often use old growth forests within the Interior Cedar - Hemlock (ICH) and Engelmann Spruce - Subalpine Fir (ESSF) zones. These forests are also highly valued by the timber industry, and it is no coincidence that logging activities are linked to declining populations of caribou. Stevenson (1994) lists several factors in particular that render the caribou vulnerable to the effects of human activity:

- Logging decreases the amount of old growth habitat available for caribou. In some places, forest areas do not become suitable winter habitat until they are beyond the average rotation age. Clearcuts are of low value to caribou, and dense young stands may present barriers to movement.
- Logging tends to benefit moose at the expense of caribou, and moose are often accompanied by wolves. Caribou avoid predation by spreading out over large areas to distance themselves from predators; where there is little

spatial segregation between moose, caribou, and wolves, predation of caribou increases.

- Logging roads increase human activity in general and hunting pressure in particular. Caribou are more sensitive to human disturbance than other species and are especially vulnerable to over-hunting due to their low reproductive rates.

Because of their high sensitivity to human activity, and especially logging, the Ministry of Environment in British Columbia does not permit timber harvesting or road construction within high quality caribou habitat in the Prince George forest district[7]. Disturbances due to recreational activities such as snowmobiling, ATV's, and heli-skiing are minimized and regulated (B.C. Ministry of Environment, Lands and Parks 2000). Trials are now underway to determine whether low levels of partial cutting may be compatible with caribou habitat.

At the landscape level, ensuring the persistence of caribou populations within the Fraser Headwaters will require that

- adequate amounts of suitable old growth habitat be maintained;
- habitat fragmentation be minimized;
- human access be minimized, and where access is present, that it be carefully managed; and
- habitat separation from predators be maintained.

Consistent with these goals, high quality caribou habitat is included as one of the criteria in the analysis of ecological risk for this project (see Sections 3.3.3 and 4.2). Moreover, the design of the Protected Areas Network takes into account the needs of caribou by ensuring that connecting corridors allow travel between adjoining habitat areas, and that fragmentation on the landscape is limited.

2.5 Human History

Historically, human activity within the Fraser Headwaters study area has been focused within the Rocky Mountain Trench. With its forgiving climate, productive soils and forests, and gentle terrain, the trench has provided ideal conditions for both travel and settlement. The Lheidli T'enneh and Secwepemc peoples have lived and moved through the area for thousands of years. Railway construction, mineral extraction, and clearing for settlement and agriculture by European settlers commenced in earnest in the early 20th century. Recent decades have seen an escalation in the rate of industrial logging, including for the first time, significant incursions into side valleys.

Perhaps the greatest challenge to maintaining ecological integrity in the Fraser Headwaters will be the restoration of the degraded and fragmented ecosystems that line the bottom of

[7] High quality caribou habitat, as mapped by the Ministry of Environment for the Prince George Forest Region, are primarily upper elevation alpine, parkland, and subalpine forest areas in the ESSF zone. These areas provide calving habitat in the summer and arboreal lichens for forage throughout the winter. Some low elevation forest areas in the ICH that receive significant use in early winter are also identified as high quality habitat (B.C. Ministry of Environment, Lands and Parks 2000)

the trench. Within higher elevation side valleys, limitations need to be developed now regarding the types and amounts of human activity, particularly logging, that can be sustained before current use patterns result in fragmented and damaged ecosystem there, too.

2.5.1 Indigenous Peoples

The Fraser Headwaters study area falls within the traditional territory of two First Nations: the Secwepemc and Lheidli T'enneh. The Secwepemc are a Shuswap people who have had a presence in the area for thousands of years. Tete Jaune was originally a Shuswap settlement; the Indigenous People were relocated to Kamloops in the early 1900's so that the European settlers could build homes on the site (Wheeler 1979). The Canim Lake First Nation primarily used the Raush River watershed. The Williams Lake First Nation's traditional territory includes the headwaters of Castle Creek. The Lheidli T'enneh are a Carrier group that broke with the Carrier Sekani Tribal Council to form their own nation. Their traditional territory lies primarily within the upper Goat River watershed and Bowron Lakes Provincial Park.

First Nations' use of the Fraser Headwaters goes back thousands of years. They hunted and harvested a wide variety of animals and plants for domestic use and for trade. Local trees were cut or debarked for shelter, cooking and hunting equipment, fish traps, canoes, and fire. Plants were harvested for food and medicine. Deer, caribou, moose, mountain sheep, mountain goats, ducks, and geese were hunted for food; fox, bear, wolf, cougar, beaver, ermine, martin, otter, and marmot were snared or hunted for clothing, food, and trade materials. Controlled ground fires were likely used to enhance production of valuable food plants, and to maintain or restore animal habitat.

For a clear, complete understanding of the past and ongoing use of the study area by Indigenous people, we recommend that the reader contact the Secwepemc and Lheidli T'enneh First Nations.

2.5.2 European Settlers

A handful of early European travelers reached Tete Jaune Cache via the Yellowhead Pass during the 1800s. Among them were George McDougal, in 1827; the Overlanders, in the spring of 1862; and Milton and Cheadle in 1863 (Valemount Historic Society 1984, Bown 2001). Some of these travellers continued their journeys by boat down the Fraser River, others via the North Thompson River or overland.

European settlement commenced in earnest in the early 1900's, with the arrival of the transcontinental railroad. Grand Trunk Pacific completed the line between Jasper and Prince George in 1914 (Wheeler 1979). Railroad stops were located approximately every 7 miles and small settlements developed around them. To this day, the pattern of settlement along the railroad is visible on any map of the area.

Clearing for agriculture followed shortly after European settlement. An area six miles wide across the valley was set aside for settlement when railroad construction first began (Bachrach 2000). The establishment of a residence and clearing of five acres was sufficient to lay claim to a quarter section of land (Wheeler 1979). The first road between Dunster and McBride, in the southern part of the study area, was built in about 1925; winter roads were the only option in the northern part of the study area (north of Lamming Mills) until the 1960's (Wheeler 1979). It wasn't until 1970 that Highway 16 between Tete Jaune and Prince George was finally completed (Wheeler 1970).

The arrival of the railroad and European settlers in the valley was accompanied by profound ecological change. Much fire occurred as a direct result of both construction and settlement. Fires were set to clear land and to burn the slash remnants from construction (Wheeler 1979). Often they would burn out of control and were simply left to burn themselves out. Much of the current forest, especially in the Rocky Mountain Trench in the southern part of the study area, dates to this era.

Despite the amount of fire, logging was an important means of livelihood. A number of mills were established; cedar posts were shipped to Alberta, and lodgepole pine was cut for railroad ties (Wheeler 1979). Later, during WWII, birch peeler logs were sent to Vancouver for fighter planes (Wheeler 1979). Logging rates have accelerated over the past thirty years as mechanization has made previously untenable logging economically viable. As timber within the main valley becomes increasingly scarce, roads into previously unroaded side valleys have been and continue to be built, and timber in these side valleys is being logged. A recent study investigating forest fragmentation in the Robson valley suggests that overall forest cover declined by 18% between 1946 and 1999 (Bachrach 2000). The average size of continuous forest areas in the landscape of this study declined almost ten-fold, which suggests that fragmentation of the landscape has become a serious problem.

2.6 Summary

The Fraser Headwaters is a beautiful but harsh landscape. High rugged mountains, steep terrain, cold climate, and heavy snowpacks combine to provide both a rich diversity of ecosystems but also significant ecological sensitivity. The main ecological limits within the Fraser Headwaters include:

- steep, complex terrain. Soil stability on these slopes is largely dependent on tree and associated vegetation cover. Removing that cover will eliminate the root structure, protective canopy, and evaporative processes that work to stabilize these slopes.
- severe climate, including cold temperatures, short growing season and heavy snowpacks. These conditions are especially significant at high elevations and in side valleys. Cold air drainage originating in the alpine tundra and associated glaciers and snow fields flows through side valleys and into Rocky Mountain Trench, subjecting these areas to cold mountain air. Results of cold climates and high snowpack include lower rates of soil nutrient cycling, slower forest growth, and slow forest regeneration in response to disturbance.
- high elevation forests. The study area is dominated by high elevation ecosystems: the Alpine Tundra (32%) and the ESSF (39%). High elevation forests above 1200m are extremely sensitive to disturbance due to low

> biological recovery rates, the result of cold climates, deep snowpacks, cold soils, and slow nutrient cycling. Much of the soil activity in these forests occurs in the upper 5cm of soil. This active layer is easily degraded by any kind of logging activity, and the cold conditions result in slow site recovery and regeneration.

For millennia, Indigenous use of the Fraser Headwaters was within the ecological limits of the ecosystems found in the area. Early European use was also largely sustainable. Current settlement patterns and human activities, however, especially large scale industrial logging, are not within the ecological limits of ecosystems. To maintain and protect fully functioning ecosystems, a thorough analysis of ecological limits and ecosystem-based planning that acknowledges these limits is necessary. The following chapter outlines the methods used to develop a landscape level ecosystem-based plan for the Fraser Headwaters. This plan, known as the *Fraser Headwaters Proposed Conservation Plan*, is the first step in developing a complete multi-scale ecosystem-based plan for the study area.

3. Methods

The *Fraser Headwaters Proposed Conservation Plan* was completed primarily through spatial (map-based) analysis of forest cover and terrestrial resource data. We relied heavily on existing digital data and used Geographic Information Systems (GIS) software to produce a series of maps culminating in the proposed Protected Areas Network. Fieldwork was conducted to familiarize ourselves with the study area and to guide the digital analysis. Consultation with the Fraser Headwaters Alliance, the local community group who initiated this project, was ongoing throughout the project.

The project included three main stages:

- acquisition and preparation of existing digital data
- field sampling to collect field data to guide the digital analysis
- analysis and interpretation of data, and creation of maps

This chapter includes a summary of the methods employed during each of these stages, including a detailed description of the procedures used to produce each map. A more thorough description of the results and significance of each map can be found in Chapter 4.

3.1 Acquisition of Data

The primary data sets that were used in the project are listed in Appendix I. In brief, we relied primarily on Ministry of Forests forest cover (1:20 000) and Ministry of Environment terrestrial resource information mapping (TRIM) (1:20 000) data. This was supplemented with data layers depicting biogeoclimatic ecosystem classification (BEC) (1:250 000), parks and protected areas boundaries (scale unknown), and mountain caribou and grizzly bear habitat (1:20 000 but scale varies). Paper and/or digital copies of forest development plans (varying scales) were obtained from each of the timber companies operating within the study area and digitized. Black and white aerial photographs (approximate scale 1:70 000) covering the study area were also obtained.

3.2 Field Sampling

The overall purpose of the fieldwork was to familiarise ourselves with the study area, and to collect primary data to guide the spatial analysis and design of the proposed Protected Areas Network.

3.2.1 Sampling Plan Development

Sample sites were chosen to assess composition, structure, and functioning at two scales: the landscape level and stand level.

- **Landscape level**: The overall objective was to sample the range of variability in stand species composition and age at the landscape level. A preliminary GIS analysis of landscape diversity was conducted using forest cover and terrestrial resource information mapping data (see Section 3.3.2). The product of this analysis, a landscape diversity map, was used for both assessing the range in ecosystem variability and highlighting rare ecosystem types. Additional maps showing biogeoclimatic ecosystem classification (BEC) subzones, old growth forests, and slope and aspect, were also produced to highlight the locations of ecologically important sites. Potential sampling sites were selected to reflect the range of variability both within and between BEC subzones (valley bottom to subalpine ecosystems), forest ecosystem types (antique, old growth, snow-dominated ecosystems), stand composition (leading tree species), and stand age. Once potential sampling sites were selected using these maps, more precise transect and plot locations were determined using aerial photographs.

- **Stand level**: A number of stand-level issues with landscape level significance were selected for examination in the field: impacts of clearcut logging on stand structure (particularly coarse woody debris); the practice of salvage logging; and the potential for ecologically responsible timber management. Potential sampling sites were identified using the maps produced with the GIS (as described above for landscape level), forest cover maps, and airphotos.

A total of 58 potential sampling sites were identified on the basis of the landscape and stand-level criteria mentioned above (see Appendix II). This pool of potential sites was then narrowed based on practical considerations such as access, sampling efficiency, and budget. Priority was given to easily accessible sites that met multiple sampling objectives. Sampling sites were distributed as evenly as possible (given the constraints of access) over the entire geographic region. The final field work itinerary included two alternate plans for each day to maintain some flexibility in response to local conditions.

3.2.2 Field Work

In total, we sampled 18 plots at 12 locations during a ten day period from October 1st to 10th, 2000. A summary of the field work conducted and final sampling locations are contained in Appendix III.

One to two sample plots were established at each sampling location. Plot radius varied from 5.64m to 20.00m depending on stem density and stand structure. On average, plots contained from 12 – 20 trees. At each plot, individual trees and snags were numbered, mapped, and measured (see below). Basic site information was gathered, as was data on all coarse woody debris (fallen dead trees in all states of decay). Photographs documenting field work were taken throughout.

Specific data collected at each plot included:

- **Site characteristics**: terrain uniformity, slope %, slope position, aspect, understory vegetation presence and abundance (by species), biogeoclimatic variant and site series, edatopic grid position, soil depth, soil texture, soil drainage, soil coarse fragments composition, soil depth to impermeable layer, and wildlife sign.
- **Silvicultural Assessment**: (for each tree and snag) height class, species, diameter at breast height, % live crown, crown width, overall health and vigor, pathological remarks (conks, scars, mistletoe, broken tops etc.). Within each plot,

a representative tree of each species in each height class was measured for height and cored to determine age.

- **Coarse Woody Debris**: (for each piece of CWD) species, decay class, average diameter within plot, length in plot, average total diameter, and total length.

Further description of field methods can be found in the *Silva Field Work Manual* (Silva Ecosystem Consultants 1999).

3.2.3 Data Analysis

Data were analysed using SILVASS II, software developed specifically for the analysis of ecological inventory and silvicultural data (Silva Ecosystem Consultants 2000). Stand volume by tree species and height class, coarse woody debris volume, and a number of descriptive statistics were calculated for each plot. The variables contained in the plot data provide the basis for understanding stand level composition, structure, and functions, and for extrapolating this data to the landscape level. Results are found in Appendix III.

3.3 Map Design

A series of 6 maps was designed for the Fraser Headwaters:

- *Map 1: The Fraser Headwaters*
- *Map 2: Landscape Diversity*
- *Map 3: Ecological Risk*
- *Map 4: Antique and Old Growth Forests*
- *Map 5: Human Disturbance*
- *Map 6: Proposed Protected Areas Network*

Map 1 is a base map and provides an orientation to the study area. Maps 2 through 5 are analytical maps and provide the data needed to design the Protected Areas Network. The final map, Map 6, is a synthesis map; it ties together the ecological data shown in the previous maps and presents the final results of the project.

Maps were created using mostly existing digital data (see Section 3.1). Geographic Information Systems (GIS) software was used for spatial analysis. Analysis was performed primarily using ArcInfo 7.1.2 (ESRI 1997); map layout and production were done using ArcView 3.1 (ESRI 1998). Water feature names, place names, and topographical names were taken from paper National Topographic System (NTS) maps.

Descriptive statistics included with the report were generated in ArcInfo and manipulated in Microsoft Excel. Due to the scale of the project, the size of the study area, the varying degrees of accuracy of the different data layers, and the use of vector GIS for analysis, the total areas cited in the report do not always agree. For example, the alpine tundra covers 32% of the study area based on the biogeoclimatic data layer but 37% of the study area based on the forest cover data. The biogeoclimatic data are less accurate, having been developed at a smaller scale, yet are the only source of BEC zones for the study area. Similar data inconsistencies occur in a few other tables in the report.

The following section outlines the basic objective for each map in the series as well as a technical description and rationale for how it was produced. The analytical maps (Maps 2-5) are discussed in detail in Section 4 of this report.

3.3.1 Map 1: The Fraser Headwaters

Objective

The Fraser Headwaters map is the first in the series of maps for this project. Its main purpose is to orient the viewer to the biophysical and geopolitical characteristics of the study area.

Technical Description and Rationale

A 3-dimensional Digital Elevation Model (DEM) in the form of a Triangulated Irregular Network (TIN) was constructed using elevation points from the Ministry of Environment TRIM1 data. Rivers, lakes, creeks, wetlands, glaciers, roads and railroads from TRIM1 were draped over the TIN. Where newer roads were not found in TRIM1, roads were taken from the Ministry of Forests forest cover database. Most of these occur in the Morkill River and Goat River watersheds.

3.3.2 Map 2: Landscape Diversity

Objective

The main purpose of this map is to show the variability in and distribution of forest types across the Fraser Headwaters landscape. Forest types were defined primarily by leading tree species (the tree species with the highest timber volume in a stand) and stand age.

Technical Description and Rationale

Inventory type groups (ITG) from forest cover data were amalgamated into 8 categories based on leading species (species with the highest timber volume): Douglas-fir (ITG 1-8), western redcedar (ITG 9-11), western hemlock (ITG 12-17), Engelmann/white spruce and subalpine fir (ITG 18-26), lodgepole pine (ITG 27-32), western larch (ITG 33-34), trembling aspen (ITG 41-42) and other deciduous species (ITG 35-40). Amalgamation was necessary to reduce the number of categories; the stands combined within each new category are sufficiently ecologically similar to justify combining them at this scale.

The amalgamated Engelmann/white spruce/subalpine fir group was divided into two types based on biogeoclimatic subzone: high elevation (Engelmann Spruce - Subalpine Fir subzone), and low elevation (Sub-Boreal Spruce and Interior Cedar - Hemlock subzones). This was done to reflect the major ecological differences between valley bottom and higher elevation spruce-fir forests. For example, hybrid white spruce, as opposed to Engelmann spruce, is generally found at lower elevations.

Finally, these forest types were subdivided by stand age as shown in the following table:

Leading species	Stand Age		
	Young	Mid-aged	Old
pine, aspen, other deciduous	0-60 years (Age Class 1-3)	61-120 (Age Class 4-6)	121-250+ (Age Class 7-9)
all others	0-60 years (Age Class 1-3)	61-140 (Age Class 4-7)	141-250+ (Age Class 8-9)

Pine, aspen, and other deciduous species are early successional species (they are usually the first to regenerate following a disturbance) and shorter lived than species such as Douglas-fir, cedar, or hemlock. As such, they commonly have old growth attributes at a younger age.

3.3.3 Map 3: Ecological Risk

Objective

The main purpose of the Ecological Risk analysis was to assess the ecological sensitivity to disturbance of the Fraser Headwaters study area, for the purpose of identifying and protecting areas of high ecological risk. A more detailed discussion of the concept of risk is provided in Section 3.3.3.

Two versions of this map were produced: *Map 3a, Ecological Risk in Summary* and *Map 3b, Ecological Risk in Detail.* The "*in Detail*" map (3b) shows a breakdown of all categories of sensitivity used to determine risk. The " *in Summary*" map (3a) combines these categories into five main groups: high risk (alpine), high risk, medium risk, low risk, and unknown risk (insufficient data to assess). Further planning will be necessary in the future at the watershed and stand levels to increase the resolution of this analysis in order to verify or revise, as appropriate, interpretations made at this large landscape level. Further planning will also be needed to determine risk in areas where there are currently insufficient data.

Technical Description and Rationale

Table 3 shows the five main categories of risk (*in Summary* map), the sub-categories contained within each main category (*in Detail* map), and a technical definition of each sub-category. A non-technical definition and rationale for each sub-category can be found in Section 4.2.

The GIS analysis of ecological risk was carried out in a hierarchical fashion, such that risk categories and the sub-categories within them were removed sequentially from the land base in order of their importance. In other words, a riparian ecosystem around a small stream flowing through the alpine tundra would be shown as alpine, and not riparian, on the map, since alpine occurs above riparian in the hierarchy of risk (Table 3). Although the hierarchy employed is subjective to a certain degree, it does not unduly influence the final result: rearranging the hierarchy would result in a different *in Detail* map, but the final *in Summary* map would remain the same.

Table 3: Ecological Risk Categories. The table shows both a complete list of all categories of risk as shown on *Map 3b, Ecological Risk in Detail*, as well as the way in which these categories were combined on *Map 3a, Ecological Risk in Summary*. The categories are listed in the order in which they were identified during the analysis. For example, wetlands that occur within the alpine tundra would be identified as alpine and not wetlands. The names in brackets refer to the organization that developed the criteria for each category of risk: MoF – B.C. Ministry of Forests; MoELP – B.C. Ministry of Environment, Lands and Parks; SFF – Silva Forest Foundation.

Ecological Risk Categories		
In Summary (Map 3a)	***In Detail (Map 3b)***	**Technical Definition**
High Risk (alpine)	Alpine tundra (MoF)	Forest cover data: basic class 2
High Risk	Alpine forest (MoF)	Forest cover data: basic class 10
	Wetlands (MoF)	TRIM1 data: swamps and marshes Forest cover data: basic class 35
	Environmentally sensitive areas (high) (MoF)	Forest cover data: ESA = Es1, Ep1, Ep2, Ea1 and Er1[8]
	High quality caribou habitat (MoELP)	MoELP digital caribou habitat data: suitability = high
	Very steep slopes (SFF)	Slopes > 60% from TIN created from digital elevation points from TRIM1
	Riparian buffers (SFF)	80m each side: large rivers (double line features); 40m each side: rivers, streams, lakes and wetlands; 20m each side: intermittent streams
Medium Risk	Environmentally sensitive areas (moderate) (MoF)	Forest cover data: ESA = Es2, Ew1 and Ew2[9]
	Moderately steep slopes (SFF)	Slope: 40-60%, from TIN created from digital elevation points from TRIM1
Unknown Risk	Unknown Risk (SFF)	Forest cover data: remaining basic classes
Low Risk	Low Risk (SFF)	Land area not fitting into any of the above sub-categories

[8] Es1 = soil sensitivity: terrain stability class V terrain; Ep1 and Ep2 = forest regeneration problems; Ea1 = snow avalanche; and Er1 = recreation.

[9] Es2 = soil sensitivity: terrain stability class IV terrain; Ew1 and Ew2 = wildlife.

Alpine tundra, alpine forest, and wetlands are ecosystems that are commonly omitted from the timber landbase because they do not contain merchantable trees. We feel they are not suited to any kind of consumptive human use because of their high sensitivity to disturbance.

The Timber Supply Analysis (TSA) completed by the Ministry of Forests (MoF) for the Robson Valley Timber Supply Area omits a certain proportion of lands classified as environmentally sensitive from the timber landbase (B.C. Ministry of Forests 2000). One hundred percent of land classified as Er1 (recreation); and 90% of land classified as Es1 (soil sensitivity: terrain stability class V terrain), Ep1/2 (forest regeneration problems), and Ea1 (snow avalanche) are removed from the timber landbase. Because the MoF considers these lands too sensitive to log, we felt that this was sufficient criteria to classify them as high risk. Similarly, the Robson Valley TSA omits 10% of lands classified as Es2 (soil sensitivity: terrain stability class IV terrain) and Ew1/2 (wildlife) from the timber landbase; we felt it reasonable therefore to classify these areas as medium risk[10].

High quality caribou habitat data was provided by the Ministry of Environment, Lands and Parks (MoELP). MoELP does not permit logging on lands zoned as high quality caribou habitat.

The "very steep slopes" (high risk) and "moderately steep slopes" (medium risk) categories were developed by the Silva Forest Foundation based on past field data collection, data analysis, and general observations. It is our understanding that the MoF Es1 category (contained within the "environmentally sensitive areas – high" ecological risk category) includes all slopes greater than 70%. We believe that this standard is too aggressive for an ecosystem-based approach, and have therefore adopted a slightly more precautionary view than the MoF by including slopes greater than 60% in the "very steep slopes" category.

Finally, nominal buffer widths around riparian features were designed by the Silva Forest Foundation to model riparian ecosystems on the landscape (see Table 3). Actual delineation of riparian ecosystems requires the use of airphotos and field assessments and is typically carried out at the watershed level of ecosystem-based planning.

3.3.4 Map 4: Antique and Old Growth Forests

<u>Objective</u>

The purpose of this map is to show the distribution of candidate antique and old growth forests within the Fraser Headwaters study area. Forests that have been heavily disturbed by logging and/or hemlock looper are also shown.

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[10] Although the majority of the study area (70%) falls within the Robson Valley forest district, approximately 30% is within the Prince George forest district, which has a slightly different set of guidelines to determine which lands are removed from the timber landbase (B.C. Ministry of Forests 1998). With respect to environmentally sensitive areas, the percent reductions are similar. There is no systematic bias in the differences; that is, where there are differences, sometimes the Robson Valley guidelines are more stringent and other times the Prince George guidelines are more stringent. Since it was not possible to implement the criteria from both forest districts due to time limitations, we chose to use the Robson Valley guidelines, because most of the study area falls within that district.

Technical Description and Rationale

All ecological information for the antique forests portion of this analysis was provided by Trevor Goward[11], the lichenologist who coined the term “antique forest.” In consultation with him, a list of the variables that best characterize antique forests was developed: old stand age, wet biogeoclimatic subzones, low elevation, decreased lightning incidence, and toe slope terrain position.

Using existing digital data, areas with the following characteristics were located: stand age >140 years, biogeoclimatic subzones ICHwk and ICHvk, and elevation <1200m. We attempted to incorporate lightning data into the analysis, but the data were of insufficient resolution to be useful. Further work to incorporate lightning data is planned for future projects.

We then attempted to determine digitally the location of toe slopes. Without a mathematical description of toe slopes, however, automating this process proved difficult. Using two known antique forest locations and the Digital Elevation Model (DEM) of the study area, we determined that 70% of the known antique forest occurs on slopes <30%. We thus combined this slope criterion into the analysis to create a map of candidate antique forests.

Finally, the map of all candidate antique forests was plotted with contour intervals. Priority candidate stands for antique status were manually delineated by Goward. His criteria included stand age, stand condition (based on logging and looper disturbance described below), and toe slope position (based on contour intervals), as well as personal knowledge developed through previous field work. These areas are the most likely to contain antique forest stands although it is certainly possible that antique forest exists outside of these areas. Further field work is necessary to confirm the antique status of candidate areas.

Potential old growth forests were determined in areas outside of the locations of candidate antique forests using the same criteria as for old growth in the landscape diversity analysis (see Section 3.3.2 above).

Disturbance by logging and hemlock looper is also shown on the map. Candidate antique stands with a history of logging, and either stand age less than 60 years, or canopy cover less than or equal to 30% were considered to be heavily disturbed. All stands (candidate antique or otherwise) that experienced mortality of severity code 3 or 4 during the 1993-1995 hemlock looper outbreak were considered to be heavily disturbed.

The draft map of candidate antique forests was reviewed by Trevor Goward, and his proposed revisions were incorporated into the final map of candidate antique forests.

3.3.5 Map 5: Human Disturbance

Objective

The purpose of this map is to show human disturbance in the Fraser Headwaters study area. Disturbances mapped include past logging (heavily and lightly disturbed), planned

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[11]Enlichened Consulting Ltd., Box 131, Clearwater, B.C. V0E 1N0

logging, cleared land, private land, existing roads (paved and unpaved) and railroads, and planned logging roads.

<u>Technical Description and Rationale</u>

Information on past logging was obtained from forest cover data. Interestingly, some stands with a history of logging currently support trees of relatively old age (in some cases greater than 140 years). Preliminary examination suggests that these may be stands that were partially cut, likely 30-40 years ago, although the definition of "partially cut" likely varies widely. Most of the "partial cutting" probably was highgrading, or removal of the best trees.

Stands with a history of logging were divided into two categories, heavily disturbed and lightly disturbed, based on stand age and canopy cover. Stands with a history of logging, stand age greater than 60 years, and canopy cover greater than or equal to 30% were considered to be lightly disturbed. All other stands with a history of logging were considered to be heavily disturbed. The final analysis was compared with recent landsat imagery to ensure a reasonable level of completeness. Further fieldwork will be necessary to verify the accuracy of the heavily vs. lightly disturbed classification system.

Forest development plans were obtained from all timber companies operating within the study area (see Appendix I). Planned logging blocks including information, proposed approved, approved, and permitted categories were digitized, as were all proposed logging roads.

The negative effects of road-building and logging, particularly clearcutting, extend well beyond the actual footprint of the disturbance. In most projects, the Silva Forest Foundation models "zones of influence" of 100 meters and 500 meters around past and planned logging and roads. The zone of influence was not modeled on this map, however, because the small map scale rendered the zone of influence barely visible. The reader is therefore reminded that the actual impacts of roads and logging extend beyond that shown on this map.

Cleared land and land under private tenure was obtained from forest cover data.

Two versions of the map were produced, one on paper and one on clear mylar. The mylar map can be overlaid on any of the other final maps to highlight those areas that have been subject to human disturbance.

3.3.6 Map 6: Proposed Protected Areas Network

<u>Objective</u>

The proposed Protected Areas Network (PAN) Map is the final map in the Fraser Headwaters series. It shows the network of Proposed Full Protection and Proposed Conservation Emphasis areas that we feel are necessary to maintain the ecological integrity of the Fraser Headwaters. Existing protected areas and proposed ecosystem-based management areas are also shown on the map, although they are not strictly part of the PAN. This map is the result of broad landscape level planning. It is the first step in multiple spatial scale ecosystem-based planning towards determining the types and amounts of human activity that can be sustained within particular locations on the landscape. Finer resolution ecosystem-based planning needs to be undertaken at both the watershed and stand levels before any final decisions regarding logging, mining, tourism, and other human activities can be made.

<u>Technical Description and Rationale</u>

A transparent mylar overlay showing the study area boundary and existing protected areas (both within and bordering the study area) was used to facilitate the planning of the proposed Protected Areas Network (PAN).

A gap analysis was first completed to determine BEC zones and forest types that are currently under-represented within the existing system of parks and protected areas in the study area. This information was used to ensure sufficient representation of all BEC zones, subzones, and variants within the PAN.

Each map within the Fraser Headwaters map set was then systematically analysed to determine candidate areas for both full protection and partial (conservation emphasis) protection. The mylar was overlaid on each map in turn and candidate areas were outlined manually. For example, the landscape diversity map shows that the Raush River watershed has the highest level of landscape diversity outside of the Rocky Mountain Trench. The human disturbance map shows that the Raush River and Goat River watersheds are the last remaining watersheds that are largely untouched by human disturbance. Each of these watersheds was therefore outlined as a candidate area for protection.

Once all maps were analysed, the mylar showing all candidate areas was assessed. Areas that were highlighted for potential protection on the basis of more than one criteria were generally accorded full protection status. Candidate areas that were less ecologically sensitive, but provided important buffers or linkages between existing or proposed protected areas were accorded conservation emphasis. Where needed, additional linkages were delineated to ensure connectivity. The remaining areas were classified for ecosystem-based management.

The final PAN outlined on the mylar was digitized. The map shows Proposed Full Protection, conservation emphasis, and ecosystem-based management areas, as well as existing protected areas. Within each of these categories, areas of high, medium, and low ecological risk are shown. A more detailed rationale for each component of the PAN is provided in Chapter 5.

4. Analytical Maps

This Chapter describes the four main analytical maps in the Fraser Headwaters mapset[12]:

- *Map 2: Landscape Diversity*
- *Map 3: Ecological Risk*
- *Map 4: Antique and Old Growth Forests*
- *Map 5: Human Disturbance*

Each section begins with an introduction to the map, followed by a discussion of results and interpretations of the analysis. The final synthesis map, *Map 6: Proposed Protected Areas Network*, is described in Chapter 5.

4.1 Map 2: Landscape Diversity

Diversity is an inherent characteristic of natural ecosystems, occurring at a range of spatial and temporal scales. Diversity can be expressed in smaller areas as the number of species in an ecosystem, and in larger areas as the pattern of ecosystems in a landscape. Temporal diversity can range from predator-prey cycles that fluctuate yearly to climate conditions that change over millennia.

The ecological role of biological diversity is still a matter of debate among scientists. At the species level, it has been hypothesized that biodiversity contributes to the resilience of an ecosystem, or its ability to resist change and recover more quickly following disturbance. Unfortunately, few experimental studies have been conducted to test this hypothesis, and the handful that have been undertaken suggest that the relationship between biodiversity and resilience is far from simple (Vogt *et al.* 1997). Most scientists would agree, however, that there is a critical threshold of diversity below which ecosystem functioning ceases. Perhaps the best way of stating the issue is not that complex or diverse ecosystems are more resilient than simple ecosystems, but that *simplified* ecosystems (through human intervention) are less resilient than their unmanaged counterparts (Perry 1994).

> *"Ehrlich and Ehrlich… compared species extinctions to removing rivets from an airplane wing: the plane may continue flying for a while, but when some critical number of rivets have been removed, it is going to crash."*
>
> Perry (1994)

At a landscape level, diversity can be defined as the abundance and distribution of ecosystem types, or forest types in the case of the Fraser Headwaters, across the landscape (Figure 17). As with species biodiversity, the relationship between landscape diversity and stability is far from well understood. We do know, however, that diversity contributes to stability in a number of important ways (Perry 1994). First, high diversity translates into a higher number of different habitat types for individual species.

[12] *Map 1: The Fraser Headwaters* is the base map for this project and was discussed in Chapter 2

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Map 2: Landscape Diversity

Figure 17: Landscape diversity within the Fraser Headwaters is exhibited as a patchwork of different forest types on the landscape. This photograph shows the high landscape diversity in the Rocky Mountain Trench, with a coniferous forest in the foreground, a leafless deciduous stand behind it, and a small strip of conifers along the river's edge. Landscape diversity is the result of a complex mosaic of different soil types, slopes, and aspects, as well as the disturbance history of individual forest areas. High landscape diversity results in a higher number of wildlife habitat types, slows the spread of disturbance events across the landscape, and speeds the recovery of ecosystems following disturbance.

Secondly, diversity increases the number of source populations that can colonize disturbed areas from other undisturbed areas. Finally, high diversity can reduce the rate of spread of disturbance across a landscape. Insect populations, for example, spread more easily across homogeneous landscapes, because they have a uniform continuous food supply, and predators tend to be missing or in low numbers.

The purpose of Map 2 is to show the pattern of diversity at a landscape scale within the Fraser Headwaters study area: how many different forest types are present, what is the shape and size of the forest types, and how are these forest types distributed across the landscape?

The definition of a forest type is subjective to a certain degree. What counts as a different type of forest will differ depending on your perspective. To a mountain pine beetle, which attacks only lodgepole pine trees larger than a certain size, there is a very distinctive difference between an old growth pine stand and a newly regenerating one. To a small bird searching for nesting habitat in a stand of trembling aspen, all lodgepole pine stands, regardless of age, are uninteresting.

The definition of a forest type is also dependent on the scale of analysis. At a fine resolution, such as that used to classify site series within the biogeoclimatic ecosystem classification (BEC) system, two forest types might have very similar overstory tree composition and differ only by the species of shrubs, herbs, mosses, and lichens that grow beneath the canopy. At a broader scale of analysis, such as the landscape level approach taken in this project, forest types might be defined based on the main tree species that make up the overstory canopy. Finally, at continental scales, forest types are often classified very generally into such categories as coastal rainforest, boreal forest, and eastern hardwood forest. These approaches are complimentary; each offers advantages and disadvantages, and has value primarily at its respective spatial scale.

For the purposes of this analysis, we took a general approach to identifying forest types. Two main variables were used: species composition and age of the trees within forest stands.

Seven forest types were identified based on the species of tree that had the highest timber volume:

- Douglas-fir
- western redcedar
- western hemlock
- Engelmann/white spruce-subalpine fir
- lodgepole pine
- trembling aspen
- other deciduous (including cottonwood and birch)

The Engelmann/white spruce-subalpine fir type was then broken into two categories based on biogeoclimatic (BEC) zone to reflect the large ecological differences between the higher productivity low elevation communities (SBS and ICH), and the less productive communities that occur at higher elevations (ESSF).

Each forest type was then broken into three age groups: young, mid-aged, and old.

A more detailed description of the methods used to carry out this analysis is provided in Section 3.3.2. Map 2 shows the pattern of landscape diversity within the Fraser Headwaters study area.

Table 4: Summary Statistics - Landscape Diversity. Area occupied is shown in both hectares and as a percent of the total forested area.

Landscape Diversity								
Leading Species	Stand Age						Total	
	Young		Mid-aged		Old			
	area (ha)	%	area (ha)	%	area (ha)	%	area (ha)	%
Douglas-fir	2488	0.4	7414	1.1	3688	0.5	13590	2.0
Western redcedar	1313	0.2	1178	0.2	57213	8.2	59704	8.6
Western hemlock	882	0.1	4391	0.6	20312	2.9	25585	3.7
Spruce - subalpine fir (low elevation)	44609	6.4	27784	4.0	85913	12.4	158306	22.8
Spruce - subalpine fir (high elevation)	30611	4.4	31705	4.6	265352	38.2	327668	47.2
Lodgepole pine	26443	3.8	33623	4.8	7662	1.1	67728	9.8
Trembling aspen	3172	0.5	22337	3.2	690	0.1	26199	3.8
Other deciduous	3879	0.6	8317	1.2	3149	0.5	15345	2.2
Total (%)	113397	16.4	136749	19.7	443979	64.0	694125	100.0

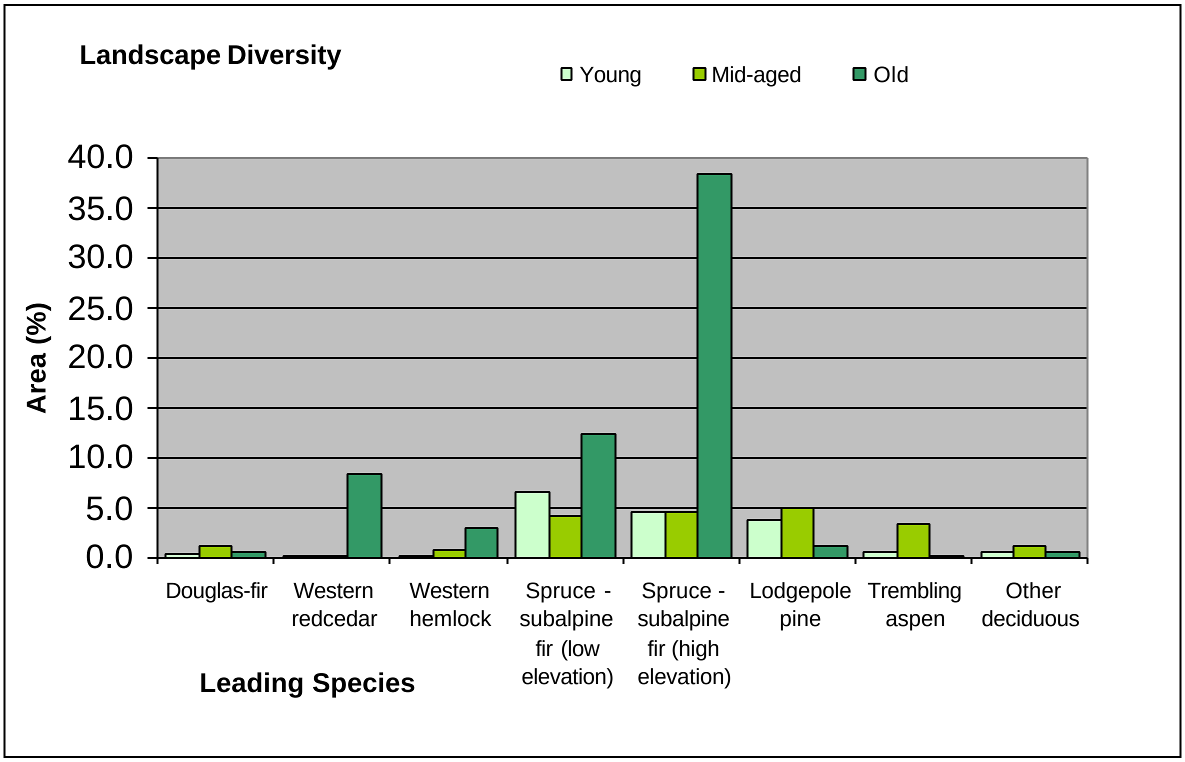

Figure 18: Landscape diversity classes (percent of total forested area)

4.1.1 Results and Interpretations

- The most common forest type is Engelmann/white spruce-subalpine fir forest; low elevation stands make up 23% of the total forested area while high elevation stands make up 47% of the forested area. The six other forest types together comprise the remaining 30% of the forested area (Table 4, Figure 18, Figure 19).
- Sixty-four percent of the forested area is composed of old growth forests. Engelmann/white spruce-subalpine fir (both low and high elevation), western redcedar, and western hemlock forest types are predominantly old growth; while Douglas-fir, lodgepole pine, trembling aspen, and other deciduous forest types have a higher proportion of mid-aged stands (Table 4, Figure 18, Figure 20).
- Young forests make up 16% of the forested area; approximately 70% of these stands are the result of logging activity and should therefore not be considered representative of historical conditions within the Fraser Headwaters (Table 4, Figure 20).
- The highest landscape diversity, or number of different forest types, occurs in the Rocky Mountain Trench and at lower elevations in side valleys (Map 2). This is not surprising, given the mountainous character of the study area. The Rocky Mountain Trench supports the gentlest topography and mildest climate, and therefore the most accommodating conditions within the study area.

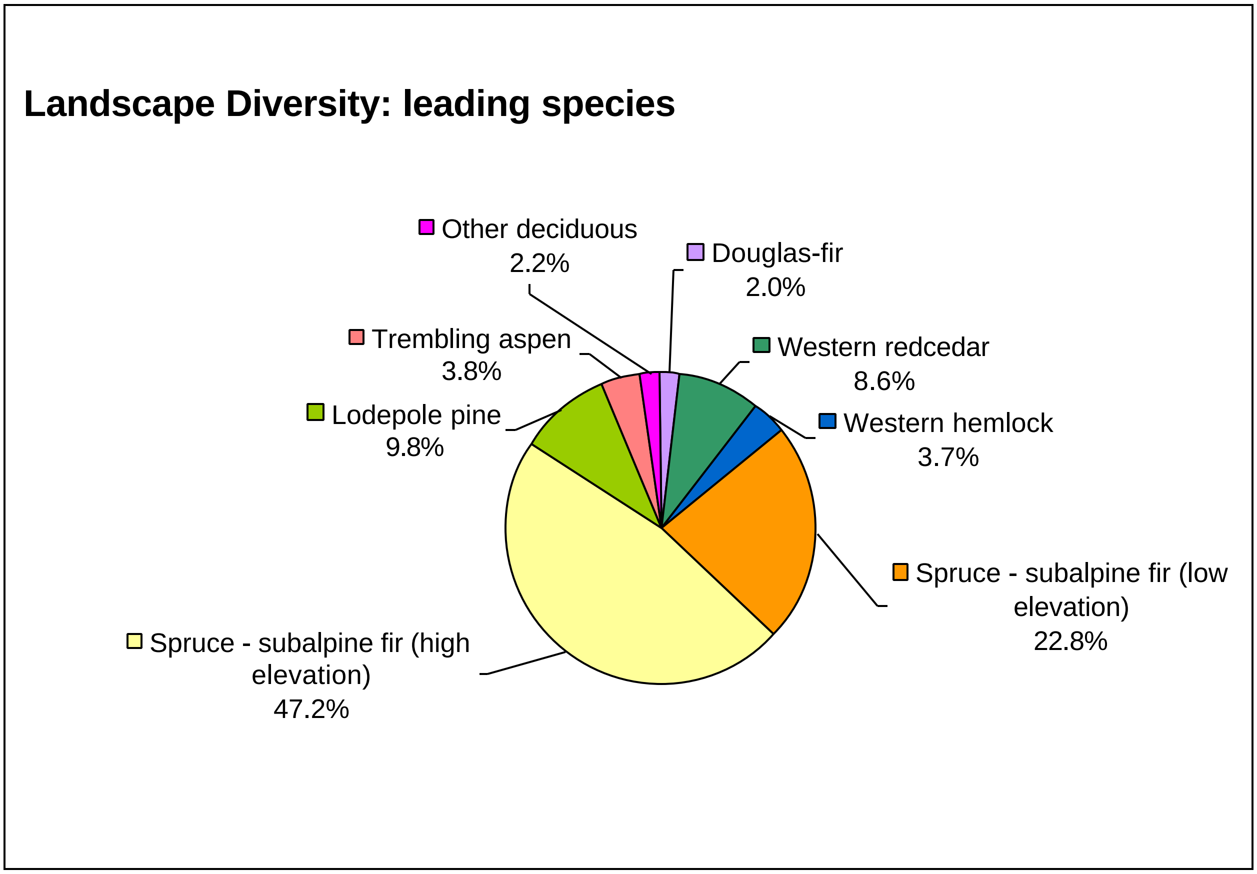

Figure 19: Landscape Diversity: forest types shown by leading species (as percent of total forested area).

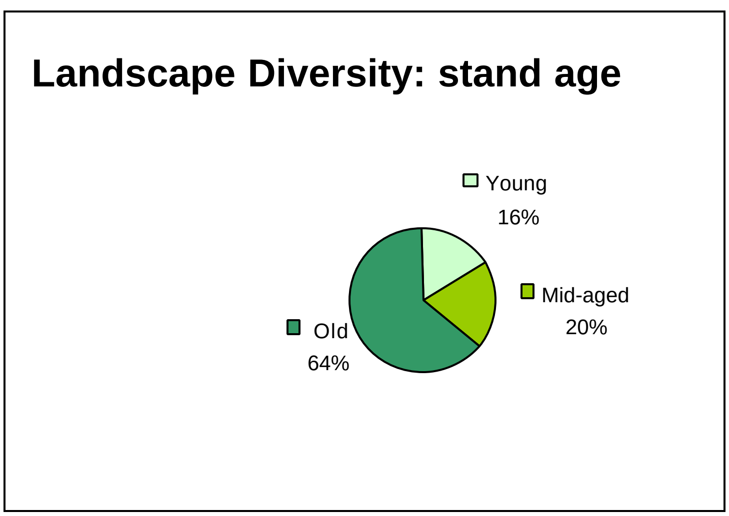

Figure 20: Landscape Diversity: forest types shown by stand age (as percent of total forested area).

The side valleys, on the other hand, are much narrower, steeper, and higher in elevation, which results in much harsher climate and growing conditions. Compared to the number of species found in the Trench, far fewer plants and animals are adapted to living under such limiting conditions. It is no coincidence that humans have also chosen to focus activities within the Rocky Mountain Trench (see *Map 5: Human Disturbance*, Section **3.3.5**, below). Ensuring adequate protection and maintenance of the full suite of landscape diversity is therefore especially important within the trench.

- Higher elevation forests, especially those in tributary watersheds, are relatively homogeneous in composition at this landscape scale of analysis (Map 2). These forests are sensitive to human disturbance because of steep broken topography and cold climates, and should therefore not be considered expendable simply due to their abundance. For example, forest soils at high elevations are cold, shallow, and exhibit slow nutrient cycling, all of which render them sensitive to disturbance. High elevation forests also play a vital role in connectivity at the large landscape level, linking the Rocky and Columbia Mountains across the Rocky Mountain Trench. Finally, although these forests may seem homogeneous at this landscape scale of analysis, finer resolution mapping at the watershed and stand level would show more fine-grained differences not apparent in this analysis, showing the importance of planning at multiple scales.
- The Raush River valley contains the highest landscape diversity of any side valley in the southern part of the study area (Map 2). Since it has also sustained the lowest level of human disturbance (see Map 5), the Raush is an ideal candidate for protection. As the topography flattens out in the northern part of the study area, there is a general increase in the landscape diversity within side valleys. Examples include the lower Morkill River, the Torpy River, and Slim Creek. Many of these area, however, have already been subject to clearcut logging.

4.2 Map 3: Ecological Risk

The fundamental philosophy of ecosystem-based planning, as practiced by the Silva Forest Foundation, is to focus on what to leave rather than on what to take. Which parts of the landscape are most sensitive to disturbance? Which parts play an unusually important role in regulating ecosystem functioning? Which parts are least able to sustain consumptive human uses?

Map 3a, Ecological Risk in Summary and *Map 3b, Ecological Risk in Detail* show a landscape-level analysis of Silva's interpretation of ecological sensitivity to disturbance. For this analysis, we have attempted to categorize risk in terms of the *precautionary principle*, which states that "when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically" (Raffensperger and Tickner 2000). The categories range from high risk—landscape elements that we suspect are least resilient to human disturbance, or play a critical role in the composition, structure, and functioning of the ecosystem—to low risk—those landscape elements with characteristics that render them most resilient to human influence.

Two versions of the map were produced: *Map 3a, Ecological Risk in Summary*, which shows the different types of risk combined into five categories: high(alpine), high, medium, unknown and low risk; and *Map 3b, Ecological Risk in Detail*, which shows a comprehensive breakdown of risk.

The analysis was done at a landscape level, which means that it is a coarse, broad scale consideration of patterns relevant over large areas. As such, further analysis will be required at the watershed and stand-level (including field checking) to refine the assessment of risk for further planning and on-the-ground implementation. It is likely that there will be small zones of low risk within the larger blocks of high risk, and vice versa.

Five major categories of risk were identified during this analysis: high (alpine), high, medium, unknown, and low. The high and medium categories each include several subcategories of risk. A description of each category and subcategory of risk follows.

High Risk (alpine)

The waters of the Fraser River originate in the alpine tundra, the climate-limited region that lies beyond treeline in high mountain areas (Figure 21). With its very thin soils and harsh climate, the alpine is one of the most fragile ecosystems in the study area, and can take from decades to centuries to recover from disturbance (B.C. Ministry of Forests 1988).

Because over one-third of the study area is comprised of alpine tundra, we have chosen to depict it as a separate category of high risk. Although the alpine is not of commercial value for the timber industry, other human activities such as heli-skiing are potentially disruptive to these fragile ecosystems.

Figure 21: The alpine tundra lies at high elevations beyond treeline. Alpine ecosystems are highly sensitive to disturbance. Harsh climate conditions are the norm here, including long, cold winters, heavy snowpacks, high winds, and very short growing seasons. Thin soils, slow rates of decomposition and nutrient cycling, and slow vegetation growth and regeneration are also characteristic. The few trees that manage to gain a foothold here are a testament to the harsh conditions that prevail; gnarled and twisted, trees only a few feet tall may be hundreds of years old.

High Risk

Below the alpine tundra, the high risk category includes the most delicate strands in the forest ecosystem web: alpine forest, wetlands, environmentally sensitive areas (high), high quality caribou habitat, very steep slopes (>60%), and riparian buffers. These areas require full protection.

- Alpine Forest

Alpine forests form the transition between upper elevation forests and the alpine tundra (Figure 22). Deep snow is the primary limiting factor in these open-canopied forests, constraining both tree establishment and growth.

Figure 22: Alpine forests are the patchy, open-canopied forests that occur along treeline. Tree growth and regeneration is slow—the result of deep snowpacks, a short growing season, and cold temperatures.

Figure 23: Wetlands include areas that are periodically or permanently inundated by surface or groundwaters. Wetlands can include marshes, fens and swamps, and may support shrubs and trees in addition to herbs and grasses. Wetlands provide critical migratory and breeding habitat for many species of ducks and geese, as well as resident species such as moose. They also function as elaborate water filters, purifying and regulating the flow of water. In addition to these valuable ecosystem services, wetlands are particularly sensitive to disturbance due to saturated soil conditions.

- Wetlands

Wetlands play a critical role in regulating water flow and quality, as well as providing important habitat for many species, including resident and migratory waterfowl such as ducks and geese (Figure 23). Soils in, and adjacent to wetlands are wet, often fine-textured, and sensitive to disturbance.

Figure 24: Avalanche chutes are a common feature at higher elevations within the Fraser Headwaters. Steep slopes and heavy snowpacks combine to provide a dynamic winter landscape where tree growth and regeneration is limited by the recurring sweep of walls of snow.

- Environmentally Sensitive Areas (High)

The Ministry of Forests designates certain forest lands as environmentally sensitive or significantly valuable for other resources. Many forest areas with high soil sensitivity, forest regeneration problems, recurrent avalanches, and high recreational value are considered too sensitive by the Ministry to include within the timber harvesting landbase (B.C. Ministry of Forests 2000) (Figure 24).

- High Quality Caribou Habitat

The Ministry of the Environment designates certain areas as high quality mountain caribou habitat (Figure 25). These areas occur primarily at higher elevations in the alpine tundra and alpine/subalpine forests, and are used as calving habitat in the summer and feeding grounds in the winter. Certain low elevation forests that receive significant use in the early winter are also designated as high quality habitat. The Ministry of the Environment recommends maintaining unfragmented old growth forests and minimizing human disturbance within Caribou High zones. As such, it does not permit logging or road construction within these areas, and suggests that recreational use be minimal (B.C. Ministry of Environment, Lands and Parks 2000).

Figure 25: The endangered mountain caribou are dependent in the winter on arboreal lichens found primarily in old growth forests (Stevenson *et al*. 1994). Most of this lichen grows on the branches of standing trees. Snags, in particular, often contain a high percentage of the lichen in any given stand. The extra height provided by the snowpack enables the caribou to reach greater amounts of these lichens. Younger forests do not contain adequate amounts of lichen. Maintaining old growth forests on the landscape is therefore the first step to ensuring the persistence of caribou populations within the Fraser Headwaters.

- Very Steep Slopes

Areas with very steep slopes (greater than 60% gradient) are prone to landslides and other forms of soil erosion, especially after logging and road construction (Figure 26 and Figure 27). Moreover, the stability of these slopes may continue to decrease for many years following logging, as tree roots decay. Although it might be economically feasible to log such sites, they are generally too ecologically sensitive for sustainable timber management. The Ministry of Forests designates slopes greater than 70% slope gradient within the ESA (Environmentally Sensitive Areas) category Es1 (soil sensitivity: terrain stability class V terrain). Es1 is included within our Environmentally Sensitive Areas (high) category; therefore, most slopes greater than 70% have already been designated as high risk. However, we feel that slopes between 60% and 70% gradient are also ecologically sensitive to disturbance and are therefore included within the high risk category.

Figure 26: Steep terrain on mid and upper valley slopes illustrates the difference between an ecosystem-based approach and a conventional approach regarding the extent of the timber management landbase. Plainly, these areas are forested and grow merchantable trees. Technology exists to log them economically. However, an ecosystem-based approach recognizes the inherent limits imposed by steep slopes and relatively shallow soils. These limits include limited biological productivity, shallow soils that are easily disturbed and degraded, and inherently unstable slopes. These sites are easily degraded by construction of access roads and trails, and by removal of trees and biomass from the site, regardless of logging method. An ecosystem-based approach identifies these steep forested slopes as ecologically sensitive and not suitable for long-term, sustainable, timber management, regardless of short-term economic potential. A conventional approach includes them in the "operable" timber management landbase.

Figure 27: Logging and road construction on steep slopes may trigger landslides. This photo was taken in the Milk River watershed; the landslide was likely the result of a plugged culvert on a badly designed road built on an excessively steep slope.

- Riparian Buffers

Riparian ecosystems are the wet forest areas (riparian zones) and upland forests (riparian zones of influence) adjacent to rivers, lakes, streams, and wetlands. They are critical areas of biological activity and diversity, play important roles in maintaining stream channel structure and functioning, and provide corridors or linkages throughout the landscape.

The size of the riparian ecosystem depends on the characteristics and size of the water feature, and can usually only be determined in the field. Due to the scale of this analysis, therefore, computer generated buffers of fixed width were placed around each water feature in order to estimate the overall amount of riparian ecosystems that occur at the landscape level. Buffer widths used were:

- seasonal (intermittent) creeks: 20m on either side
- creeks and small rivers: 40m on either side
- larger rivers: 80 m on either side
- ponds, lakes, and wetlands: 40m all around

Figure 28: A small stream ecosystem in the Kiwa Creek watershed illustrates the connections between watercourses and the riparian forests that surround them. Large fallen trees in streams maintain the streambed by creating pools that control erosion and sediment levels. These pools are also habitat for invertebrates, and in larger streams, fish. Intact riparian forests also shade streams, which helps to moderate water temperature and reduce ultraviolet levels, and provide habitat near water for terrestrial animals.

<u>Medium Risk</u>

The medium risk category includes moderately environmentally sensitive areas (as defined by the Ministry of Forests) and moderately steep slopes. These areas may be able to sustain low to moderate levels of ecosystem-based timber management once more detailed planning has been conducted.

Figure 29: Areas with moderately steep slopes or moderate environmental sensitivity occur primarily along the lower flanks of side valleys within the Fraser Headwaters. Slopes are less steep, soils somewhat deeper, and climate conditions more forgiving than forests within high risk areas. Long-term, ecologically sustainable, timber management is possible in these areas using an ecosystem-based approach. Further planning is required to identify high risk inclusions not evident at this scale of analysis and to determine desirable land use options within these areas. More stringent timber management guidelines acknowledging the vulnerability of these medium risk areas are also necessary.

- Moderately Steep Slopes

Areas with moderately steep slopes (40-60% gradient) are not suitable for ground-based logging systems, but may be suitable for carefully planned logging using cable yarding or aerial (helicopter) techniques.

- Environmentally Sensitive Areas (Moderate)

The Ministry of Forests designates certain forest lands as moderately environmentally sensitive or valuable for other resources. Forest areas with moderate soil sensitivity and high to moderate wildlife values are not usually removed from the timber harvesting landbase (B.C. Ministry of Forests 2000). They do, however, require special planning and consideration.

<u>Unknown Risk</u>

Insufficient information is available to assess risk for several land-cover types, including meadows, rock bluffs, and clearings. The main digital data on vegetation cover used in this project was Forest Cover data. Developed by the Ministry of Forests, the major objective of this data is to support the management of timber resources. As such, the mapping of non-commercially viable ecosystem types is often not very accurate. More detailed information combined with airphoto interpretation, will be necessary at the watershed or stand level to determine risk for these ecosystem types.

Low Risk

Areas that were net categorized as High, Medium, or Unknown risk areas are Low Risk—those areas most able to accommodate carefully planned human activities. These areas generally contain stable, well drained soils on gentle slopes.

Further planning will be required at the watershed and site level to identify small high or moderate risk areas not visible at this scale of analysis. Furthermore, representative areas need to be fully protected to maintain full ecosystem functioning, including old growth reserves and corridors for wildlife movement. Once these ecological issues have been accommodated, final determination of human use in low risk areas can be carried out through forest use zoning, a community-based decision-making process.

Figure 30: Most of the forest areas classified as low risk within the Fraser Headwaters occur along the bottom and lower flanks of the Rocky Mountain Trench. These sites are typically on gentle to moderate slopes, and contain deep, well-drained soils. They are the most conducive to ecosystem-based timber management. However, the fact that physical or ecological reasons have not been identified at this scale to remove these areas from the timber management landbase does not mean that timber management is therefore the desirable land-use option for all of these areas. Additional planning at the watershed and stand levels is needed to identify smaller inclusions of high and medium risk areas and to design protected landscape and ecosystem networks. Finally, a community-based decision-making process is needed to determine appropriate human use zones.

A more detailed description of the methods used to carry out this analysis is provided in Section 3.3.3. Map 3a and 3b show areas of ecological risk within the Fraser Headwaters study area.

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Map 3a: Ecological Risk In Summary

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Map 3b: Ecological Risk *In Detail*

4.2.1 Results and Interpretations

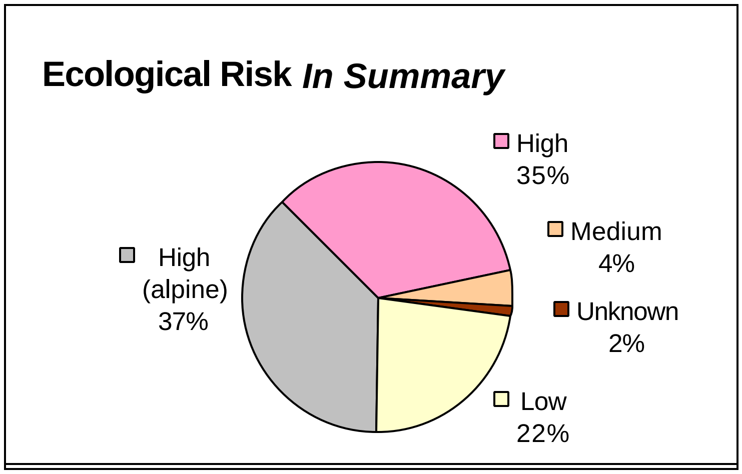

Figure 31: Ecological Risk In Summary

- 72% of the study area was classified as high risk: 37% in alpine tundra[13], and 35% at lower elevations (Figure 31, Table 5). The majority of high risk area at lower elevations is made up of environmentally sensitive areas-high, high quality caribou habitat, and riparian buffers (Figure 32). These areas are not suited to most types of industrial human use and need to be fully protected. Certain types of low-intensity non-consumptive human activity may be accommodated within these areas, but this is subject to more detailed analysis at the watershed and stand level. Traditional cultural activities of Indigenous people are appropriate in high risk areas.
- 4% of the study area was classified as medium risk (Figure 31, Table 5). These are areas that can likely sustain low intensity, carefully planned human use.
- 22% of the landscape was classified as low risk (Figure 31, Table 5). This percentage is close to the figure used by the Ministry of Forests to determine the timber harvesting landbase (the land area suitable for timber management, as defined by the Ministry). In the Robson Valley district, for example, the timber harvesting landbase is approximately 17% of the total land area (B.C. Ministry of Forests 2000). Note, however, that while virtually all of the Ministry of Forests timber harvesting landbase is available for timber extraction, not all Silva low risk areas are open to consumptive human uses. Certain areas will be fully protected as part of the Protected Areas Network. Moreover, further analysis will be necessary at the watershed and stand levels to refine the determination of ecological sensitivity to disturbance and ecological limits. In many cases, however, carefully planned ecologically responsible timber management and other forest uses can be accommodated within low risk forest areas.
- Further information needs to be collected for the 2% of the study area where risk is unknown (Figure 31, Table 5). Such analysis could easily be completed at the watershed or stand level using airphoto interpretation.

[13] Results from the analysis of biogeoclimatic zones suggests that 32% of the landscape is alpine tundra (see Section 2.3.1). The discrepancy is due to the difference in scale of the two datasets; BEC data was mapped at a much coarser scale (1:250 000) than the forest cover data (1:20 000) that was used to complete the analysis of ecological risk.

Table 5: Summary Statistics - Ecological Risk. The left side of the table shows the area (in ha and %) occupied by each of the five main categories of risk, as depicted in *Map 3a: Ecological Risk in Summary*. The right side of the table shows the area (in % and ha) ocupied by each of the sub-categories making up the summarized categories of risk depicted in *Map 3b: Ecological Risk in Detail*. ESA = Environmentally Sensitive Areas.

Ecological Risk					
In Summary			***In Detail***		
Category	**Area (ha)**	**% Total**	**% Total**	**Area (ha)**	**Category**
High (alpine)	477252	37	37	477252	**Alpine Tundra**
High	439900	35	4	45401	**Alpine Forest**
			1	12537	**Wetlands**
			15	184911	**ESA (high)**
			6	82047	**Caribou High**
			3	34058	**Very Steep Slopes**
			6	80946	**Riparian Buffers**
Medium	51383	4	2	24352	**ESA (moderate)**
			2	27031	**Mod. Steep Slopes**
Unknown	20131	2	2	20131	**Unknown**
Low	286076	22	22	286076	**Low**
TOTAL	1274742	100	100	1274742	**TOTAL**

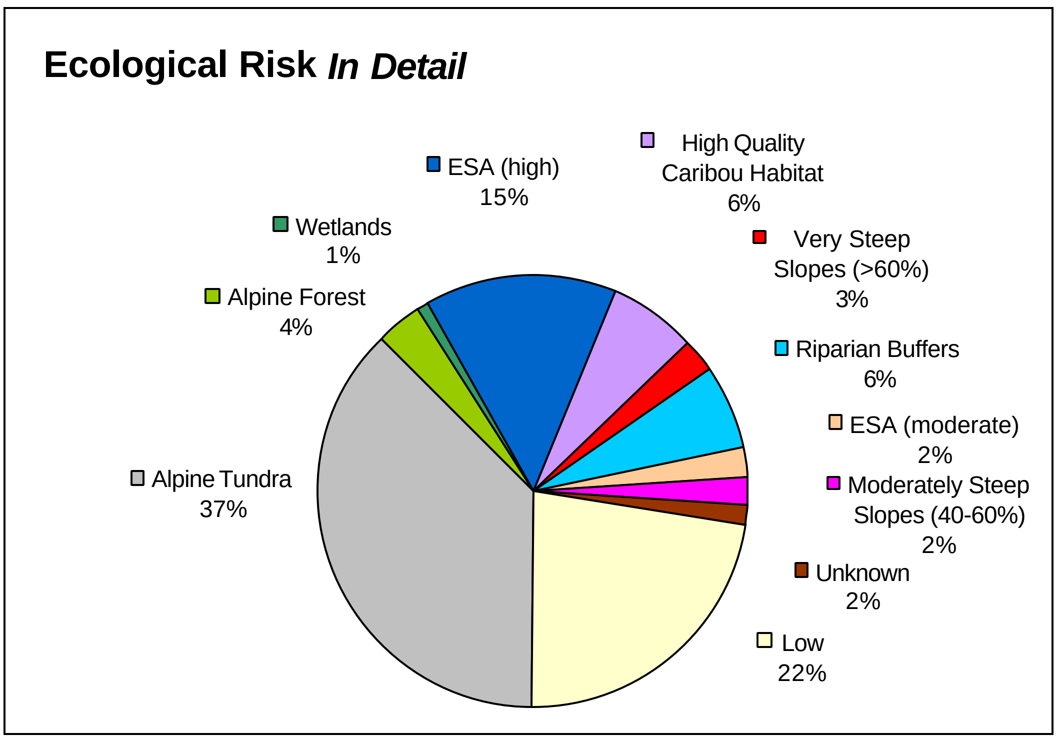

Figure 32: Ecological Risk In Detail

4.3 Map 4: Antique and Old Growth Forests

Old growth forests are complex ecosystems generally characterized by old trees, a multi-level canopy, canopy gaps, and high numbers of standing dead trees and decaying fallen trees (Figure 33, Figure 34). This structural complexity results in an abundance of unique habitat types that in turn supports the highest numbers of species, compared to other successional phases. Many of the species found in old growth are dependent on old growth for their survival. Invertebrates such as insects are especially diverse, and include a high number of carnivorous insects that control levels of herbivores, or plant-eating insects.

Old growth forests also produce the highest quality water, compared to other successional phases. The multi-layered canopies accumulate water from the atmosphere. High levels of decaying wood store and filter water. The huge root masses of old trees hold soils and nutrients in place, thus reducing the amount of sediment and dissolved materials in the waters that flow from old growth. Old growth forests are also valuable as ecological benchmarks, reservoirs of genetic variation, and for recreation and spiritual replenishment.

Over 60% of the forests within the Fraser Headwaters are old growth. Two thirds of the old growth occurs at upper elevations—the lower productivity, climate-limited subalpine forests. The other third is found at lower elevations. These are the more highly productive

Figure 33: Large diameter trees and multilayered canopies common in many old growth forests provide structures not found in younger forests. Cavity nesters, bark crevice dwellers, and many other species cannot easily persist in habitats without such structures. Compared to other successional phases, the greatest number of specialist species, including an especially rich complement of lichens, mycorrhizal fungi, and carnivorous insects, are found in old growth forests.

Figure 34: The large diameter trees in old growth forests are just as critical to ecosystem functioning in death as in life. The sheer size of fallen old growth trees results in slow decomposition and remarkably stable temperature and humidity inside the fallen tree. This stable environment is required habitat for many species of amphibians, arthropods, fungi, and bacteria. The cumulative activities of these biota result in important ecosystem functions, such as the decay of wood and the transfer of nutrients and water stored in fallen trees to live trees. Small fallen trees found in younger forests do not support similar functions as they are, in comparison, transient structures that have variable interior environments.

forests that often provide the public image of old growth.

The wettest low-elevation areas within the Robson Valley contains some of the province's most extensive—and perhaps oldest—inland rainforests. While there has been considerable research and publicity on the unique nature of British Columbia's coastal rainforests, relatively little is known about their inland counterparts.

The archetypal expression of these rainforests occurs within the wettest biogeoclimatic subzones (the Interior Cedar - Hemlock very wet/cool and wet/cool types) between Purden Lake (just north of the study area) and McBride. The climate in this region is unusually humid: high spring snowmelt is followed by ample rainfall during the summer growing season. Forests with this particular combination of humidity and continentality are not known to occur elsewhere.

The oldest of these inland rainforests, termed "antique forests," may be up to several thousand years old. Most forest stands are initiated by a disturbance event, often fire or wind, that kills many, if not most, of the trees in the stand, and begins the successional cycle anew. Thus the age of the forest stand is usually the same as that of the oldest trees within it. Antique forests, on the other hand, are significantly older than the oldest trees within them, having survived many hundreds and perhaps thousands of years without a major disturbance event.

Because of their longevity, antique forests support a higher number of old growth dependent species than younger old growth forests. Antique forests contain a particularly rich assemblage of epiphytic (tree-dwelling) lichens, symbiotic organisms made up of a fungus and an alga. A lichen is essentially a fungus that has discovered agriculture: the algae photosynthesize, thus providing the fungus with food and other nutrients, while the fungus provides the algae with shelter from the elements. Gold dust lichen is found in antique forests and may provide a good indicator of the antique status of a particular stand (Figure 35).

Antique forests appear to function as biological storehouses, providing source populations for the future, and supporting the development of high local diversity. Some of the lichens found in the antique forests in the Robson Valley were once thought to occur only within coastal localities; that is, they were not known to occur inland. Many other lichen species, by contrast, are apparently unique to inland antique forests; they do not occur in coastal areas.

Many of these forest storehouses are currently being clearcut; what was once an extensive archipelago of closely spaced old growth islands and antique atolls is quickly being reduced to widely spaced remnant patches in a sea of clearcuts and plantation forests (Figure 36). Moreover, many of the larger remaining patches have recently been defoliated by the hemlock looper, which has in some cases killed a large proportion of the trees in these forests.

Figure 35: Gold dust lichen, which resembles a gold-coloured powder on the main trunk of a tree, may be an indicator of the antique status of an old growth stand. The hypothesis is that the height to which the gold dust lichen grows up the trunk may be related to the age and other characteristics of antique forests. Should this hypothesis be verified through field research, gold dust lichen will provide a relatively quick and easy way to evaluate the antique status of a given forest stand.

Figure 36: Perhaps the greatest tragedy associated with the salvage logging of antique forests, shown here near Ptarmigan Creek, is that much of the timber that is cut is left behind as waste. Cedar trees, in particular, are prone to heart-rot, where the interior of the tree begins to decompose while the tree is still living. While such trees are not very valuable from the perspective of conventional timber management, the outer shell of these trees still contain much sound wood and can provide the basis for many small-scale value-added wood products, such as furniture, cabinets, and musical instruments.

Inland antique rainforests are unique phenomenon in British Columbia, and may not exist anywhere else on the planet[14]. Given the international significance of these antique forests, the remnant patches need to be fully protected. To ensure the long-term ecological integrity of these systems, a proportion of areas formerly occupied by antique forest also need to be set aside as antique forest recruitment areas. These areas should be selected so as to maximize connectivity between adjacent patches.

Potential old growth forests were mapped using stand age greater than 120 years for pine, aspen and other deciduous leading stands, and greater than 140 years for all other leading species. We refer to the old forests identified by this process as “potential old growth” because we have used only age to identify the stands in question. These forests stands may or may not have the ecological characteristics of old growth forests, which in addition to old trees, include multi-layered canopies; patchy, open canopies; and large standing dead trees and fallen decaying trees[15]. The identified stands are the most likely locations to find old growth forests at this time, and these stands will develop a full complement of old growth attributes more quickly than younger stands.

Antique forests were delineated based on biogeoclimatic zone and subzone, stand age, elevation, and slope percent. Priority candidate stands for antique status were manually delineated by Trevor Goward, a scientist who has spent many years studying lichens and antique forests in B.C., based on field work, extensive knowledge of antique forests, topographic position (toe slopes), and analysis of spatial data. Further field work is necessary to confirm the antique status of candidate areas. Future studies will likely also reveal the existence of antique forest stands outside the areas denoted.

Candidate antique forest stands that have been heavily disturbed by logging are also shown on the maps, as are all stands subjected to heavy mortality during the 1993-1995 hemlock looper outbreak.

A more detailed description of the methodology used to create this map can be found in Section 3.3.4. Map 4 shows the extent of potential old growth and candidate antique forests within the Fraser Headwaters area.

[14] It is possible that a few outlier antique stands occur in northern Idaho and adjacent Montana but certainly the main range of these forests occurs within the Robson Valley.

[15] Digital data for these attributes is not available in the Ministry of Forests forest cover inventory data sets. Stand age is the only old growth characteristic that can be easily mapped. Moreover, even the stand age data contain inaccuracies. For example, the age of a given stand may be incorrectly assessed; smaller old growth forest patches may not be mapped at all; and partially-cut uneven-aged stands such as young forests with a moderate number of old trees could be classified as an old forest within the forest cover data. Despite these problems, the forest cover inventory data are the only readily available source of vegetation mapping for the province and the Fraser Headwaters study area.

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Map 4: Antique and Old Growth Forests

4.3.1 Results and Interpretations

- Sixty-three percent of the forests within the Fraser Headwaters can be classified as potential old growth (including candidate antique forests) [16] (Figure 37, Table 6). The majority of these forests are in the climate-limited subalpine region at higher elevations in the tributary watersheds that adjoin the Rocky Mountain Trench. These snow-dominated climate-limited Engelmann spruce-subalpine fir forests have developed over long periods of time and are slow to recover from disturbance. Lower elevation old growth forests may be more biologically productive and less sensitive to disturbance but have already been subjected to extensive logging.
- Candidate antique forests make up 10% of the total forest area (Figure 37, Table 6). Just under half of these are older than 250 years; the rest are from 140-250 years. Of the candidate antique forests, 18% were classified as areas of priority candidate stands for antique status (Table 7). These areas are the most likely to exhibit characteristics of antique forests and therefore have the highest priority for conservation. Further field work is necessary to ground-truth the status of these candidate stands.

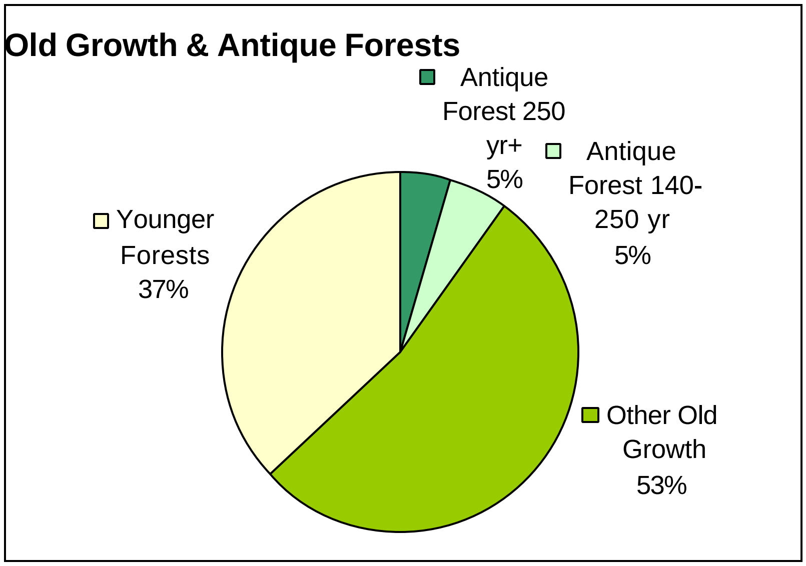

Figure 37: Area occupied by potential old growth and candidate antique forests as a percentage of total forested area within the Fraser Headwaters study area. All categories include forest areas with heavy disturbance by hemlock looper, but not heavy disturbance by logging.

Table 6: Summary Statistics – Antique and Old Growth Forests. Area occupied by potential old growth and candidate antique forests is shown in hectares and as a percentage of the total forested area within the Fraser Headwaters study area. Categories include forest areas with heavy disturbance by hemlock looper but not heavy disturbance by logging.

Candidate Antique & Old Growth Forests		
Category	**Area (ha)**	**% of total**
Candidate Antique Forests		
250 years and older	33035	4.7
140-250 years	37746	5.4
Other Potential Old Growth	373305	53.1
Younger Forests	258712	36.8
TOTAL Forested Area	702798	100.0

[16] Results from the analysis of Landscape Diversity suggest that 64% of the forests can be classified as old growth. The discrepancy is an artifact due to the slightly different methods used to produce each map, the large sizes of the landscape and dataset, and the use of vector analysis for this project.

Table 7: Summary Statistics - Priority Candidate Stands for Antique Status. Area is shown in hectares and as a percentage of the total candidate antique forests. Forest area includes those stands with heavy disturbance by hemlock looper.

Priority Candidate Stands for Antique Status		
Category	**Area (ha)**	**% of total**
Priority Candidate Stands	12728	18.0
Total candidate antique forest	70781	100.0

- Approximately 21% of the candidate antique forests have been heavily disturbed by logging[17] (Figure 38, Table 8). A further 22% experienced severe mortality due to hemlock looper during the 1992-5 outbreak. Candidate antique forests that have been clearcut will likely never re-develop the characteristics of antique forests. These forests have developed over thousands of years in the absence of severe disturbance; restoration is therefore not a simple or short-term prospect. However, restoration can help to restore these forests to the point where they would serve as "near old growth" buffers to the remnant antique stands. This solution might also be applicable to those stands that have experienced severe mortality due to hemlock looper. Where canopy mortality is high, the characteristics critical to the development and maintenance of antique forests (especially high ambient humidity) may be lost. However, many of the structures critical to the development of old growth and antique stands, (in particular, high levels of large standing dead and large fallen trees) remain within these forests. Restoration to the point where they would form good buffers for the remnant candidate antique forest stands would therefore be valuable. Given the international significance of antique forests, and the fact that almost 43% of them have already been affected by heavy logging and hemlock looper disturbance, remnant stands need to be fully protected and disturbed stands need to be restored so as to buffer and decrease fragmentation between remnant stands.

[17] Ministry of Forests forest cover inventory data include information on the history of disturbance by logging for each forest polygon. Data on the forest cover existing previous to the logging disturbance is not available and must therefore be assumed. For this analysis, we assumed that forest polygons with a history of logging that met all criteria for candidate antique status (including biogeoclimatic zone and subzone, elevation, and slope percent) except stand age had a high probability of containing candidate antique forest before logging occurred.

Table 8: Disturbance in Candidate Antique Forests. Area of antique forests that are undisturbed, heavily disturbed by logging, and heavily disturbed by hemlock looper, is shown in hectares and as a percentage of total candidate antique stands.

Candidate Antique Forests		
Category	**Area (ha)**	**% of total**
Undisturbed		
250 years and older	21859	24.5
140-250 years	29407	32.9
Heavily disturbed		
logging	18546	20.8
hemlock looper	19515	21.8
TOTAL area	89327	100.0

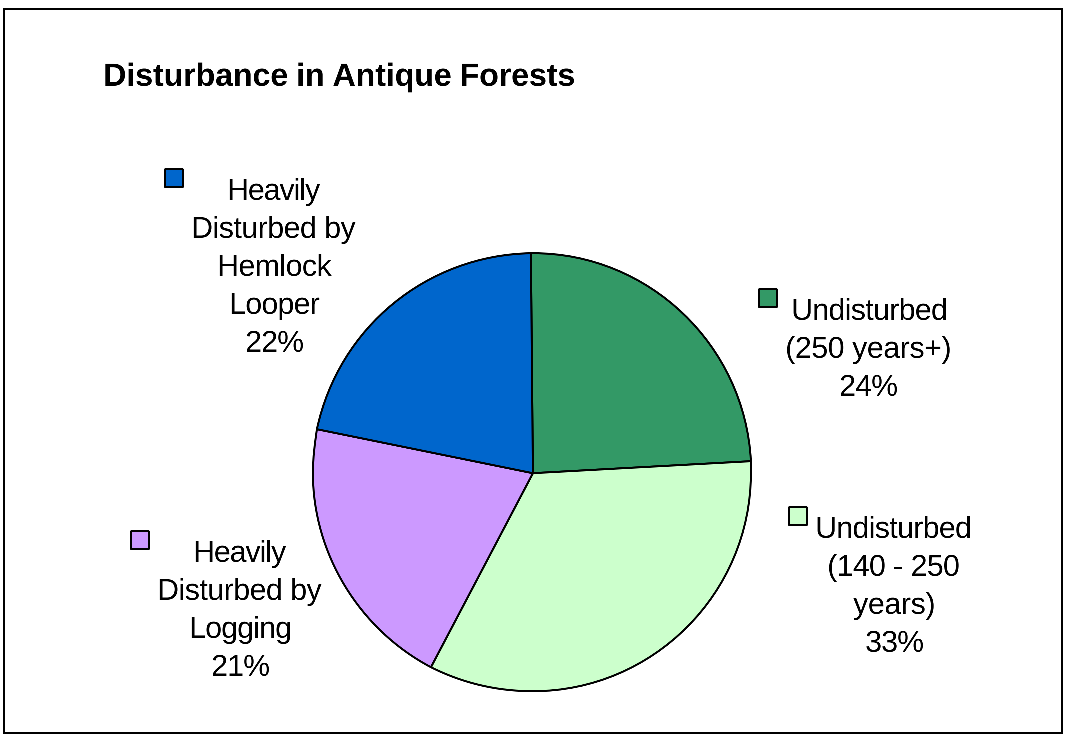

Figure 38: Disturbance in candidate antique forests.

- One of the most important characteristics of antique and old growth forests are the large amounts of dead fallen trees (termed coarse woody debris by scientists) within the forest stand. Dead trees form the foundation of future forests.

  In old growth stands in particular, large dead fallen trees persist for an extremely long time. Their large size results in slow decomposition, thus providing a buffered interior environment with relatively stable temperature and humidity. This environment provides critical habitat for many species of arthropods, fungi, and bacteria. These species, in turn, provide important ecosystem functions such as the decomposition of wood, and the transfer of nutrients and waters stored in fallen trees to live trees. In addition to providing critical habitat, dead fallen trees provide important water storage and filtration services. Dead fallen trees in streams create small ponds where sediment collects, thus increasing water quality while the water storage capacity of large fallen trees helps to modify the timing and quantity of water flows.

  One of the greatest impacts of conventional logging practices is the loss of coarse woody debris (dead fallen trees) in logged stands. Natural young forests, such as those that result from fire, retain a high level of coarse woody debris, and a large number of standing dead trees that will eventually become fallen dead trees. Logging practices, on the other hand, tend to crush or otherwise displace existing coarse woody debris. Since logging is planned to occur on short cycles or rotations, and to remove all merchantable trees, large snags and fallen trees will never again occur in forests managed for timber using clearcutting and tree plantations.

  Surveys of coarse woody debris in a number of plots in the Fraser Headwaters illustrates this concern. A comparison of paired logged and unlogged blocks showed that coarse woody debris was five time higher in unlogged old growth forests than in adjacent forests that had been recently logged (Table 9). Moreover, forests that had been logged twenty-five years ago still have very low levels of coarse woody debris.

Table 9: Effects of Logging on Coarse Woody Debris. Table shows a comparison of the volume of coarse woody debris in unlogged and recently logged plots in Forgetmenot Creek, Milk River, and Ptarmigan Creek. Slim Creek plots were logged approximately 25 years ago. Although no paired plots are available for comparison, the data suggest that low levels of coarse woody debris persist long after the logging disturbance.

Effects of Logging on Coarse Woody Debris

Location	BEC	Coarse Woody Debris (m^3/ha)	
		Unlogged Plot	Logged Plot
Forgetmenot Creek	ESSFmm1	312.8	58.6
Milk River	ESSFwk1	203.5	49.8
Ptarmigan Creek	ICHwk3	111.5	147.1
Slim Creek	ESSFwk1	n/a	67.4
Slim Creek	ICHvk2	n/a	1
Slim Creek	SBSvk	n/a	32.1

While the loss of coarse woody debris has mostly been discussed as an issue of concern at the stand level, given the rapid rate of logging in the Fraser Headwaters, it is quickly becoming a major issue of concern at the landscape level. The loss of large amounts of critical habitat, such as that provided to mammals, birds, arthropods, fungi, and bacteria by large snags and fallen trees, will affect the biodiversity and functioning of forests at the landscape level.

4.4 Map 5: Human Disturbance

The earliest inhabitants of the Fraser Headwaters were Indigenous Peoples who lived ecologically sustainable subsistence lifestyles. Europeans began to settle in the valley in the 1800’s and the rate of settlement and development activities has increased steadily since that time. A brief overview of the human history of the area can be found in Section 2.5.

The human disturbance map shows the cumulative footprint of many of the post-colonial human activities within the Fraser Headwaters: logging (past and planned), cleared land, private land, roads and railroads.

Stands with a history of disturbance by logging were divided into two categories: heavily and lightly disturbed. Those areas classified as heavily disturbed were likely clearcut. Lightly disturbed stands were probably only partially cut, and retain a component of older trees or relatively continuous canopy cover. Planned logging blocks and logging roads were obtained from forest development plans from all timber companies operating within the Fraser Headwaters study area.

Although not all private land has necessarily been subject to heavy human disturbance, much of it supports human activity of some type. Moreover, there are few rules regulating the types of activity that are permitted on private land. Thus, private land is often at risk for non-sustainable activities.

Figure 39: The impact of roads and other human disturbances penetrates far beyond their immediate footprint. In addition to the direct loss of habitat, roads allow the incursion of hunters, predators, insects, and pathogens into areas that were previously difficult to access.

Certain types of human activities are not shown on the map, such as water diversions, mines, and gravel pits. While these activities have a very definite impact on the functioning of ecosystems, they are difficult to map at this scale and are thus more suited to watershed and stand level planning. As has been stated before, this landscape level planning exercise is just the first step in the process and needs to be followed with ecosystem-based planning at both the watershed and stand levels.

Figure 40: As this photograph of the Milk River shows, fragmentation is becoming an increasingly serious concern within the Fraser Headwaters, especially at higher elevations. As logging blocks proliferate on the landscape, the amount of forest “edge”—the outer perimeter of a forest area—increases. Newly created edges (resulting from the division of larger forest areas) have a profound impact on the adjoining forest, with changes in wind speed, solar radiation and microclimate penetrating well into the newly exposed adjacent forest. Edges also facilitate the movement of parasites and predators into new areas, thus increasing mortality. As forest areas become smaller in size due to fragmentation, the amount of “interior” habitat within them—habitat that is not affected by edge effects—declines. Once fragments become smaller than some critical threshold, the entire fragment is essentially edge habitat. Research shows that smaller fragments of this type support much lower abundance and diversity of wildlife. Those species dependent on interior habitat can no longer persist.

While the map provides a reasonable indication of the overall footprint of human activity within the study area, it does not show how far the impacts of these activities spread into adjacent areas. For example, ecologists have recognized for many years that the impacts of logging, especially clearcutting, do not stop at the edge of the logging block. Increased sunlight, increased exposure to wind, and decreased habitat quality can extend from tens to hundreds of meters into the surrounding forest. Roads have both direct and indirect impacts on wildlife—directly, by increasing mortality through road kill, and indirectly, by fragmenting habitat and increasing hunting access and pressure in formerly remote areas. At a landscape level, fragmentation due to roads and cutblocks can negatively impact wildlife abundance and movement; increase the spread of insects, pathogens, and invasive species; and alter long-term forest dynamics[18]. As such, the actual impacts of human use are higher than what is actually shown on the map.

A more detailed description of the methods used to carry out this analysis is provided in Section 3.3.5. Map 5 on the next page shows the extent of human disturbance within the Fraser Headwaters study area.

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[18] Further information on how the impacts of human disturbance extend beyond their immediate footprint can be found in the literature review, *Assessing the Ecological Impacts of Timber Management: Apparent Impacts, Actual Impacts, and Precautionary Forest Development,* which can be downloaded from the Silva Forest Foundation website at www.silvafor.org.

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Map 5: Human Disturbance

4.4.1 Results and Interpretations

- Eleven percent of the forest area within the Fraser Headwaters study area has been heavily disturbed by logging (Table 10). To put this in perspective, the amount of land logged is equivalent to 28% of the existing low-risk areas (as defined in the analysis of ecological risk) which are those areas most suited to ecologically responsible human uses (Table 10, Figure 41). Much of the rest of the landscape is dominated by high elevation forests on steep slopes, sensitive soils, riparian ecosystems, or otherwise ecologically sensitive areas where logging is inappropriate for ecological reasons, and often economic reasons as well. Approximately three percent of the forested landscape has been lightly disturbed by logging, which represents an area equivalent to 6.5% of the low risk area within the Fraser

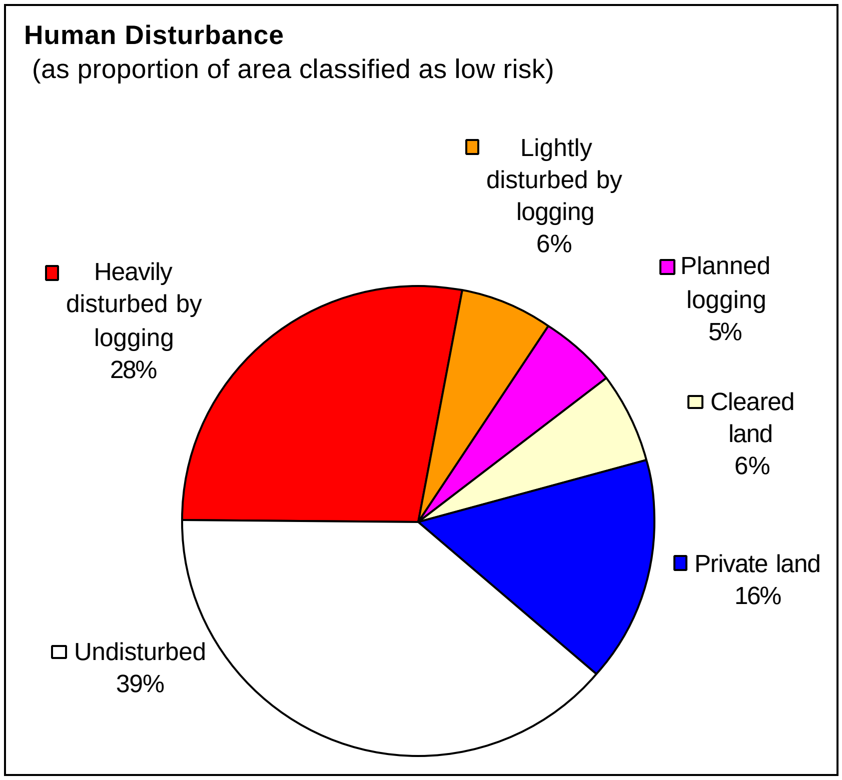

Figure 41: Human disturbance within the Fraser Headwaters, as a percentage of the area classified as low risk in the analysis of ecological risk.

Table 10: Summary Statistics - Human Disturbance. Area occupied by each type of human disturbance is shown in hectares, and as a percentage of the total study area, the forested area within the study area, and the low risk area within the study area.

Human Disturbance				
Category	**Area (ha)**	**% of total area**	**% of forested area**	**% of low risk area**
Heavily disturbed by logging	80174	6.2	11.4	28.0
Lightly disturbed by logging	18542	1.4	2.6	6.5
Planned logging	14703	1.1	2.1	5.1
Cleared land	17804	1.4	2.5	6.2
Private land	44550	3.5	6.3	15.6
TOTAL	175773	13.6	25.0	61.4

Headwaters study area. Taken together, approximately 14% of the forested region, equivalent to 24.5% of the area classified as low risk, has already been logged.

- Approximately 70% of heavy logging disturbance and 85% of light logging disturbance has occurred at lower elevations, within the SBS and ICH biogeoclimatic subzones (Figure 42). The remaining logging has occurred at higher elevations within the ESSF zone. These numbers are especially striking given that only 29% of the study area occurs at low elevations while 71% occurs at high elevations. Low elevation forests tend to be more easily accessible, both in terms of road distance and terrain accessibility. They are also more biologically productive, and therefore contain larger timber volumes than forests at higher elevations. As low elevations forests become increasingly scarce due to logging and other types of human activity, logging effort is increasingly shifting towards higher elevation forests. Figure 43 illustrates this trend, showing how an increasing proportion of logging activity is occurring at higher elevations. The speed at which high elevation forests are being roaded, logged, and fragmented became graphically obvious to us when we examined aerial photographs for the Fraser Headwaters study area. Many of the photographs were taken in the mid 1980's. Today, many of the side valleys contain large numbers of roads and clearcuts. In the aerial photos from the 1980's, however, many of the same side valleys, including the Milk River, Morkill River, and Forgetmenot Creek areas are pristine.

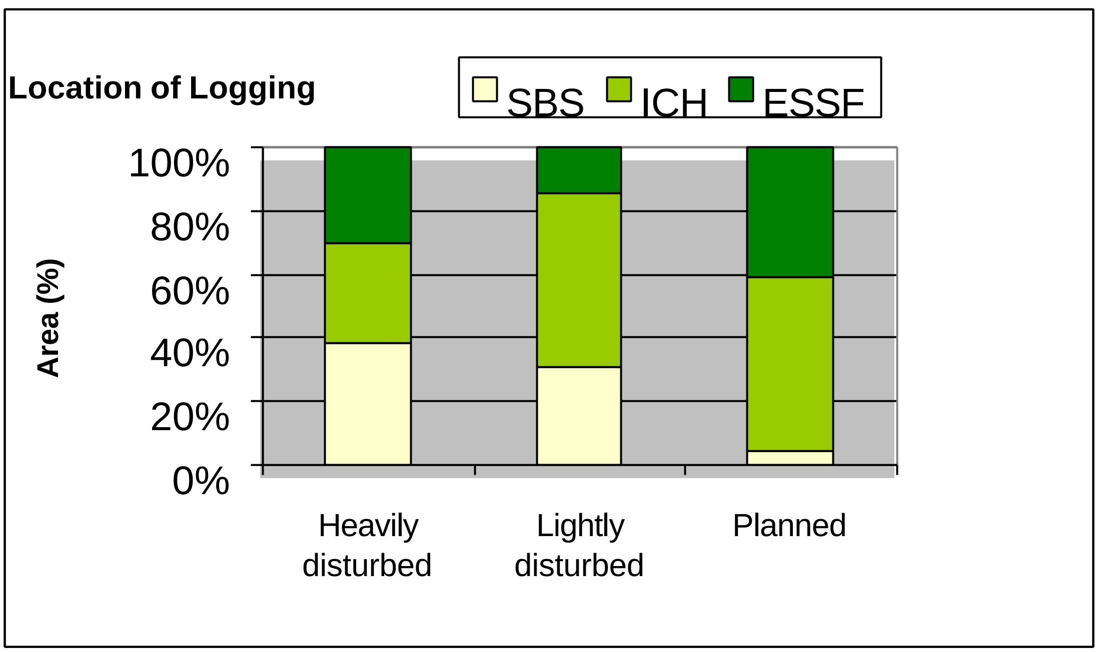

Figure 42: Location of logging disturbance (existing heavily disturbed, existing lightly disturbed, and planned) by biogeoclimatic zone. Abbreviations are: SBS: Sub-Boreal Spruce, ICH: Interior Cedar - Hemlock, and ESSF: Engelmann Spruce - Subalpine Fir.

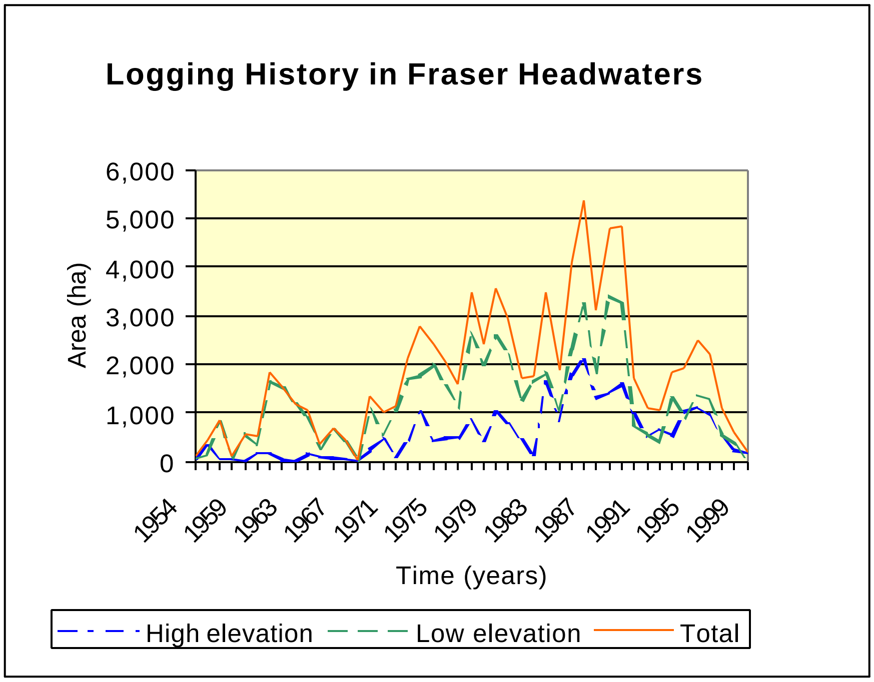

Figure 43: Change over time in the location of logging within the Fraser Headwaters study area. Note that high elevation forests constitute a growing proportion of the forests being logged from 1954 to 1999. Date of logging disturbance was not available for approximately 20% of logging blocks; these areas are therefore not included in the graph and total logged areas for individual years may be incomplete. High elevation forests include those areas within the Engelmann Spruce - Subalpine Fir zone; low elevations forests include those areas within the Sub-Boreal Spruce and the Interior Cedar – Hemlock zones.

- The impacts of logging extend well beyond the direct footprint of the roads and logging cutblocks. A complete analysis of the zone of influence of all human disturbance types was beyond the scope of this project. However, preliminary analysis of these impacts was calculated for areas that were heavily disturbed by logging. Approximately 80,000 ha of forest land has been heavily disturbed by logging (Table 10). An additional 50,000 ha of land lies within 100m of these logged areas, and more than 200,000 ha lies within 500m (Figure 44). Although impacts decrease as the distance from the logging block increases, an area up to 4 times as large as the logged area itself may be adversely affected by the logging disturbance. While an analysis of the zone of influence around roads was not undertaken, the zone of influence around roads is often proportionally larger than that around logging disturbances because roads are long linear features.

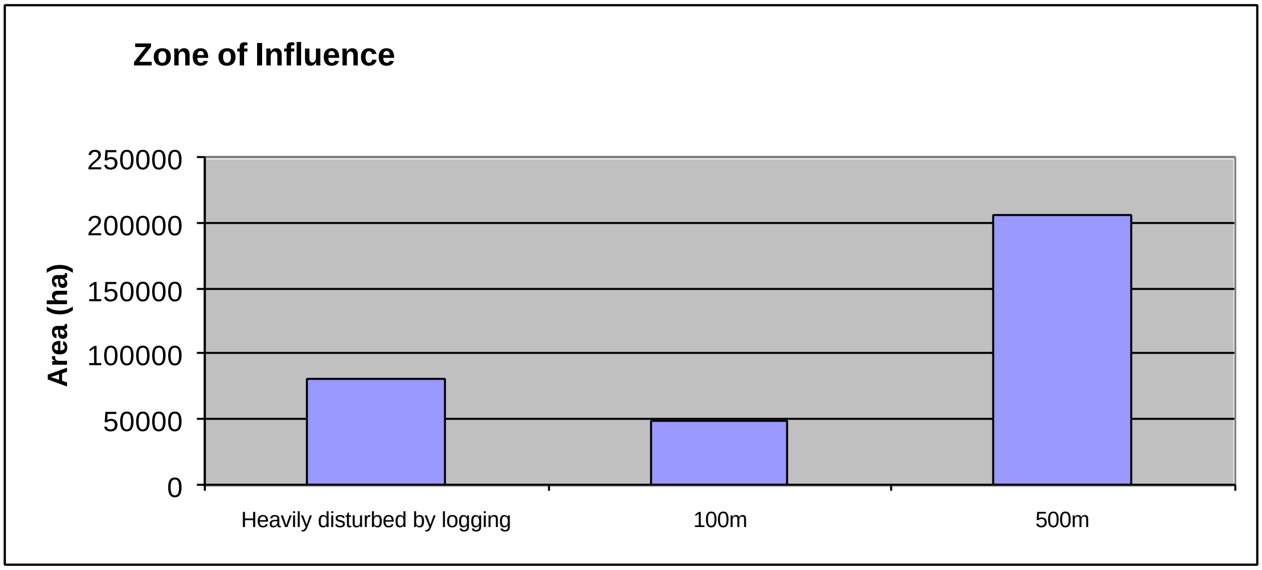

Figure 44: Zone of influence of heavy logging disturbance. Graph shows the area impacted directly by heavy logging disturbance, as well as area within the 100m and 500m zones of influence surrounding the logged area. Although the area directly affected by human disturbance is often obvious, the impacts on surrounding forest areas are often less obvious. Impacts include changes in air temperature, wind speed, and solar radiation; increased mortality due to increased hunting pressure and predator access; and disruptions in animal behaviour due to increased human presence.

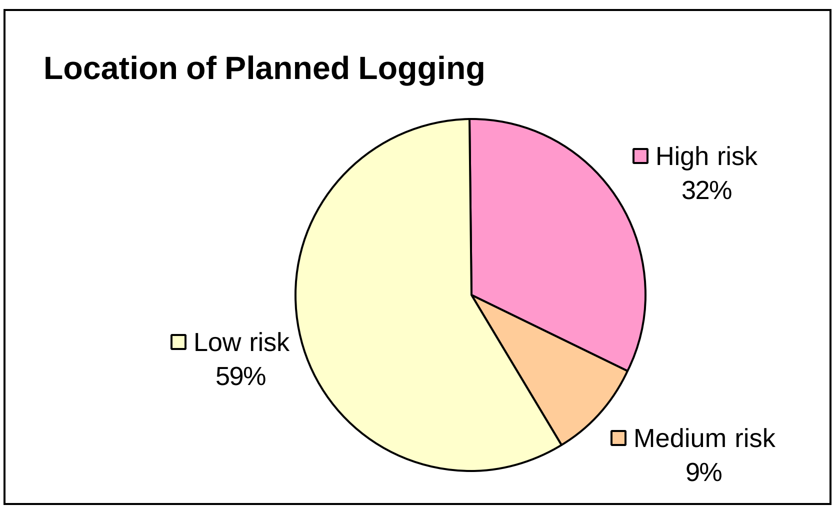

Figure 45: Location of planned logging within area classified as high, medium, and low ecological risk.

- Over the next five years, logging is planned for 2% of the forested landscape, or an area equivalent to 5% of the area classified as low risk (Table 10, Figure 41). Planned logging includes both those blocks that have been permitted or approved, as well as those at the "information" stage. As such, final cutblocks may differ from the planned blocks portrayed on the map. Thirty-two percent of the planned logging occurs in areas of high ecological risk, 9% in areas of medium risk, and 59% in areas of low risk (Figure 45).
- The study area currently include 4822 kilometers of roads. An additional 400 km of roads are planned to be constructed in the next five years. As previously mentioned, the zone of influence around roads is particularly high because of their long, linear shape.
- The study areas includes approximately 1% and 4% cleared and private land respectively (Table 10). To put this into perspective, this represents an area equivalent to about 6% and 16% of the total area classified as low risk (Figure 41). Much of the cleared and private land occurs at low elevations in the bottom of the Rocky Mountain Trench where human settlement is concentrated.

5. Proposed Protected Areas Network

The fundamental philosophy of ecosystem-based planning is to focus on what to leave rather than on what to take. Instead of determining the amount of timber that could be cut from a landscape, an ecosystem-based plan determines which parts of the landscape need to be conserved in order to ensure the continued ecological health of the entire system at multiple spatial scales. The philosophy and practice of ecosystem-based planning is described in greater detail in Section 1.2.

The final map for the project, *Map 6: Proposed Protected Areas Network*, is the culmination of the ecosystem-based planning process. Based on the biophysical and human disturbance assessments contained in the previous five maps, and following the fundamental precepts of landscape ecology and conservation design, the proposed Protected Areas Network (PAN) is designed to:

- protect ecologically significant areas, including antique forests and areas of high landscape diversity
- provide well-distributed, representative protected areas
- provide broad corridors for animal movement and plant dispersion within the study area
- provide connectivity between the surrounding large protected areas

The PAN is composed of three different components:

- **Existing protected**: areas that are already legislated as protected areas.
- **Proposed protected**: areas that play a critical role in maintaining ecological integrity, ensuring connectivity, protecting ecologically significant features, and providing well distributed representation of all ecosystem types within the study area. We recommend these areas for full protection.
- **Proposed conservation emphasis**: areas that contribute to ecological integrity, representation, and connectivity in an important way. We recommend these areas be subject to more stringent ecosystem-based management guidelines than those applied in the matrix.

The areas outside the PAN represent the matrix, the landbase where human activities are concentrated. Maintaining the integrity of the matrix is key to maintaining the integrity of the PAN.

The task of designing a PAN requires the blending of science with art. The first step in designing the PAN for the Fraser Headwaters involved the analysis of the maps depicting landscape diversity, ecological risk, antique and old growth forests, and human disturbance in order to discern areas of high ecological significance. Areas with unusually high landscape diversity, higher than average ecological risk, rare old growth characteristics (such as the antique forests), and low human disturbance were considered to be ecologically significant.

Once areas of ecological significance were highlighted, we assessed the existing system of parks and protected areas to determine whether it adequately represents the diversity and distribution of ecosystems within the study area. While the existing network of parks and protected areas was more representative than expected, lower elevation ecosystem types were less well represented than those at higher elevations. As such, emphasis was placed on including a greater amount of low elevation ecosystems within the PAN.

The final challenge was to ensure connectivity throughout the study area. Perhaps the greatest problem with the current system of protected areas is the lack of connectivity between individual parks. As intensive industrial activity increases in the matrix, protected areas become increasingly like islands—separated from one another by a sea of clearcuts, plantation forests, mines, farms, roads, and other modifications. This isolation inhibits movement of plants and animals across the landscape, thus increasing the risk of local population extinctions, decreasing the probability of recolonization following disturbance, and threatening the overall ecological functioning of these parks. These effects are becoming increasingly apparent in areas such as Banff National Park, for example, where the wolf population is in serious decline (Banff-Bow Valley Study 1996). One of the solutions is to increase the linkages in the landscape, providing protected corridors for movement between parks. Of course, the ultimate solution is to practice ecologically responsible human use throughout the landscape. If ecological integrity were maintained within the matrix itself, the need for protected areas would decline.

In designing the PAN, we began with a working map showing the areas of high ecological significance (as mentioned above) and areas underrepresented in the current parks system. We analyzed the distribution of these areas, noting where areas of ecological significance overlapped and where gaps in connectivity occurred. Proposed Full Protection and Proposed Conservation Emphasis areas were located so as to protect and/or link areas of high ecological significance. The overall goal was to ensure that there was a main corridor down the Rocky Mountain Trench and at least two cross-valley corridors across the trench linking the large protected areas in the Rocky and Columbia mountains.

One important caveat bears repeating. This is a landscape level plan—a purposely broad and coarse analysis designed to ensure that ecological functioning is maintained and restored at the large landscape level. The large protected areas and corridors necessary to maintain ecological integrity at this level have been identified. But this is not sufficient on its own. Further planning is necessary at both the watershed and stand levels, especially in those areas designated as conservation and ecosystem-based management emphasis (see Section 1.2).

Each watershed needs to be analyzed individually and a Protected Landscape Network (PLN—similar to the Protected Areas Network, but at a more detailed scale) needs to be developed. Ecologically sensitive areas, old growth nodes, riparian ecosystems, cross-valley corridors, and representative ecosystems need to be included in the Protected Landscape Network. Areas identified as high ecological risk in the PAN will likely form part of the PLN at the watershed level.

Once ecosystem-based planning has been carried out for each watershed in the study area, a community-based decision-making process can be initiated to design human use zoning throughout these watersheds. This process will determine where timber management, hunting, trapping, fishing, recreation, and other human activities can be accommodated.

Section 5.1 provides an overview of the PAN by highlighting the key results and interpretations of the analysis. Section 5.2 offers a more detailed description of the individual components of the PAN. Further information on the methods used to carry out this analysis is provided in Section 3.3.6. Map 6 shows the proposed Protected Areas Network.

5.1 Results and Interpretations

- Existing protected areas within the study area form 6.6% of the PAN (Table 11, Figure 46). Existing protected areas *within* the Fraser Headwaters study area are:
  - Sugarbowl-Grizzly Den Protected Area (partially within the study area)
  - Slim Creek Protected Area
  - Erg Mountain Provincial Park
  - Ptarmigan Creek
  - West Twin Provincial Park/Protected Area
  - Wolverine—extension of Bowron Lake Provincial Park (partially within the study area)
  - Betty Wendle—extension of Bowron Lake Provincial Park (partially within the study area)
  - Cariboo River—extension of Bowron Lake Provincial Park (partially within the study area)
  - Sunbeam Creek Ecological Reserve
  - Holliday Creek Ark Protected Area
  - Lower Raush Protected Area
  - Upper (Middle) Raush Protected Area
  - Small River Caves Provincial Park
  - Swiftcurrent River Provincial Park
  - Rearguard Falls Provincial Park
  - Jackman Flats Provincial Park

  Existing protected areas *outside* of the study area (at the North end) include:
  - Evanoff Provincial Park
  - Close-to-the-Edge Protected Area

  These protected areas are not distributed uniformly throughout the Fraser Headwaters (Map 6). The largest concentration of existing protected areas is clustered in the vicinity of the Goat River watershed (although there are no existing protected areas within the Goat River watershed itself). No protected areas occur on the Rocky Mountain side of the Fraser River north of about McBride (with the exception of a small part of West Twin Provincial Park/Protected Area). Little to no connectivity exists between the protected areas.

- The Proposed Full Protection component of the PAN comprises 18.6% of the PAN (Table 11, Figure 46). It is composed of three main corridors: the antique forest, Goat-Morkill, and Raush-Chalco (Map 6). The antique forest corridor runs along the bottom of the Rocky Mountain Trench and protects the antique forests between West Twin Provincial Park/Protected Area and Driscoll Creek. The Goat-Morkill corridor runs from the Goat River watershed across the Fraser River, along the southeast side of the Morkill River and across several small watersheds to Bastille Creek and the upper McGregor River. It therefore provides a large connecting corridor between Bowron Lake and Kakwa Provincial Parks. The entire Goat River watershed is included within the corridor, thus providing connectivity between the existing smaller protected areas in the region and protecting the last major unroaded watershed in the area. The Raush-Chalco corridor includes the Raush River watershed, the south side of the lower Holmes River watershed and the entire Chalco Creek watershed. The corridor provides a link across the southeastern end of the study area, and connects Wells Gray and Willmore Wilderness Provincial Parks.
- The Proposed Conservation Emphasis areas comprise 13.4% of the PAN and include the Rocky Mountain Trench corridor and Morkill-McGregor-Torpy loop (Table 11, Figure 46, Map 6). The Rocky Mountain Trench corridor extends the length of the trench within the study area. The corridor provides a buffer for the full protection antique forest corridor in the northwestern part of the study area and a movement corridor along the entire trench. The Morkill-McGregor-Torpy loop provides a conservation buffer for the Morkill River Proposed Full Protection corridor and for Kakwa Provincial Park. It also enhances movement between the Fraser and McGregor Rivers, two major river systems with high individual flows of energy and nutrients.
- Ecosystem-based Management areas, or the matrix—what is "left" once the PAN has been designed—forms 61.4% of the Fraser Headwaters study area (Table 11, Figure 46). Following further planning at the watershed and stand levels (which will involve the design of Protected Landscape and Ecosystem Networks) these areas will be available for ecosystem-based forestry and other ecologically responsible human uses.

Table 11: Summary Statistics: Proposed Protected Areas Network (PAN). Area occupied by PAN components is shown in both hectares and as a percentage of the total study area. Proposed ecosystem-based management areas are not part of the PAN but form the matrix within which the PAN is embedded.

Proposed Protected Areas Network		
Category	Area	
	ha	%
Existing Protected	85637	6.6
Proposed Full Protection	239501	18.6
Proposed Conservation Emphasis	172506	13.4
Proposed Ecosystem-based Management	790716	61.4
TOTAL	1288360	100

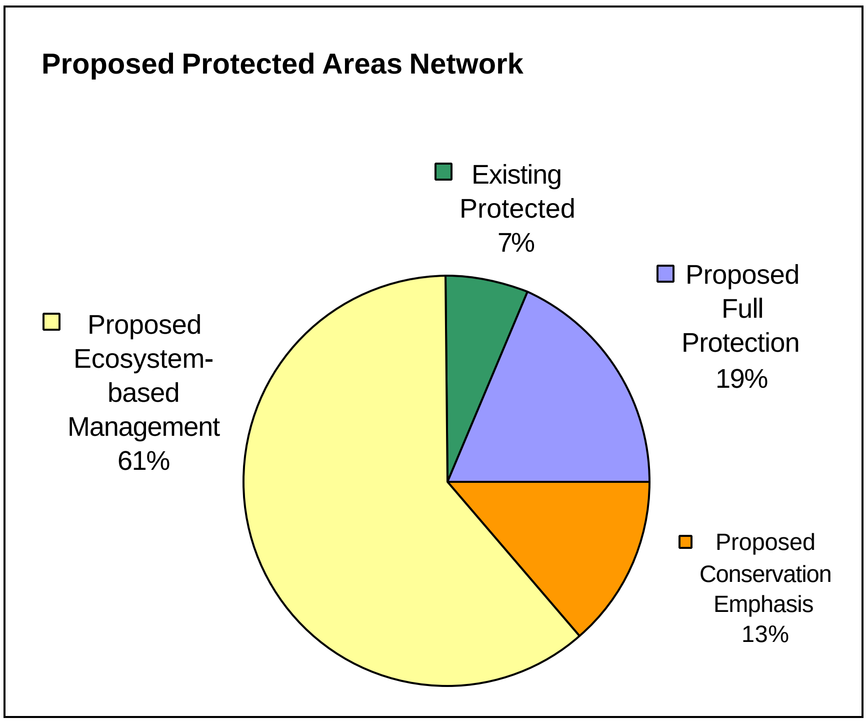

Figure 46: Composition of the proposed Protected Areas Network. Proposed ecosystem-based management areas are not part of the PAN but form the matrix within which the PAN is embedded and where human activities occur.

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Map 6: Proposed Protected Areas Network

5.2 Components of the PAN

5.2.1 Existing Protected Areas

A well designed system of protected areas needs to representative of all ecosystem types, and well distributed throughout the landscape in question. Individual parks must also be well connected to one another. While much focus has been placed in the last decade on setting aside a certain *percentage* of the landbase in protected areas, such goals are misleading. They are most often politically motivated and have no basis in science. Without proper representation, distribution, and connectivity, no parks system will succeed in protecting the ecological integrity of the individual parks, let alone the landscape as a whole.

There are currently a number of existing parks and protected areas both within and surrounding the Fraser Headwaters study area. While these certainly contribute to maintaining ecological integrity in the region, they are not sufficient on their own to ensure long-term maintenance of ecological composition, structure, and functioning.

In the following sections, we provide an initial analysis of the current state of protected areas both within and outside the study area: what they are protecting, where they are located, and how well they are connected.

5.2.1.1 Inside the study area

Existing protected areas make up 6.6% of the Fraser Headwaters study area[19].

An initial analysis of the biogeoclimatic composition suggests that these protected areas do not provide even representation of all ecosystem types (Table 12). Alpine tundra ecosystems are the best represented. Within the Engelmann Spruce - Subalpine Fir zone, the ESSFmm1 is significantly under-represented while the ESSFwc3, wk, and wk1 are over-represented. Within the Interior Cedar - Hemlock zone, the ICHmm and ICHvk2 are under-represented and the ICK wk3 is over-represented. Finally, all Sub-Boreal Spruce variants are under-represented.

Summarizing biogeoclimatic variants and subzones into zones, it is apparent that existing parks are fairly representative of the AT, ESSF, and ICH zones (Table 13). The SBS, however, is significantly under-represented. The lack of protected areas at lower elevations is critical since these are typically the most productive and diverse ecosystems, and thus provide much high quality habitat for various animals. Future protected areas should therefore be located in these lower elevation ecosystems.

[19] Strictly speaking, Mount Robson Provincial Park and a portion of Kakwa Provincial Park, which are not included within the study area, fall within the upper Fraser Headwaters drainage basin. Several smaller parks that are in the study area, such as the Wolverine, Betty Wendle, and Cariboo River extensions to Bowron Lake Provincial Park, are not within the upper Fraser River drainage basin. It is, therefore, difficult to provide a correct total percentage of protected areas within the Fraser Headwaters. Moreover, as explained above, focusing on the percentages (rather than the characteristics of the areas that are protected) is misleading.

Table 12: Biogeoclimatic (BEC) Composition of Protected Areas Inside Study Area. The table shows how the biogeoclimatic composition of the protected areas compares with that of the total study area. For a parks system to be representative, the percent area of each BEC type within the protected areas should be approximately equivalent to that within the total study area. Abbreviations for BEC zones are: AT: Alpine Tundra; ESSF: Engelmann Spruce - Subalpine Fir; ICH: Interior Cedar - Hemlock; SBS: Sub-Boreal Spruce. Subzones are: mm - moist mild; wc - wet cold; wk – wet cool; vk – very wet cool; dh – dry hot. Numbers following subzone indicate distinct variants. Further information on many of these ecosystem types can be found in Section 2.3.1.

Existing Protected Areas inside the study area			**Total Study Area**
BEC	**Area (ha)**	**Area (%)**	**Area (%)**
AT	25962	30.3	32.3
ESSFmm1	6956	8.1	20.4
ESSFwc3	5435	6.3	1.0
ESSFwc2	0	0.0	0.0
ESSFwk2	0	0.0	7.4
ESSFwk	5100	6.0	0.9
ESSFwk1	20896	24.4	9.5
ICH mm	1464	1.7	4.3
ICH vk2	2264	2.6	5.9
ICH wk2	0	0.0	0.5
ICH wk3	12653	14.8	7.0
ICH wk4	1338	1.6	0.3
SBS dh	910	1.1	4.2
SBS vk	334	0.4	6.3
SBS wk1	2299	2.7	0.2
TOTAL	85610	100.0	100.0

Perhaps the greatest problem with the existing protected areas is in the way they are distributed across the landscape, and the lack of connectivity between individual parks (Map 6).

Most of the parks are situated at higher elevations; few occur within the Rocky Mountain Trench. Moreover, most of the parks in the study area are located on the Columbia side (southwest) of the trench; very few occur on the Rocky Mountain side (northeast) of the trench. Several of the parks, including a number of the larger ones, are clustered in the vicinity of the Goat River watershed. These include the West Twin Provincial Park/Protected Area, Ptarmigan Creek Provincial Park/Protected Area, and the Wolverine, Betty Wendle and Cariboo River extensions to Bowron Lake Provincial Park.

Moreover, there is no connectivity between individual parks. The parks exist as islands within the rest of the landscape; as development increases in non-protected areas, flow between parks will become increasingly limited. This will hinder the movement of animals, plants, and microorganisms across the landscape, will decrease the flow of genetic materials crucial for adaptation, and will restrict the ability of species to move as habitats change in response to global climate change.

In summary, although existing parks are reasonably representative of the range of ecosystem types currently found within the Fraser Headwaters drainage basin, a greater amount of land needs to be fully protected at lower elevations, and all parks must be well distributed throughout the entire landscape. Parks must also be linked by a network of protected corridors. Unless management in areas outside of parks changes considerably in the near future, the current system of parks is highly unlikely to be sufficient to maintain ecological integrity across the entire landscape.

Table 13: Summary of the Biogeoclimatic (BEC) Composition of Protected Areas Within the Study Area. The biogeoclimatic zones have been summarized to zone. The table shows how the biogeoclimatic composition of the protected areas compares with that of the total study area. For a parks system to be representative, the percent area of each BECV type within protected areas should be approximately equivalent to that within the total study area. Abbreviations for BEC zones are: AT: Alpine Tundra; ESSF: Engelmann Spruce - Subalpine Fir; ICH: Interior Cedar - Hemlock; SBS: Sub-Boreal Spruce.

Existing Protected Areas inside the study area			**Total Study Area**
BEC	**Area (ha)**	**Area (%)**	**Area (%)**
AT	25962	30.3	32.3
ESSF	38387	44.8	39.2
ICH	17719	20.7	17.9
SBS	3543	4.1	10.7
Total	85610	99.9	100.1

Table 14: Biogeoclimatic (BEC) Composition of Protected Areas Outside Study Area Compared to Composition of the Study Area. Abbreviations for BEC zones are: AT: Alpine Tundra; ESSF: Engelmann Spruce - Subalpine Fir; ICH: Interior Cedar -Hemlock; IDF: Interior Douglas-fir; SBS: Sub-Boreal Spruce

Existing Protected Areas outside the study area			**Total Study Area**
BEC	**Area (ha)**	**Area (%)**	**Area (%)**
AT	429677	37.2	32.3
ESSF	445625	38.6	39.2
ICH	228711	19.8	17.9
IDF	2995	0.3	n/a
SBS	47948	4.2	10.7
Total	1154954	100.0	100.1

5.2.1.2 Outside the study area

The Fraser Headwaters study area is surrounded by a number of large protected areas: Kakwa Provincial Park, Willmore Wilderness Provincial Park, Jasper National Park, and Mount Robson Provincial Park in the Rocky Mountains; and Bowron Lake, Cariboo Mountains, and Wells Gray Provincial Parks in the Columbia Mountains (Map 6). Mount Robson Provincial Park and a portion of Kakwa Provincial Park are within the upper Fraser River drainage basin; the other parks are not. Willmore and Jasper lie on the other side of the continental divide, in Alberta, while Bowron Lake, Cariboo Mountains, and Wells Gray lie on the other side of the Columbia Mountains divide .

While these protected areas are very large and contain breathtaking scenery, most of them lie high in the mountains. Lower elevation ecosystem types are less likely to be well represented within parks of this nature. As such, we began by assessing which ecosystem types were being protected within these parks. The only data easily available for this assessment were Biogeoclimatic Ecosystem Classification (BEC) data. As these data are available only within British Columbia, the parks within Alberta (Willmore and Jasper) were not included in this analysis.

Table 14 shows the results of the analysis. We compared the percentage of each BEC type within the surrounding protected areas with the percentage of these BEC types within the study area. Although the areas are not strictly comparable from an ecological perspective, we felt that this approach would provide an estimate of how well the BEC zones within the study area are represented in the surrounding parks. The analysis shows that there is a higher proportion of Alpine Tundra (AT) within the parks and a lower proportion of the lower elevation ecosystems (Table 14). The low representation of the

Sub-Boreal Spruce zone is of special concern because this biogeoclimatic zone is also under-represented in the protected areas within the study area. Future additions to the parks system should therefore be located at lower elevations and include significant proportions of the more productive valley bottom ecosystem types.

The spatial distribution of parks outside the study area is difficult to asses without a larger frame of reference. What is clear, however, is that there is no connectivity between the large protected areas in the Rocky and Columbia Mountains. While there is good connectivity between the contiguous blocks of parks within each respective mountain chain, there are no protected corridors allowing for movement between them. This is a critical gap. If these larger protected areas are to contribute fully to the maintenance of ecological composition, structure, and functioning within the Fraser Headwaters, corridors connecting them through the study area are vital.

5.2.2 Proposed Full Protection

The Protected Areas Network includes a number of areas or watersheds that we feel need to be accorded full protection. This Proposed Full Protection component of the PAN makes up 18.6% of the Fraser Headwaters study area (Table 11, Figure 46). It includes a portion of the antique forests, a corridor running the length of the Goat River and Morkill River watersheds, and a second corridor encompassing the Raush River and Chalco Creek watersheds. These areas were selected to fulfill a number of objectives:

- to protect areas of high ecological significance, such as the antique forests and areas of high landscape diversity,
- to increase the representation of lower elevation ecosystems within protected areas, and
- to create connectivity both within the study area and between the large parks surrounding the study area.

Where possible, we tried to ensure connectivity between existing protected areas within the study area; those parks outside of the main network will need to be linked at the watershed level when more detailed ecosystem-based planning is undertaken.

5.2.2.1 Antique Forests

As explained earlier, antique forests are a phenomenon unique to at least British Columbia, and perhaps Canada or even the North American continent as a whole (see Section 4.3). Sheltered from the effects of major disturbance events for millennia, antique forests are storehouses for species not found elsewhere in the Fraser Headwaters. Given their ecological complexity and the length of time it has taken for these forests to develop, restoring them following logging is doubtful. If they could be restored, it will not be possible to restore them in a reasonable time frame once they have been logged or otherwise developed. Approximately 27% of antique forests have already been logged; those remaining have been severely fragmented by the highway, railroad, and other secondary roads. In order to maintain what is left of this unique ecosystem type, and to retain the best possibility of maintaining ecological functioning within them, the remnant stands must be accorded full protection.

Most of the antique forests with high conservation priority occur in a band along the bottom of the Rocky Mountain Trench between approximately West Twin Creek and Driscoll Creek (see Map 4). Because of the ecological significance of antique forests, this band was included within the Proposed Full Protection component of the PAN. Some stands within the antique forest band have already been disturbed, through partial cutting, clearcutting, salvage logging, and other types of human use. While it is unlikely that we can ever restore the antique characteristics of these disturbed forests, we may be able, with time, to restore old growth structures within them. Restored in this way, these stands will play an important role in buffering the remnant antique forests.

In addition to protecting antique forests, this part of the Proposed Full Protection component also provides a wildlife movement corridor along the bottom of the Rocky Mountain Trench. Before the increase in human activity and development in the trench this century, the valley bottom would have provided both the highest quality habitat for many species of animals, as well as the most easily traversed terrain. In order to maintain and restore ecological functioning in the trench, a main movement corridor is needed along the length of the entire valley bottom.

5.2.2.2 Raush-Chalco corridor

The Raush-Chalco corridor is the southern of two corridors that provide linkages across the study area and between the large protected areas surrounding the Fraser Headwaters. The corridor includes the Raush River watershed, the southeast bank of the lower Holmes River and the Chalco Creek watershed.

The Raush River watershed (Raush) is highly ecologically significant for a number of reasons. To begin with, it has the highest level of landscape diversity of any of the tributary watersheds (see Map 2). In other words, unlike many other watersheds, which are composed primarily of high elevation Engelmann Spruce - Subalpine Fir (ESSF) ecosystem types, the Raush contains significant amounts of lower elevation Sub-Boreal Spruce (SBS) and Interior Cedar - Hemlock (ICH) ecosystems (see Figure 11). This high level of ecosystem diversity results in a high number of habitat types for both plant and animal species. Since the existing protected areas within the study area do not contain adequate amounts of lower elevation ecosystems (particularly SBS), the Raush is an especially good choice for inclusion within the PAN.

Figure 47: The Raush River watershed has a higher level of landscape diversity and a higher abundance of low elevation forest types than any other side valley in the southeastern half of the Fraser Headwaters study area. For these reasons it has very high conservation potential and has been include as part of the Protected Areas Network.

The Raush is also only one of three large roadless watersheds within the study area (the Goat River and Walker Creek watersheds are the other two). In addition to fragmenting landscapes, roads permit access into areas previously difficult to reach. So while the main purpose of a road might be to allow logging, multiple impacts of ecosystem functioning often occur due to increased hunting, poaching, and recreational activity. Decommissioning of roads is often very difficult, primarily because the proponents of various recreational activities do not want to lose access to these areas.

Finally, according to the available Forest Development Plans, there are currently no plans to log within the Raush. This is likely due to the steep and rugged terrain contained within the watershed.

Because of the high ecological significance of the Raush, and its low potential from a timber perspective, the Raush is an excellent choice for the Proposed Full Protection component of the PAN.

The Raush-Chalco corridor traverses the Rocky Mountain Trench at the confluence of the Raush and Fraser Rivers. Every effort was made to limit the amount of private land that fell within the Proposed Full Protection component, while maximizing the amount of forested land. The corridor then follows the east bank of the Holmes River, until it meets Chalco Creek. The upper end of the corridor encompasses the entire Chalco Creek watershed.

Figure 48: The Chalco Creek watershed is composed primarily of younger forests resulting from a fire approximately forty years ago. Fire leaves behind much higher levels of structural diversity at both the landscape and stand levels than does logging. At the landscape level, shown in the photograph, older patches of forest that escaped burning are interspersed with younger stands. At the stand level, younger forests retain high structural diversity in the form of both dead standing trees and dead fallen trees. Logged areas have much lower levels of structural diversity and will therefore develop old growth characteristics more slowly than will natural young forests.

The Chalco Creek watershed (Chalco) is unique among watersheds in the study area in that it contains a large proportion of natural young forests (see Map 2). This is primarily the result of a major fire that occurred about 40 years ago. The effects of the fire are still evident in the watershed in the pattern of forest stands on the landscape, and the occasional fire killed snag still standing.

Natural young forests differ from those that follow logging in a number of ways, but perhaps the most important difference is in the amount of structure that remains following the disturbance. Logging kills trees and removes them from the site, and can also extensively damage any existing fallen dead trees. As a result, the young forests that follow have few dead standing trees and intact large fallen trees; it will take years for these structures to be recreated. Fire, on the other hand, kills trees, but doesn't haul them away. Moreover, fire tends to skip through forest stands, burning patchily. Some areas are burned intensely while others escape entirely. The forests that regenerate therefore retain lots of structure—from patches of older forest interspersed with younger forests to large numbers of standing dead trees and large fallen trees. This high level of structural diversity in turn creates high quality habitat for many different species of plants and animals.

Little logging has occurred in the Chalco Creek watershed, and there are no current plans for logging in the near future (see Map 5). This is primarily due to the young age of these forests. There is, however, a logging road that runs almost the entire length of the watershed. The road appears to be used primarily to facilitate silvicultural activities in the forests in the watershed.

Because of its unique ecological history and minimal human disturbance, the Chalco Creek watershed presents some interesting possibilities for conservation. Clearly, a corridor is needed to connect the Raush to the large protected areas bordering the study area in the Rocky Mountains. Although the Chalco does not contain much old growth forest, the younger forests are mostly a product of ecological disturbance and not human disturbance (although some tree planting and thinning has occurred). As such, there is a much higher likelihood that the forests will develop the characteristics of the former naturally occurring old growth forests than if they had been logged.

In summary, the Raush-Chalco corridor runs from the Raush River watershed in the south, across the Rocky Mountain Trench, up the east side of the Holmes River, and into the Chalco Creek watershed. The Raush is highly ecologically significant because it contains a high diversity of ecosystem types and is only one of three remaining large roadless watersheds in the study area. The Chalco contains primarily younger forests that developed following a major fire disturbance. Because of minimal human disturbance in the Chalco, old growth forests will likely develop in the watershed over time. Neither the Raush nor the Chalco contains planned logging blocks, so little modification of short term timber management plans would be needed to establish this part of the PAN.

5.2.2.3 Goat-Morkill corridor

The Goat-Morkill corridor encompasses the Goat River watershed, a portion of the Rocky Mountain Trench adjacent to the West Twin Provincial Park/Protected Area, the southeast side of the lower Morkill River and lower Forgetmenot Creek watersheds, and uppermost portion of the Bastille Creek watershed. This corridor provides a landscape level linkage between Kakwa and Bowron Lake Provincial Parks.

The Goat River watershed (Goat) is one of only three large roadless watersheds remaining in the study area (the other two are the Raush River and Walker Creek watersheds). The Goat is a rugged high elevation watershed, containing primarily old growth Engelmann spruce and subalpine fir forest, and is largely untouched by the effects of human activity.

A number of protected areas occur in the vicinity, including the Betty Wendle and Wolverine extensions to Bowron Lake Provincial Park, Ptarmigan Creek Provincial

Park/Protected Area and West Twin Provincial Park/Protected Area. These parks exist in isolation, with no linkages or corridors between them. As previously explained, unless linkages between parks are created, the ecological integrity of individual parks will slowly decline as they are isolated in the matrix of human development. The Goat River watershed is ideally located for this purpose, because it provides a natural bridge between all of the parks and protected areas in the vicinity.

Figure 49: The historic Goat River trail was first cleared in 1886 by a mining survey team. Today used primarily as a hiking trail, it is an example of a low intensity human use that is both sustainable in the long term and appropriate within a Protected Areas Network.

The Goat River watershed also has unique heritage importance as an historical trail from Barkerville to the Fraser River and upstream communities. Although the origin of the trail is not known, it was likely used first by Indigenous People living in the area[20]. In 1886, the Goat River Trail was cleared by a mining survey team, who were working for the Gold Commissioner of the Cariboo (Parnell 2000). The trail was also considered as a possible location for the transcontinental railroad (Campbell 1992). Recent efforts have been made by the Fraser Headwaters Alliance to restore the trail and raise awareness about the history of the region (Parnell 2000). The trail is also a section of the National Trail, a hiking trail that extends across Canada. A low impact trail of this kind is compatible with the Proposed Full Protection status of the Goat River watershed.

Future use of the Goat River watershed is an issue of much contention. Some residents of the Robson Valley are proponents of a plan to build a road to Quesnel along the Goat River. McBride Forest Industries (MFI) has plans to build a logging road and begin logging in the very near future. Under the recent LRMP, the Goat was classified as a Multiple Resource Use Zone, which suggests that multiple uses should be accommodated within the same area. MFI has suggested that the historic Goat River Trail could co-exist with the logging road. Because the proposed road right-of-way lies along almost exactly the same location as the trail, this seems unlikely. Should co-existence not be possible, MFI intends to “move” the trail (McBride Forest Industries 2000).

Given both the ecological significance of the Goat River watershed as one of the few remaining roadless areas, and a good linkage between a number of existing parks, we feel that the watershed needs to be accorded full protection. This should be done before logging and road-building activities commence in the watershed and compromise the watershed’s ecological values.

[20] The Goat River is in the traditional territory of Shuswap (Secwepemc) and Carrier Nations.

From the Goat River watershed, the Goat-Morkill corridor crosses the Rocky Mountain Trench at a spot adjacent to the West Twin Provincial Park/Protected Area. This design ensures that the West Twin is connected to other parks in the vicinity. The corridor also connects with the antique forest corridor at this point. This region of the trench has extremely high ecological value: antique forests, high quality caribou habitat in the West Twin, and the rich and diverse ecosystems that occur at the confluence of the Fraser River with both the Goat and Morkill Rivers.

From the Fraser River, the corridor runs along the southeast side of the lower Morkill River and lower Forgetmenot Creek drainages, before cutting across the pass into Idol Creek and the uppermost reaches of Bastille Creek.

The Morkill River watershed (Morkill) is somewhat less rugged than the more southerly portions of the Fraser Headwaters study area. The valley bottoms are slightly wider and lower in elevation. Thus, there is a higher proportion of low elevation ecosystem types, including Sub-Boreal Spruce (SBS) and Interior Cedar - Hemlock (ICH). Information from a local wildlife biologist suggests that wildlife abundance is very high in the lower reaches of the Morkill River watershed (Dr. R. Zammuto, pers. comm.); this is corroborated by the fact that the Morkill is a popular destination for hunters. Although a logging road runs much the length of the watershed, hunters are not allowed to use motorized transport while hunting or transporting hunted game. This regulation was an attempt to limit the side effects that often result when a road is built into previously inaccessible terrain.

Logging has already modified the lower Morkill and adjacent Rocky Mountain Trench. As such, some restoration work will be necessary to assist natural processes to restore former ecological composition, structure, and functioning. A number of planned logging blocks are also located in this area. Consequently, some changes to existing forest development plans will be necessary to establish this corridor.

From the lower Morkill, there were a number of potential ways to link the corridor to the large protected areas bordering the study area: via the upper Morkill River, upper Forgetmenot/Ptomaine Creeks, or Bastille Creek. Bastille Creek was chosen for a number of reasons. First, it provides the shortest linkage between the lower Morkill and large protected areas in the Rocky Mountains. Secondly, it is the westernmost linkage, thus providing a corridor to Kakwa Provincial Park, rather than to Willmore Wilderness Provincial Park, which is already linked by the Raush-Chalco corridor. The Bastille Creek connection also provides a nice link to the McGregor River, which is a major animal movement corridor in the region. Finally, Bastille Creek is the only one of the choices that has not been logged, and that is not planned to be logged in the near future. As such, there is little restoration work necessary, and no changes will need to be made to existing forest development plans.

In summary, the Goat-Morkill corridor runs from the Goat River watershed in the south, across the Rocky Mountain Trench adjacent to West Twin Provincial Park/Protected Area, up the east side of the lower Morkill River, and into upper Bastille Creek. The Goat River watershed has high ecological significance because it is only one of three remaining large roadless watersheds in the study area and provides natural linkages between the existing parks in the region. The Morkill River watershed contains highly productive low elevation old growth forests and abundant wildlife. The upper Bastille Creek links the corridor to both Kakwa Provincial Park and the McGregor River. While there is little planned logging in the Bastille Creek and lower Morkill River areas, proposed road-building and logging is planned in the near future for the Goat River watershed. From an ecosystem-based perspective the Goat River watershed needs to be fully protected if the ecological integrity of the Fraser Headwaters is to maintained.

5.2.3 Proposed Conservation Emphasis

The Proposed Conservation Emphasis component of the PAN comprises 13.4% of the study area. It is designed to complement the Proposed Full Protection component in order to maintain ecological integrity within the Fraser Headwaters study area. Proposed Conservation Emphasis areas:

- buffer adjacent Proposed Full Protection areas,
- create movement corridors through prime habitat, and/or
- provide connectivity between existing or proposed protected areas.

Two main conservation emphasis corridors have been identified: a corridor along the bottom of the Rocky Mountain Trench, and a loop following the Morkill, McGregor, and Torpy Rivers. Smaller corridors run from the Raush River to the Fraser River via a tributary to Kiwa Creek, and from the Fraser River up the Slim Creek drainage.

The Proposed Conservation Emphasis areas will include significant roadless areas, as well as low road density. Where roads are present, permanent deactivation of some exist roads will be undertaken to meet road density targets and to restore some areas to roadless status.

The Proposed Conservation Emphasis areas will be subject to somewhat more stringent management prescriptions than those usually followed under ecosystem-based management guidelines. For example, larger riparian buffers, larger old growth nodes, more frequent linkages or corridors, and lower intensity human activities than in the ecosystem-based management areas. The details of these more stringent standards will need to be refined as part of ongoing ecosystem-based planning.

5.2.3.1 Rocky Mountain Trench corridor

Figure 50: The Rocky Mountain Trench contains both the gentlest terrain and most productive ecosystems, as well as the most extensive fragmentation and human disturbance. In order to maintain wildlife habitat and movement along the trench, significant restoration work will be necessary.

Many of the human activities that have occurred over the past century in the study area have been concentrated within the Rocky Mountain Trench (Figure 50). There is good reason for this: the trench contains the most productive and diverse ecosystems, the least rugged terrain, and the most forgiving climate. The characteristics that draw people to the trench are also inviting to other species of animals. Before the influx of settlers this century, the trench most likely contained the highest quality wildlife habitat for many species of animals. Fragmentation, logging, and increased human activity has decreased the effectiveness of much of this habitat; if these trends continue, the trench is likely to lose its ability to sustain former levels of biodiversity.

A corridor running the length of the Rocky Mountain Trench has been delineated as Proposed Conservation Emphasis. This corridor will provide multiple benefits. To begin with, it will ensure that plants and animals can move relatively unhindered from one end of the valley to the other. Secondly, a proportion of the original high quality habitat in the trench will be available in strategic locations to meet a wide variety of needs for these species, including feeding and reproductive habitat. Finally, the corridor will provide a critical buffer to the antique forests at the northern end of the trench. While much of the antique forest has been included within the Proposed Full Protection component of the PAN, some of it occurs outside this designated area. Moreover, the effectiveness of the protected antique forest area will be diminished if it is bordered by clearcuts and other intensive human uses. Impacts from these uses spread a long distance (from 100m to 4km depending on the impact) into adjacent forests. Because the band of antique forests is long and thin, impacts could easily penetrate much of the proposed protected antique forest if it were surrounded on all sides by intensive human activities.

5.2.3.2 Morkill-McGregor-Torpy loop

The Morkill-McGregor-Torpy Proposed Conservation Emphasis loop follows a number of large rivers flowing through mostly low-elevation valley bottoms: the lower Morkill River, lower Forgetmenot Creek, upper McGregor River, Goodson Creek and lower Torpy River.

This area contains a high proportion of high productivity valley-bottom ecosystems, and somewhat more gentle terrain than is found in much of the rest of the study area. Although few wildlife data are available, the characteristics of the area are similar to those often associated with high quality wildlife habitat and greater levels of biodiversity. Spatial grizzly bear habitat data from the Ministry of the Environment suggests that the area contains a high proportion of medium to high quality habitat (the southwestern part of the study area, by contrast, contains mostly low to medium quality grizzly bear habitat).

The loop provides both a plant and animal movement corridor through this area, as well as a buffer for existing protected areas and Proposed Full Protection areas. This is especially critical in the region bordering Kakwa Provincial Park. This region has been very heavily logged to the point where the lower elevation ecosystems are almost a continuous cut-block. Although some of these logging blocks may have "greened-up," the trees in these blocks are very young and old growth characteristics such as dead standing and fallen trees are mostly absent. These features are critical structures for high quality wildlife habitat, among other things. Effective reserve design requires that protected areas be surrounded by regions of less intensive human use; the ability of protected areas to contribute to landscape integrity at a landscape scale is much reduced if they are surrounded by intensive human development activities.

Figure 51: The Morkill-McGregor-Torpy loop protects the confluence of several major watersheds. In the foreground, the Fraser River weaves a path through the Rocky Mountain Trench. The Torpy River runs between the two ridges visible in the left-central area of the photograph before merging with the Fraser. Far in the distance, the McGregor River flows in the valley below the snow-capped mountains. Maintaining connectivity between these large river systems is critical to ensuring the continued flow of energy, nutrients, and wildlife between them.

Because much of the Morkill-McGregor-Torpy conservation emphasis loop has already been severely degraded by past logging practices, long-term restoration work will be necessary to restore ecological functioning within the loop. This area is unique in the surrounding landscape, and furnishes large landscape connectivity that cannot be duplicated elsewhere. Therefore, restoration of the Morkill-McGregor-Torpy loop will provide important conservation benefits.

5.3 Ecosystem-based Management

Sixty-one percent of the Fraser Headwaters study area has been classified for proposed ecosystem-based management (Table 11, Figure 46). These are the areas that are left over once the PAN has been designed. Ecosystem-based management areas are not part of the PAN; they are the matrix within which the PAN is embedded.

In terms of designing ecologically sustainable human economies, the proposed ecosystem-based management areas are the best place to begin doing more detailed watershed and stand level planning. The process of undertaking ecosystem-based planning at multiple spatial scales has been detailed elsewhere in this report (see Section 1.2). In brief, however, the process involves undertaking successive rounds of ecosystem-based planning in increasingly greater detail for increasingly smaller areas. Each planning iteration designates sensitive, unique, and representative elements of ecosystems for full protection. The PAN is designed at the large landscape level, the PLN (Protected Landscape Network) at the watershed level, and the PEN (Protected Ecosystem Network) at the stand level. Areas, for example, that were classified as “high ecological risk” but are not part of the PAN, will in most cases become part of the PLN and PEN when further planning is undertaken.

Although we tend to focus on the creation of protected areas as the solution to environmental problems, parks alone cannot maintain ecological integrity at a landscape level if they are embedded in a matrix of intensive industrial activity. Maintaining ecological functioning, from stands to watersheds, to landscapes, will require that the network of protected areas be embedded in a landscape of ecologically responsible human use. This is the promise of ecosystem-based management.

6. Conclusions and Recommendations

The Fraser Headwaters is a landscape of diversity, from high mountain glaciers and steep forested slopes to the more gentle terrain and productive forests of the Rocky Mountain Trench. Linking all of these different ecosystem types are the rushing streams and rivers that flow into the Fraser River.

As has been described in this report, many of these ecosystems are highly ecologically sensitive. One-third of the study area is alpine tundra. A further 39% is composed of high elevation, low productivity forests. Almost three-quarters of the study area has been classified as high ecological risk. Cold climate, steep complex terrain, and young soils are major contributors to the high sensitivity of many of these ecosystems.

Human activity in the Rocky Mountain Trench has been increasing steadily over the past century. As the availability of timber products, in particular, decreases in the trench, increasing attention has been directed toward side valleys. Unroaded and relatively inaccessible until the early 1980's, areas such as the Morkill and Milk River valleys are today highly fragmented by logging roads and clearcuts. An examination of current forest development plans suggests that this trend will only increase in the future.

The *Fraser Headwaters Proposed Conservation Plan* is intended as a catalyst for discussion about the future of the Fraser Headwaters landscape. In order to protect, maintain, and where necessary, restore ecological integrity in this landscape, a new approach to developing ecologically sustainable human economies must be implemented. We believe that ecosystem-based planning and management is a viable solution.

The list below provides a number of suggestions and recommendations for both refining and implementing this landscape-level ecosystem-based plan. We hope that these ideas will spur further work to promote the balanced and ecologically responsible use of the forests and waters of the Fraser Headwaters, and we look forward to the dialogue that ensues.

- Carry out meaningful consultation with Indigenous Peoples regarding the design of the PAN, incorporation of traditional ecological knowledge, and inclusion of First Nations issues and concerns. This consultation needs to respect and accommodate Aboriginal title and rights, and be participatory.
- Complete a peer review of the Fraser Headwaters Proposed Conservation Plan by both the scientific community and by local community groups. While the overall design of the Protected Areas Network is unlikely to change, minor revisions to strengthen the design may be incorporated in response to suggestions.
- Test the PAN with a guild of species to ensure that the needs of umbrella and keystone species in particular are being met.
- Establish a plan to protect and restore all antique forests within the Fraser Headwaters. Restoring antique characteristics in forests that have been logged or severely defoliated by hemlock looper is a long-term project and will not be achievable within single human lifetimes. Nonetheless, beginning to restore old

growth characteristics within these forests will aid in buffering the remnant antique forests.

- Establish a plan to restore forest composition, structure, and functions in areas that have been heavily logged. Priorities include those areas within the Proposed Full Protection and Proposed Conservation Emphasis components of the PAN, such as the Morkill River, upper McGregor River, lower Torpy River, and Slim Creek watersheds.

Restoration of antique forests and restoration of heavily logged areas will contribute important employment and economic benefits.

- Work with private landowners to establish conservation covenants, particularly for old growth forests and rare ecosystems on private land in the Rocky Mountain Trench. The trench has the highest proportion of private land and much of this area is highly fragmented. Much of the trench was also formerly high quality habitat for many species of plants and animals. Therefore, working with private landowners to maintain and restore these habitats is critical.
- Continue the process of ecosystem-based planning at multiple spatial scales by undertaking watershed and stand level ecosystem-based plans for sub-regions of the Fraser Headwaters study area. High priority watersheds for consideration include those that are located outside the PAN (inside the area identified as proposed ecosystem-based management) such as the Holmes River, Milk River, upper Forgetmenot Creek, upper Morkill River, and Cushing Creek. Once watershed level ecosystem-based planning has been completed, wholistic forest use zoning can be carried out through a community decision-making process. Such zoning could be undertaken in the Horsey Creek watershed, where watershed-level ecosystem-based planning has already been completed.
- Analyze the existing economy and develop an ecological economic plan for the Fraser Headwaters. This plan will compare the benefits and burdens of the current economy to an ecosystem-based economy.
- Design the transition to an ecologically sustainable community-based economy. An important aspect of this transition strategy will be the design of ecologically sustainable timber management that focuses on diverse, labour-intensive timber extraction, stand management, and value-added wood products manufacturing.

7. References

Arsenault, A. and T. Goward. 2000. Ecological characteristics of inland rainforests. Ecoforestry (Winter): 20-23.

Bachrach, T. 2000. Investigating forest fragmentation in the Robson Valley, British Columbia. B.Sc. Honours Thesis. Department of Geography, University of Victoria, British Columbia.

Banff-Bow Valley Study. 1996. Banff-Bow Valley at the crossroads. Technical report of the Banff-Bow Valley Task Force. Prepared for the Minister of Canadian Heritage. Ottawa, Ontario.

Bown, S.R. 2001. The historic adventures of Milton and Cheadle. Part 1. Beautiful British Columbia Magazine (Spring): 12-19.

British Columbia Conservation Data Centre. 2001. Vertebrate animal tracking list: Robson Valley forest district. http://www.elp.gov.bc.ca/rib/wis/cdc/trackinglists/vertebrates/atrack43.doc

British Columbia Ministry of Environment, Lands and Parks. 1995. Biodiversity guidebook. Victoria, B.C.

British Columbia Ministry of Environment, Lands and Parks. 2000. Mountain caribou management strategy for the Prince George Forest Region. Prince George, British Columbia.

British Columbia Ministry of Forests, Research Branch. 1988. Biogeoclimatic zones of British Columbia, 1988. Victoria, B.C.

British Columbia Ministry of Forests, Prince George Region. 1996. Draft field guide insert for site identification and interpretation for the southeast portion of the Prince George forest region. (Draft) Prince George, B.C.

British Columbia Ministry of Forests, Timber Supply Branch. 2000. Robson Valley timber supply area analysis report. Victoria, B.C.

Campbell, J. 1992. Goat River recreational trail pre-feasibility study. Prepared for North Cariboo community futures. Wells, B.C.: Ecogystics Consulting Associates.

Carroll, C., R.F. Noss, and P.C. Paquet. no date. Carnivores as focal species for conservation planning in the Rocky Mountain Region. Toronto, Ontario: World Wildlife Fund Canada.

Columbia Encyclopedia. 2001. Sixth edition. New York: Bartleby.com. http://www.bartleby.com/65/fr/FraserRiv.html.

Environment Canada. 1980. Canadian climate normals. Temperature and precipitation 1951-1980: British Columbia. Environment Canada, Atmospheric Environment Service.

Environment Canada. 1982. Canadian climate normals. Volume 6. Frost: 1951-1980. Environment Canada, Atmospheric Environment Service.

Environment Canada. 2001. Species at risk: woodland caribou, southern mountain population. Internet URL: http://www.speciesatrisk.gc.ca/Species/English/SearchDetail.cfm?SpeciesID=638.

ESRI, Inc. 1997. ArcInfo Version 7.1.2. Redlands, California: Environmental Systems Research Institute, Inc.

ESRI, Inc. 1998. ArcView Version 3.1. Redlands, California: Environmental Systems Research Institute, Inc.

Forman, R.T.T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge: Cambridge University Press.

Gadd, B. 1986. Handbook of the Canadian Rockies. Jasper, Alberta: Corax Press.

Goward, T. 1995. Macrolichens of the old growth forests of the Robson Valley. Part 1: Goat River to Ptarmigan Creek. Report prepared for the Robson forest district, McBride, British Columbia.

Hammond, H. 1991. Seeing the forest among the trees: the case for wholistic forest use. Vancouver, B.C.: Polestar Press.

Holland, S.S. 1976. Landforms of British Columbia: a physiographic outline. Bulletin 48. Victoria, B.C.: British Columbia Department of Mines and Petroleum Resources.

Jones, P.K., and R. Annas. 1978. Vegetation. In: Valentine, K.W.G., P.N. Sprout, T.E. Baker, and L.M. Lavkulich. (eds.) The soil landscapes of British Columbia. Victoria, B.C.: British Columbia Ministry of the Environment, Resource Analysis Branch.

Lewis, K.J., and B.S. Lindgren. 2000. A conceptual model of biotic disturbance ecology in the central interior of B.C.: How forest management can turn Dr. Jekyll into Mr. Hyde. The Forestry Chronicle 76(3):433-443.

MacKinnon, A., D. Meidinger, and K. Klinka. 1992. Use of the biogeoclimatic ecosystem classification system in British Columbia. The Forestry Chronicle 68(1):100-120.

McBride Forest Industries Ltd. 2000. Forest Development Plan. October 1,2000 to September 30, 2005. Robson Valley forest district. McBride, British Columbia.

Meidinger, D., A. McLeod, A. MacKinnon, C. DeLong, and G. Hope. 1988. A field guide for identification and interpretation of ecosystems of the Rocky Mountain Trench, Prince George Forest Region. Land management handbook No. 15. Victoria, B.C.: British Columbia Ministry of Forests and Lands, Research Branch.

Parnell, K. 2000. Recreating history: hikers raise awareness about the historic Goat River. Quesnel Cariboo Observer, Sept. 24, 2000, page A21.

Perry, D.A. 1994. Forest ecosystems. Baltimore: Johns Hopkins University Press.

Raffensperger, C. and J. Tickner. 2000. Implementing the precautionary principle. In: Eco-compass: the internet guide to environmental information. Island Press. http://www.islandpress.org/ecocompass/prevent/

Rowe, J.S. 1997. The necessity of protecting ecoscapes. Global Biodiversity 7(2):9-12.

Ryder, J.M. 1978. Geology, landforms, and surficial materials. In: Valentine, K.W.G., P.N. Sprout, T.E. Baker, and L.M. Lavkulich. (eds.) The soil landscapes of British Columbia. Victoria, B.C.: British Columbia Ministry of the Environment: Resource Analysis Branch.

Safranyik, L., H. Barclay, A. Thomson, and W.G. Riel. 1999. A population dynamics model for the mountain pine beetle, *Dendroctonus ponderosae* Hopk. (Coleoptera: Scolytidae). Information Report BC-X-386. Victoria, B.C.: Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre.

Silva Ecosystems Consultants. 1999. Silva Field Work Manual. 1999 edition. Slocan Park, B.C.: Silva Ecosystem Consultants.

Silva Ecosystem Consultants. 2000. SILVASS II. Slocan Park, B.C.: Silva Ecosystem Consultants.

Silva Forest Foundation. 1997. Initial report on the Raush River watershed forest analysis. Slocan Park, B.C. (http:\\www.silvafor.org)

Silva Forest Foundation. 1999. Ecosystem-based landscape analysis of the Fraser Headwaters: Horsey Creek landscape. Slocan Park, B.C. (http:\\www.silvafor.org)

Soule, M.E. and Terborgh, J. 1999. Continental conservation: scientific foundations of regional reserve networks. Washington, D.C.: Island Press.

Stevenson, S.K. 1994. Managing forests for caribou in southern British Columbia. Canadian Forest Industries (Oct.):32-35.

Stevenson, S.K., H.M. Armleder, M.J. Jull, D.G. King, E.L. Terry, G.S. Watts, B.N. McLellan, and K.N. Child. 1994. Mountain caribou in managed forests: preliminary recommendations for managers. Victoria: B.C. Ministry of Forests, Research Branch.

Valemount Historic Society. 1984. Yellowhead Pass and its people. Valemount, B.C.

Vasbinder, W. 2001. Forest fire in the mountain ranges of northeastern British Columbia: a historical perspective. M.Sc. thesis. University of Northern British Columbia, Prince George, B.C.

Vogt, K.A., J.C. Gordon, J.P. Wargo, D.J. Vogt, H. Asbjornsen, P.A. Palmiotto, H.J. Clark, J.L. O'Hara, W.S. Keaton, T. Patel-Weynand, E. Witten. 1997. Ecosystems: balancing science with management. New York: Springer-Verlag.

Vogt, K., E. Moore, S. Gower, D. Vogt, D. Sprugel, and C. Grier. 1989. Productivity of upper slope forests in the pacific northwest. In: Perry, D.A., R. Meurisse, B. Thomas, R. Miller, J. Boyle, J. Means, C.R. Perry, and R.F. Powers. (eds.) Maintaining the long-term productivity of pacific northwest forest ecosystems. Portland, Oregon: Timber Press.

Wheeler, M. (ed.) 1979. The Robson Valley story. McBride, B.C.: The McBride Robson Valley Publishing Group.

Appendix I: Data Sources

Data	Attributes	Source	Date	Scale	Format
Forest Cover	Inventory Type Group, stand age, site index, environmental sensitivity, roads, etc.	MoF[1]	1992-2000	1:20 000	digital (fcl & fip)
Terrestrial Resource Information Mapping (TRIM1)	Digital elevation model, water features, roads, etc.	MELP[2]	1997 [3]	1:20 000	digital (saif)
Biogeoclimatic Ecosystem Classification (BEC) (Ver. 3)	BEC zone, subzone & variant	MoF/MELP[4]	1995/8	1:250 000	digital (e00)
Parks & Protected areas					
Robson Valley district	parks & protected areas	MoF	n/a	n/a	digital (e00)
Prince George district		MoF	n/a	n/a	digital (e00)
Caribou & grizzly bear habitat					
Robson Valley district	caribou & grizzly habitat	MoF	n/a	n/a	digital (e00)
Prince George district		MELP	1997	1:50 000	digital (e00)
Forest Development Plans					
McBride Forest Industries (formerly Zeidlers)	Proposed logging blocks	MFI	2000	1:20 000	paper (plot files)
Slocan Forest Products		SFP	1999	1:30 000	paper (plot files)
TRC Cedar		TRC Cedar	2000	1:20 000	digital (dgn)
Hauer Brothers		Hauer Brothers	2000	1:20 000	paper (plot files)
Northwood (formerly Canfor)		Northwood	2000	1:50 000	paper (plot files)
Small Business Forest Enterprise Program		MoF	2000	1:20 000	digital (e00)
Aerial Photographs		Geographic Data BC	1984-1986	approx. 1:70 000	B/W photos
National Topographic Series (NTS) Maps	toponyms	DEMR[5]	1986-1989	1:250 000	paper maps
Forest Health Network aerial detection survey	hemlock looper defoliation severity	CFS[6]	1993-1995	1:250 000	digital (e00)

[1]Ministry of Forests; [2]Ministry of Environment, Lands, and Parks; [3]Although some aerial photographs used in data production date as far back as 1988; [4]Produced by MoF 1995, minor revisions by MoELP 1998; [5]Surveys & Mapping Branch, Dept. of Energy, Mines, and Resources.

Appendix II: Field Sampling Plan

Field Sampling Plan

Fraser Headwaters Proposed Conservation Plan

September 2000

1. Geographic Region

The FWH study area covers a total of almost 1.3 million hectares. For the purposes of analysis, it has been divided into 13 watershed units. Preliminary sampling sites were distributed as evenly as possible (given the constraints of access) over the entire geographic region. Field sampling has been conducted in past years in the Horsey Creek and Raush River watershed units as part of previous ecosystem-based plans; it may be possible to use these data for the FHW plan.

2. Sampling Objectives

The FHW Project is slightly different from any of the other eco-system based plans completed by Silva in the past. First, it covers a much larger area – 1.3 million ha – thus the resolution of both the analysis and the field sampling is necessarily much coarser. Secondly, the project is not intended to provide a detailed determination of ESD, potential timber management zones, etc.; although some analysis along these lines will certainly be conducted, such planning is more appropriate at a larger scale (smaller region) of analysis. The focus of this project is on designing a system of core reserves and linkages that will connect the surrounding large parks while maintaining the structure and functioning of the FHW landscape. Areas of potential timber management will be highlighted for more detailed planning at the watershed level. The sampling plan, therefore, focuses less on assessing timber potential, and more on assessing overall landscape structure and functioning.

Overall objectives of the sampling plan are:

- to sample as much of the variation in ecosystem types as possible (including a range of leading species, seral stage, BEC zone, terrain type and position, ecosystem condition, etc.)
- to field check both the assumptions made and issues raised during the preliminary analysis
- to field check potential linkages identified during the preliminary analysis

3. Steps for Locating Preliminary Sampling Sites

Potential sampling sites were first located on the basis of 3 criteria: ecological diversity, testing of assumptions, and potential linkages. Details of these criteria are provided below. This pool of potential sites was then narrowed based on practical considerations such as access, sampling efficiency, and budget. Priority was given to easily accessible sites that met multiple sampling objectives.

3.1 Ecological diversity

A preliminary GIS analysis of ecological diversity within the FHW was conducted using MoF forest cover and MoELP TRIM data. A map of Landscape Diversity was created by plotting a matrix of ITG (7 classes, grouped by leading species) by Stand Age (3 classes: 1-3, 4-6, 7-9) and Site Index (4 classes: 1-13, 14-20, 21-25, 26+). This was used as the base map for both assessing the range in ecosystem variability and highlighting rare ecosystem types. Additional maps showing: BEC subzones; old growth forests; rare, endangered, and threatened communities (based on CDC point occurrence data); and slope and aspect, were also used to highlight the locations of ecologically important sites.

Potential field sampling sites were selected to reflect the diversity of ecosystem types within the FHW. Emphasis was placed on locating areas that contained either a high diversity of ecosystem types or a concentration of rare ecosystem types. Potential locations were selected using GIS maps and subsequently checked with airphoto coverage.

3.2 Issues Raised during Preliminary Analysis

A number of assumptions were made and issues raised during the preliminary analysis of ecosystem diversity. Field sampling sites were also selected in order to ascertain the legitimacy of the underlying assumptions in the methodology. Assumptions and issues raised included:

- accuracy of Age Class 7 label: There was some discussion over whether it was more likely that stand age for Class 7 polygons had been overestimated or underestimated, and therefore with which seral stage these polygons would best be grouped.
- diversity of ITG x BEC variant: During preliminary mapping of Landscape Diversity, we lumped ITG by leading species to reduce the total number of classes. However, this resulted in, for example, the class SB (spruce balsam) occurring at both valley-bottom and in the subalpine. It is likely that there is sufficient ecological difference in certain cases to warrant further subdivision of ITG Groups, perhaps by BEC Zone. In order to test this question, it will be necessary to sample the same ITG polygon within different BEC zones. This sampling will also contribute to an understanding of the range of diversity in ecosystem types across the study area.
- beta-diversity of “SB” in the ESSF: The map of Landscape Diversity suggests that the highest diversity is found in the Fraser valley whereas the lowest levels of diversity are found in remote upper watersheds. While there are good ecological reasons to believe this trend to be true, several sample transects were located in order to determine if this trend was artificially amplified by the decision to group Spruce and Balsam ITG groups into one class. In other words, just how diverse or homogeneous are the SB subalpine forests?

3.3 Potential Linkages

Based on the very preliminary analysis completed to date, potential locations for landscape linkages are already becoming apparent. In certain places, there is the question of whether it makes more sense to locate the corridor in an area of low ecological diversity that is largely free of human activity, or in a more ecologically rich area that although impacted more heavily by humans might be restorable. Several potential sampling sites (or sampling drives along a valley) were selected to address this question.

3.4 Practical constraints

Once potential sampling sites had been identified on the basis of the criteria mentioned above, accessibility of the sites was assessed. Highway 16 runs the length of the Robson Valley, as does a network of secondary roads. Secondary roads have also been built into the most heavily impacted watersheds: the Holmes, McGregor, Torpy, and Slim watersheds. Finally, there is an entire network of "rough" roads – presumably logging roads. The current state of these is unknown, as is the condition of any bridges along them. It will be very difficult in an area this size to determine accessibility of roads before heading into the field. As most such information will have to be gleaned once there, multiple alternative sample points will be located beforehand in case first choices are not accessible.

Sampling sites were located as much as possible along easily accessible roads. Representative sites with important ecological characteristics could almost always be found close to some road. Thus, given the already ambitious sampling task at hand, as well as the lack of budget, no sampling sites requiring helicopter access were selected. Sample sites were chosen to make most efficient use of time – potential sample sites that were contiguous were favoured over those spread more distantly (while maintaining good geographic coverage of the entire study area).

4. Sampling Methodology

Two sampling techniques will be employed in the field: points and transects. Sample points will be used mainly where the objective is to ascertain the character and/or condition of a particular ecosystem type (alpha diversity).Short transects may also be used in these areas. Longer transects will be used where an understanding of beta diversity (change in diversity across ecosystem types) is desired. Finally, a fixed wing flight will be arranged across the entire FHW area to detect larger patterns of diversity (gamma diversity) and determine where best to place landscape linkages.

A tactical choice will need to be made about the amount of data to be collected at each point or transect. Given the size of the study area and the scale of analysis, it will probably make more sense to cover a greater area (more points and transects) in less detail than Silva generally does in smaller plans. I think such an approach will both serve us better, and be scientifically and ecologically defensible. I would suggest, for example, that points include no more than a brief assessment of site characteristics and not a complete silvicultural assessment (thus not a "plot" in Silva's general definition of the term). We could core a few trees in Age 7 stands to assess how well these have been aged. This, in fact, fits well with the objectives of this project – silvicultural assessments are not appropriate at this scale; more refined analysis and planning is needed. Thus I think the project would benefit much more if we were able to get a less detailed view of the whole study area than a little bit of very detailed stand-level data from a handful of spots.

5. Preliminary Sample Sites

A list of preliminary sample sites follows. Far too many days would be required to complete all sampling as listed. It is expected that the final choice of sampling sites will be made in the field taking into account local conditions and constraints, total time available, and data acquired through sampling.

Sample Area	Location	Access	Type of Sample	Time needed (days)	Sampling Objectives	Priority	Rationale
1	Valley – North	Hwy	3 points	½ - 1[21]	· sample diversity of ITG x BEC variant · (C9/H9/SB9 in ICHvk2) · sample Old Growth – big patches of it	Medium	easy access; reasonable diversity; really good option for bad weather
2	Valley – North	rough	2 points	½ - 1	· sample accuracy of Age Class 7 label · (SB, H in ICHvk2) · ascertain corridor potential	Medium	nice big patches; corridor potential; uncertain access
3	Valley – North	Hwy	2 points	½ - 1	· sample accuracy of Age Class 7 label · (SB, Pl in ICHvk2)	Medium	easy access; good bad-weather alternative; nice big patches
4	Hungary Creek (Slim)	2dary, just off hwy	2-3 points & a drive	½ -1	· sample diversity of ITG x BEC variant · (C/H/SB in ICH vk2) · see degraded watershed	Low	good access but not very high diversity; better places to go unless we want to see this particular watershed
5	Torpy	2dary	2 – 4 points	½ - 1	· sample diversity of ITG x BEC variant · (C9/SB9 in ICHvk2) · sample ecological effects of clearcuts (young stands)	Medium	good access; reasonable diversity; good chance to see fragmented watershed
6	[omit—there is no sample area #6]						

[21] Time required is usually given as a range: the lower end should be sufficient if we are going to limit ourselves to simple assessment of site character (i.e. without doing a formal Silva plot) (see my vote in favour of this approach in Sampling Methodology above. Should we decide to do full silvicultural assessments, the upper time range will be more realistic.

7	Driscoll Creek (Slim)	rough, just off hwy	4 points & a drive	½ - 1	· sample diversity of ITG x BEC variant · (C9/H9/SB9/Fd9 in ICHvk2) · sample old growth · ascertain corridor potential	Medium	reasonable access; big patches of Cedar; good corridor potential? (check this again)
8	Slim	2dary	2-3 points or just a drive	½ - 1	· sample young forests (SB, Pl) · badly fragmented watershed · some older Cedar further from road	Medium – High	depends on how much we want to see this watershed and ecological effects of huge clearcuts
9	Valley – Lower Slim	2dary, just off hwy	3 points	½ - 1	· sample diversity of ITG x BEC variant · (C9/H9/SB9 in ICHvk2) · sample old growth · ascertain corridor potential	Medium	easy access; (similar to 10,11,12,14,15)
10	Valley – Lower Slim	2dary & rough, just off hwy	2 points	½ - 1	· sample accuracy of Age Class 7 label · (C7, SB7 in ICHvk2)	Medium -high	good accessibility; one of very few C7 patches (compare to 12)
11	Valley – North	rough	1 point	¼ - ½	· sample accuracy of Age Class 7 label · (SB in ICHvk2) · ascertain corridor potential – it needs restoration, but is that okay?	Medium	big patch – many sample point choices; corridor potential; uncertain access
12	Valley – Lower Slim	2dary, just off hwy	1 point	¼ - ½	· sample accuracy of Age Class 7 label · (C in ICHvk2) · one of very few C7 patches	Medium – high	easy access; one of very few C7 patches (compare to 10)
13	Valley – Dome Creek	hwy / 2dary	2 points?	½ - 1	· CDC Rare plant occurrence · this is a marsh, which might be an interesting change!	Medium – High	easy access; only marsh point (point near river is on private land)
14	Dome Creek (Slim)	rough, just off hwy	1 point	¼ - ½	· sample accuracy of Age Class 7 label · (SB in ICHvk2/SBSvk ecotone)	Low – medium	nice patches, otherwise nothing special

15	Dome Creek (Slim)	rough, just off hwy	2 points	½ - 1	· sample accuracy of Age Class 7 label · (SB, H in SBSvk/ICHwk3 ecotone)	Medium -High	big patches, lots of choice along a lovely road just off highway
16	Valley – Lower Torpy	2dary & rough	up to 7 points	1-2	· sample diversity of ITG x BEC variant · (C9/H9/SB9 in ICHvk2; C9,SB9 in SBSvk; C9/SB in ICHwk3) · sample BEC ecotones, Old Growth, etc.	High	high diversity in small area – little stops along a lovely road not too far from hwy
17	Valley – Lower Torpy	2dary	1 point	¼ - ½	· sample accuracy of Age Class 7 label · (SB in SBSvk)	Medium – high	could easily be combined with point 16 for an efficient, diverse day.
18	Valley – Lower Morkill	rough	1 point	¼ - ½	· sample accuracy of Age Class 7 label · (SB in ICHwk3 and SBSvk)	Low – Medium	slightly higher diversity than elsewhere, otherwise nothing special; access uncertain; beware – these are close to private land
19	[omit—there is no sample area #19]				·		
20	Valley – Lower Morkill	rough	1 point	¼ - ½	· sample accuracy of Age Class 7 label · (H in ICHwk3)	Low	nothing special
21	Valley – Lower Morkill	rough	up to 6 points	1- 2	· sample diversity of ITG x BEC variant · (Ac8/SB9/C9 in SBS; SB9/C9/H9 in ICHwk3) · sample Old Growth & riparian zones	High	reasonable accessibility; very diverse area; maybe combine with a trip up the Holmes (pending accessibility)
22	Morkill	roads?	1 transect	½ - 1	· sample beta-diversity of "SB" in ESSFmm1 · many potential sites	Medium	uncertain & likely difficult access; can do this in many other places, but it would be really nice to see upper

							Morkill; (do not do both 22 & 23)
23	Morkill	roads?	1 transect	½ - 1	· sample beta-diversity of "SB" in ESSFmm1 · many potential sites	Medium	uncertain & likely difficult access; can do this in many other places, but it would be really nice to see upper Morkill; (do not do both 22 & 23)
24	Valley – Central	rough roads – not sure of access?	3-4 points & a drive	½ - 1	· sample diversity of ITG x BEC variant · (C9/H8-9/SB9 in ICHwk3) · sample old growth · lovely big points · determine corridor suitability · possible to visit river/riparian	Medium –High	may be hard access, but multiple objectives
25	Valley – North Central	rough	1 point	¼ - ½	· sample accuracy of Age Class 7 label · (H in ICH wk3)	Low-Medium	nothing special; could combine with 25 & 27
26	East Twin	rough	1-2 transects	½ – 1	· sample diversity of ITG x BEC variant	Low	uncertain access; probably much better places to do this
27	Valley – Central	rough	3-4 points	½ - 1	· sample diversity of ITG x BEC variant · (H9/C9/BS9 in ICHwk3) · sample old growth · rare patch of Ac9 in ICHwk3 · possibility of taking a peek at river & riparian zones	Medium	uncertain access, but more diverse site; (similar to 30, 28,24,21,19)
28	Valley – Central	rough – but just off	3-4 points	½ - 1	· sample diversity of ITG x BEC variant · (H9/C9/SB9 in ICHwk3, SB in ESSFwk1) · sample old growth	Medium	good access right along highway; (similar to 30, 27,24,21,19)

		Hwy			· possibility of taking a peek at the river		
29	West Twin (Goat)	rough	2 points	½ - 1	· sample accuracy of Age Class 7 label · (SB,H in ICHwk3)	Low – Medium	good access
30	Valley – Central	rough, but just off hwy	3 points	½ -1	· sample diversity of ITG x BEC variant · (H9, C9, SB9 in ICHwk3) · sample old growth	Medium	easy access; high diversity in small area; (similar to 28, 27, 24, 21, 19)
31	McKale (Holmes)	rough	2 points	½ - 1	· sample accuracy of Age Class 7 label · (SB, H in ICHmm/ESSDFmm1)	Low – Medium	several potential sample point choices; plots some distance apart
32	Lower McKale (Holmes)	rough	1 transect	½ - 1	· sample old growth in ICH · if we walk a lot, can sample diversity of BEC zones	Low	lower diversity than other places, lower accessibility
33	Valley – South-east	rough	2 points	½ - 1	· sample accuracy of Age Class 7 label · (SB, Pl in ICHmm)	Low	nothing special; reasonably close to highway
34	Chalco Creek (Holmes)	rough	2 points	½ - 1	· sample ecological effects of major burn · sample younger forests · (SB, Pl in ESSFmm1) · ascertain corridor potential	High	mainly younger forests, all but the top has escaped cutting; great potential as connector corridor from the Raush
35	Upper Chalco Creek (Holmes)	rough	1 transect	½ - 1	· sample beta-diversity of "SB" in ESSFmm1 · check out effects of major fire – the only drainage burned completely and relatively undisturbed otherwise; potential corridor	Medium - High	really interesting ecologically; worth a drive even if we choose not to sample formally

36	Valley – South-east	rough, just off hwy	1 point	¼ - ½	· Sample accuracy of Age Class 7 label (SB) · Sample BEC Ecotone (ICHmm/ESSFmm1)	Low	nothing special
37	Middle Holmes	rough	1 point	¼ - ½	· sample diversity of ITG x BEC variant · (SB9 in ICHmm) · watershed fragmented	Low	probably not the best choice, although few other SB9/ICH in an upper watershed
38	Holmes	rough	1 point	¼ - ½	· Sample accuracy of Age Class 7 label · (SB in ESSFmm1)	Low – medium	good size patches with lots of site choice; worth doing if we want to drive up the Holmes?
39	Upper Holmes	rough, long drive	1 transect	½ - 1	· sample beta-diversity of "SB" in ESSFmm1 · watershed fragmented · check out the possibility of putting a corridor through here even though it's fragmented	Medium	likely difficult access, but good excuse for a trip up the Holmes
40	Upper Horsey	rough, long drive	1 transect	½ - 1	· sample beta-diversity of "SB" in ESSFmm1	Low	not the best sample area, plus we know the Horsey Creek study area well. likely difficult access
41	Upper Small (Horsey)	rough	1 transect	½ - 1	· sample beta-diversity of "SB" in ESSFmm1	Low	not the best sample area, plus we know the Horsey Creek study area well likely difficult access
42	Lower Small (Horsey)	rough	1 transect, 1 point	½ - 1	· sample beta-diversity of "SB" in ESSFmm1 · sample rare Fd9 in ESSFmm1	Low – Medium	no other accessible Fd9 in ESSF, but not much else here to sample and we know the Horsey Creek study area well.
43	Valley – South	hwy	1 point	¼ - ½	· sample CDC Rare Plant Community – *Pinus contorta – Vaccinium – Cladonia* · Red Listed, S2 rank	High	only mapped occurrence (compare 45) a bit of a walk from hwy

44	Valley – deep South	Hwy	2 points	½ - 1	· sample accuracy of Age Class 7 label · (Pl, S) · sample diversity of ITG x BEC variant · (S in SBSdh) ·	Medium	easy access; good alternative for bad weather; decent patches, short walk from highway; not the most diverse area
45	Valley – South	rough, just off hwy	1 point	¼ - ½	· sample CDC Rare Plant Community – *Pinus contorta – Vaccinium – Cladonia* · Red Listed, S2 rank	High	only mapped occurrence; (compare 43)
46	Valley – deep South	rough	5-6 points?	1 - 2	· sample diversity of ITG x BEC variant · (SB in SBSdh, ICHmm, ESSFmm1; C9 – ICHmm, C8-SBSdh; H8 – SBSdh, ICHmm) · sample old growth stands · sample only C9 patch in the south	High	reasonable accessibility; high diversity in a small area; good coverage of study area
47	Valley – South (lower Kiwa)	2dary	2 points	½ - 1	· sample accuracy of Age Class 7 label (Pl, Fd) · sample BEC ecotone (SBSdh/ICHmm)	Low	good access; good bad weather alternative; decent size patches although not very high diversity; potential to combine with 48
48	Kiwa (Horsey)	2dary	2 points	½ - 1	· sample accuracy of Age Class 7 label · (Pl, SB in ICHmm) · sample ecological effects of clearcuts	Low – Medium	good accessibility but small patches; already know Horsey Creek quite well
49	Raush	rough	2 points & a drive	½ - 1	· sample side valley diversity – this is one of few watershed with anything other than SB · sample younger forests – Pl, Ac in ICHmm · important potential corridor	Medium – High	good contrast to many other less diverse watersheds, although SFF also knows the Raush well already
50	Castle	rough	1 point	¼ - ½	· sample accuracy of Age Class 7 label · (SB in ICHmm)	Low	nothing special

51	Lower Castle	rough	short transect; possibly some points?	½ - 1	· sample diversity of ITG x BEC variant · one of few patches of OG Fd (ICHmm & ESSFmm1) · one of few side valleys with high diversity (akin to Raush) · check out corridor potential (up NW side)	Medium – High	reasonable accessibility; only good patches of OG Fd; possible to drive up whole watershed if we so desire
52	Upper Castle	rough, long drive	short transect & maybe 2 points	½ -1	· sample beta-diversity of "SB" in ESSFmm1 · sample diversity of ITG x BEC variant · (C in ESSFmm1) · potential corridor (up NW side)	Medium – High	reasonable accessibility to high ESSF that is still relatively intact (similar to upper Raush?)
53	Upper Dore (Castle)	rough, long drive	1 point & a drive	½ - 1	· sample diversity of ITG x BEC variant · (H9 in ESSF) · possibility of driving to top of watershed (peeking into Cariboo?)	Low	one of few places with access high into side valley – may be worth combining with something
54	Dore (Castle)	rough	2 points	½ - 1	· sample accuracy of Age Class 7 label · (SB, H in ICHmm)	Low – Medium	decent sized patches
55	Valley – Lower Dore	rough	up to 6 points	½ -1	· sample diversity of ITG x BEC variant · (SB in SBSdh, ICHmm, ESSF; C9 in SBSdh, ICHmm; H9 in ICHmm) · sample old growth	High	high diversity in small area; not far from highway
56	Dore (Castle)	rough (maybe 2dary)	2 points	½ - 1	· sample accuracy of Age Class 7 label · (SB, Pl) · sample BEC Ecotone (ICHmm/ESSFmm1)	Low - Medium	nothing special; patches quite small; uncertain access
57	Upper Dore (Castle)	rough	1 transect	½ - 1	· sample beta-diversity of "SB" in ESSFmm1	Low – Medium	reasonable accessibility into unfragmented upper watershed; better places to do this unless we want to see upper Dore

58	Milk River (Upper Goat)	rough, maybe non-existent	1 transect	1	· sample beta-diversity of "SB" in ESSFmm1 · ecologically similar to unfragmented part of Upper Goat, thus we can sample corridor suitability as well as ecological effects of clearcutting	High	likely difficult/ uncertain access but the Upper Goat will likely be very important in the final plan

Appendix III: Field Work Summary

Table 1: Field Session Summary for the Fraser Headwaters Project, October 1st to 10th, 2000.

Sampling Objective		Data Collected[22]	Time spent (% of total)
Stand level	Impacts of logging on stand structure (esp. CWD)	2 unlogged / 1 logged plots (Milk) 3 young tree plots (Slim) (also logged/unlogged plots in Morkill and logged/unlogged plots in Ptarmigan)	3 days (30%)
Landscape level	Antique forests – composition & structure	1 gigantic plot (Lower Morkill) Paired unlogged/logged plots (Ptarmigan) Truck transect & photographs (Ptarmigan) 1 unlogged plot (Dome Creek)	2¾ days (27.5%)
Stand level	Site Index inconsistencies	Paired unlogged/logged plots (Morkill)	1 day (10%)
Stand level	Potential for ecologically responsible timber management	2 plots (Kiwa) (many examples of non-ecologically responsible mgmt)	1 day (10%)
Landscape level	Range of variability in Spruce/Balsam types in the ESSF	2 plots – SB/B(S) (Holmes) (Also 2 plots BS/SB in Milk, 1 S(B) plot in Morkill)	1 day (10%)
Landscape level	Range of variability in ITG types by BEC zones	1 partial plot – S in SBS (Valemount) (Also S in SBS/ICH in Kiwa and antique forest data)	½ day (5%)
Landscape level	CDC Rare plant associations	1 plot (Valemount)	½ day (5%)
Landscape level	Character & condition of riparian ecosystems	Truck transect & photographs	¼ day (2.5%)
		TOTAL:	10 days

[22] Note: Where sampling plots met multiple objectives, plots were tallied under the primary objective (for time purposes) and listed in parenthesis under the relevant secondary objectives.

Table 2: Summary of Field Data Collected for the Fraser Headwaters Project, October 1st to 10th, 2000.

Date	Location	Transect	Plot	Stand Label	Notes	BEC Variant	Plot Cards Filled				
							Silviculture	Site Char	CWD	Plot Map	Young trees
1-Oct-00	Valemount (campground)	1C	1	SAcAt 7415-25	Unlogged	SBSdh	x				
	Valemount (Airstrip)	1A	1	Pl 8315-13	Unlogged	SBSdh	x	x		x	(on plot map)
2-Oct-00	Kiwa - Woodlot Extension	2I	1	SF 5405-22	Unlogged	SBSdh	x	x	x	x	(on plot map)
			2	FSPl 6405-21	Unlogged	SBSdh	x	x		x	(on plot map)
3-Oct-00	Holmes	3C	1	SB 8415-11	Unlogged	ESSFmm1	x	x	x	x	(on plot map)
			2	B(S) 8415-15	Unlogged	ESSFmm1	x	x	x	x	(on plot map)
4-Oct-00	Milk	5C	1	BS 8415-13	Unlogged	ESSFwk1	x	x	x	x	(on plot map)
5-Oct-00	Forgetmenot (Morkill)	7A	1	S 1101-/15 L97P97	Logged	ESSFmm1	stump cruise	no soils	x	x	(on plot map)
			2	S(B) 9415-7	Unlogged	ESSFmm1	x	x	x	x	(on plot map)
6-Oct-00	Milk	5D	1	SB 9415-11	Unlogged	ESSFwk1	x	x	x	x	(on plot map)
			2	n/a	Logged	ESSFwk1	stump cruise	x	x	x	(on plot map)
7-Oct-00	Hellroaring (Morkill)	6A	1	SC(HB) 9416-12	Unlogged - 20m plot	ICHwk3	x	x	x	x	(on plot map)
8-Oct-00	Ptarmigan	AF-1	1	CH 9415-12	Unlogged	ICHwk3	x	x	x	x	(on plot map)
		AF-2	1	p512 2009/S	Logged	ICHwk3	stump cruise	x	x	x	(on plot map)
9-Oct-00	Dome	AF-3	1	CHS(F)9416-13	Unlogged	ICHvk2	x	x	x	x	(on plot map)
10-Oct-00	Hungary	SL-1	1	SB(At)1101-/15 L73/4, 79	Young tree	ESSFwk1		x	x		x
	Slim	SL-2	1	S(B)1101-/15 L80	Young tree	ICHvk2		x	x		x
	Slim	SL-3	1	S1101-/19 L74	Young tree	SBSvk			x		x

Table 3: Summary of the Silvicultural Data Collected during the Fieldwork Component of the Fraser Headwaters Project.

Transect No.	Trees/ha	Volume (m^3/ha)	Height (m)			Diameter @ Breast Height (cm)			Age			Fallen Trees (CWD) (m^3/ha)
			min	ave	max	min	ave	max	min	ave	max	
1C	402	651	32	34.1	36.1	20.9	40.7	53.8	114	115	116	-
1A	1005	192	19.6	20.4	21.8	5.7	17.3	29.8	56	60	66	-
2I	1700	992	11.2	25.7	32.2	13	26.3	48.7	15	62	80	351.8
	1300	286	21.5	23	24.6	10.8	19.5	30.5	67	75	80	-
3C	804	391	19.7	23.6	29.3	8.3	26.6	57.5	55	63	77	189.0
	603	334	11.1	20.2	26.5	7.7	25.2	57.8	50	63	74	39.1
5C	900	373	9.5	22.2	30.3	8.6	22.7	61.4	74	121	146	325.6
7A	(logged)	-	-	-	-	-	-	-	-	-	-	58.6
	550	226	8.8	23.6	32.8	8.8	21.3	43.4	43	172	234	312.8
5D	(logged)	-	-	-	-	-	-	-	-	-	-	49.8
	750	458	11	23.1	37.3	10.1	28	65	95	144	197	203.5
6A	424	376	8.7	26.7	52.1	8.4	34.7	110.7	65	105	134	266.6
AF-1	600	737	28.6	31.3	36	32.5	53.2	82.8	-	-	-	111.5
AF-2	(logged)	-	-	-	-	-	-	-	-	-	-	147.1
AF-3	650	700	8	26.2	36.9	12.7	46.4	78.3	-	-	-	322.4
SL-1	(young tree)	-	-	-	-	-	-	-	-	-	-	67.4
SL-2	(young tree)	-	-	-	-	-	-	-	-	-	-	1.0
SL-3	(young tree)	-	-	-	-	-	-	-	-	-	-	32.1