SKEETCHESTN INDIAN BAND:

RESEARCH AND DEVELOPMENT IN

RIPARIAN ZONE MANAGEMENT

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EXECUTIVE SUMMARY

The purpose of the project, “Research and Development in Riparian Zone Management” was to conduct research into low impact forest harvesting techniques in the riparian zone within Skeetchestn traditional territory, focusing on the social and economic viability of alternate timber harvesting techniques. The objective is to develop techniques that could increase opportunities for the Skeetchestn Indian Band to specialize in low impact harvesting in the riparian zone and to gather practical knowledge on First Nation cultural values. Economic comparisons are made between current standard (clearcut) harvesting methods and low impact systems on both biological and economic (employment) outcomes.

Skeetchestn Indian Band has defined Cultural Resource Management zones (CRMZs) as existing in the 100 metre buffer zone adjacent to S4 to S6 streams (as classified by the Forest Practises Code) and other water bodies where clearcut logging is permitted. Low impact harvesting is defined as removal of a percentage of the forest cover rather than clearcut logging. Skeetchestn has used different logging equipment and different levels of forest cover removal to determine impact on lesser vegetation and economic return to participating communities. The results of the study will provide socio-economic knowledge to apply to future logging considerations, as well as provide empirical data on cultural values for sharing with forest licensees operating in traditional territories.

Research variables were defined in a formal research plan developed through subcontract by the University College of the Cariboo (UCC). The plan was developed to guide

project implementation and to make sure that results are statistically sound and meaningful. Research variables explored include: forest cover type, percent canopy removal, harvesting equipment (horses, rubber tired skidder, tracked low impact processor skidder) and stream class.

Integral to the success of the project was the integration of current forest licensee priorities, and their cooperation was essential to the project. Given the short time frames involved, it was not possible to generate new, unique cutting areas. Areas already in consideration for harvest were used for the project, with the cooperation of Weyerhaeuser Canada and West Fraser Timber. All work conformed to existing provincial policies for work in the riparian zone.

To provide and account for aboriginal values for the purposes of this study, the Skeetchestn Indian Band carried out Cultural Heritage Overview and Archaeology Overview Assessments. The information obtained from these assessments was used to determine presence of plant, wildlife and other significant attributes that are of social and cultural concern to the Skeetchestn Indian Band.

The study area consisted of four individual sites; Heller Creek, Tunkwa Lake, Greenstone Mountain and Chartrand Lake. Pre and post harvest stand characteristics were examined on Heller and Tunkwa, including soil bulk density, plant incidence, and health. Pre harvest only was completed at Greenstone and Chartrand, due to contract time constraints. Treatment types included small scale harvesting (50% and 100% removal), conventional harvesting (50% and 100% removal), horse logging (50% and 100% removal), and control (no harvest).

Preliminary results have shown that understory vegetation cover is significantly reduced regardless of the harvesting treatments used or site location. However, long-term monitoring is needed to determine whether any of the post-harvest treatments will recover to pre-treatment levels. The sole immediate impact of canopy removal was on Trapper's Tea, which showed significant declines. At least 5 years of monitoring will be required to establish trends on most species.

A socio-economic analysis was conducted to determine the economic feasibility of alternative harvesting practices and the overall impact that harvesting practices may have on local employment and income. Logging costs for horse logging and small-scale machinery were higher than conventional logging costs by 160% ($24.68) and 247% ($38.14), respectively.

With small-scale and horse logging over 95% of logging costs are retained within the local economy, with labour costs for small-scale and horse logging accounting for at least 82% of all logging costs, while only 34% of total costs were attributed to labour under conventional harvesting. Increased employment in greater labour intensive harvesting activities contributes to the local area through job creation, local spending, and income taxes.

As a result of the project, Skeetchestn has increased their ability to participate in the forest economy, through building of technical forestry skill both in the field, and with Geographic Information and Mapping Systems. Other benefits of the project relate to relationship building with the University College of the Cariboo, Weyerhaeuser, West Fraser Timber, and the Ministry of Forests. A significant outcome was the inclusion of clauses respecting Skeetchestn values in a recent forest tenure issued in the traditional territory.

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1 INTRODUCTION

1.1 Purpose

The Skeetchestn Indian Band is researching opportunities for integrating low impact forest harvesting techniques as an alternative to conventional harvesting in riparian areas within their traditional territory. To address the concerns around current logging practices and legislation of S5 and S6 (see Table 1.0 for definitions of classifications of S5 and S6) headwater streams and the maintenance of ecological integrity within riparian areas, the Skeetchestn Indian Band has developed a protocol for a 100 meter special management zone. This zone is defined by the Band as Cultural Resource Management Zones (CRMZ's), and are established adjacent to all streams, wetlands and water bodies within their traditional territory. While not wanting to exclude harvesting from CRMZ's, Skeetchestn Indian Band will integrate management of timber, water, wildlife, indigenous plants, and fisheries values with scientific methodology and traditional knowledge. The Band sees changes in harvesting and legislation as a means to convey their traditional ecological, cultural and social interests and values into forest development operations, management and legislation. At the same time this will increase the employment opportunities for band members and a greater retention of provincial investments and income revenues within the community.

The purpose of this research project is to measure the vegetation ecology and socio-economic impacts of horse, small-scale mechanical and conventional harvesting systems. The Skeetchestn Indian Band and the research team realize that there are other significant attributes that are affected by riparian harvesting therefore an in-depth literature review was conducted to recognize their significance in riparian ecology and management. This two year project was designed to provide literature research on riparian ecology, riparian management, impact assessments, harvesting techniques, socio-economic analysis and First Nations values. A research methodology was developed to evaluate preliminary research on four individual harvesting experimental sites. This methodology consisted of 7 treatments. The harvesting treatments were conventional clearcut, conventional select, small-scale clearcut, small-scale select, horse logging clearcut, horse logging select and control. Treatments were replicated to increase experimental reliability.

It was the objective of this project to establish areas of 100% removal to represent current (clearcut) harvesting practices and to implement areas of alternative harvesting through selection cutting (50% removal). Timber values and characteristic sampling were conducted congruently with pre-harvest and post harvest vegetation assessments.

Treatments plots were laid out as 0.25 ha squares (0.16 ha for site #3) in the summers of 2003 for sites #1 and #2 and 2004 for sites #3 and #4. Each site consisted of 14 treatment plots (7 treatments replicated twice) in which 15 sample plots were established for pre and post vegetation assessments. Soil samples were also taken for both pre and post harvest years to determine the impact on soil bulk density which is an indicator of soil compaction. All harvesting was conducted in winters of 2003 -2004 for sites #1 and #2 and planned for 2004-2005 for sites #3 and #4. Due to unforeseen warm weather patterns, horse logging of site #4 will be postponed to the winter of 2006. It was the intention of the study to harvest only over frozen and snow covered grounds. Unsuitable condition that deviated from the logging plan was the reason for delaying harvesting until 2006.

A socio-economic analysis was used to monitor harvesting operations to determine harvesting productivity and costs, thus enabling an assessment of the operational suitability of using low impact systems as an alternative to conventional harvesting for riparian areas. Three harvested areas ranged from 8.1 to 14.0 ha and were used to evaluate man hours contributed, total labour costs, maintenance cost and total logging cost on per m^3 basis. Involvement in the project included input and cooperation from the Skeetchestn Indian Band, University College of the Cariboo, West Fraser Mills Ltd., Weyerhaeuser Ltd., British Columbia Ministry of Forests, and Ministry of Sustainable Resource Management, with facilitation by Cirque Resource Associates Ltd. This project is funded by the Economic Measures Fund through the British Columbia Treaty Negotiation Office, with in kind contributions from partners.

1.2 Background

The impetus for this research project is based deeply in the social, ecological and cultural values of the Skeetchestn Indian Band. The Band relies on the resources of the Deadman Watershed and over time this watershed has been subjected to a “disproportionate amount of human impact.” The local community has concerns around the decreased health of fish and wildlife species and forest vegetation in their traditional territory and believe that this decreased health is an indicator of a broader ecosystem dysfunction that can be attributed to forestry practices, tourism, mining, urban and agricultural development. These concerns have lead to the development of a community vision and a framework for ecosystem stewardship in the Deadman Watershed and the traditional territory of the Skeetchestn Indian Band. Riparian management has become critical to Skeetchestn Band as the 100 meter buffer in the CRMZ is considered to have the highest concentration of First Nation values for plants, wildlife, and archaeological features. These areas have been significantly disrupted through conventional logging methods and restoration of these areas through re-evaluating harvesting methods is seen as means to return functionality and health to the watershed. The band is specifically interested in assessing how to conduct economically viable harvesting operations within riparian areas and at the same time maintain the integrity of the Deadman Watershed and its riparian ecosystems.

Alternative low impact forest harvesting practices have been identified by the community as a viable option for sustainable use and management of non-timber forest products and economic development. The band has high seasonal and un-employment rates, therefore they want to develop more labour intensive, ecologically sensitive harvesting practices to increase local employment. Horse logging and small-scale mechanical harvesting methods are seen as a way of providing employment as well as providing environmentally sound alternatives to conventional harvesting. The community also believes that partial harvesting with low impact logging systems provides the best opportunity for managing for the distribution of species, age classes and succession levels in a specific riparian harvest area as well as ensuring connectivity between critical habitat areas.

This project also provides the opportunity for the community to demonstrate the importance of integrating traditional practices and incorporating traditional ecological knowledge in forestry management practices in riparian areas. Other values of this project also include development of partnership opportunities with industry, government agencies and the University College of the Cariboo to demonstrate low impact logging and promote application of scientifically based new riparian area management systems. Other targeted outcomes include building capacity and development of skills of band members in technical and professional disciplines including archaeology, forest and vegetation surveying, Geographical Information Systems (GIS) and forest operations.

1.3 Study Area

The Deadman River drains a land base of approximately 1500 km^2 into the Thompson River, 50km west of Kamloops B.C. The watershed is located within the Kamloops and 100 Mile Forest Districts of the Kamloops and Cariboo Forest Regions, respectively (Speed and Henderson 1998). This watershed encompasses six biogeoclimatic zones; Bunchgrass (BG), Ponderosa Pine (PP), Interior Douglas Fir (IDF), Montane Spruce (MS), Sub-Boreal Pine Spruce (SBPS), and Engelmann Spruce Sub-alpine Fir (ESSF) zones (ARC Environmental Ltd. 1998). Elevations within the watershed range from 606m-1728m.

Currently forest harvesting is occurring within the MS zone of the watershed. The MS biogeoclimatic zone is located between the IDF and ESSF zones at an elevation of 1300-1650 meters. Weather within this zone is characteristic of cold winters with shorter, relatively warm summers. Forest stands are generally dominated by young to moderate aged lodgepole pine stands due to the affects of the areas higher fire frequency. The MS zone provides habitat for numerous forest dwelling species and provides habitat for deer and moose during summer and fall seasons (Ministry of Forests (MOF) 2001b).

Within the Deadman Watershed there are numerous smaller watersheds. They can be divided into 12 sub basins;

- Joe Ross Creek
- Vidette Lake
- Upper Deadman River
- Upper Criss Creek
- Mow Creek
- Heller Creek
- Upper Residual Creek
- Tobacco Creek
- Gorge Creek
- Barricade Creek
- Lower Criss Creek
- Clemes Creek

(Moore 2001)

The upper headwater tributaries of the Deadman River are located within the MS zone at elevations that range from 1,400-1,500m. However, the headwaters of Criss Creek originate from the ESSF zone at an elevation of up to 1,750m (ARC Environmental Ltd. 1998). The Deadman River is characteristic of low gradients within its upper reaches with steeper gradients in lower reaches near its confluence with the Thompson River (Young *et al.* 1992).

1.3.1 Geology

The areas surrounding the Deadman watershed are comprised of volcanic extrusive bedrock with minor sedimentary portions. It consists of the Nicola and Kamloops bedrock group, being characteristic of andesite, basalt, rhyolite, associated tuff and breccia, limestone and agrillite (Young *et al.* 1992).

Surficial geology of the lower portions of the Deadman Valley includes various landforms. The valley bottoms consist of fluvial and fluvioglacial deposits, surrounded by colluvial and morainal deposits at higher elevations (Young *et al.* 1992).

The area around Vidette Lake within the Deadman Watershed is underlain by mafic volcanic rocks of the Upper Triassic Nicola Group. This area is exposed through the erosion of flat lying Miocene sedimentary rocks and plateau basalts of the Chilcotin group. The uppermost Chilcotin Group strata is comprised of an extensive layer of plateau basalts of the Chasm Formation, underlain by fluviatile and lacustrine sedimentary strata and volcanic ash of the Deadman River Formation which occupies the northwest trending Miocene channel (Geological Survey Branch 2002).

The Deadman River Formation within the Deadman River Valley is comprised of 350 meters of ash, sandstone, siltstone, shale and diatomite. Fluvial paleoenvironment is found within deeply incised north and west tending valleys (Read 1988).

1.3.2 Soils

Soils of the Deadman Watershed are generally characteristic of Eutric Brunisols at lower elevations, Gray Luvisols at higher elevations and Dark Brown Chernozems at low elevation grasslands (Young *et al.* 1992). Soils within the Deadman River Valley are generally fine textured and are extremely susceptible to erosion and contribute high quantities of sediment into surrounding watercourses (Olmsted *et al.* 1992).

1.3.3 Climate

The area surrounding Kamloops receives an average annual rainfall of 260.5 mm. The Kamloops area generally sees 2202 growing degree days (>5^{o}C) and an average of 145 freeze free days. Temperatures of the valley are characteristic of mean July temperatures of 20.9^{o}C and mean January temperatures of –6^{o}C. Average snowfall accumulation equals approximately 77.1" and the lower elevations of the Kamloops area are around 346m (Young *et al.* 1992).

1.3.4 Fish and Wildlife

The Deadman River and its tributaries provide valuable habitat for a variety of salmonid species. Within the Deadman River, pink *(Oncorhynchus gorbuscha)*, coho *(O.kisutch)*, steelhead *(O.mykiss)* and chinook *(O.tshawaytscha*) salmon can be found up to the Snohoosh Dam. It is also suggested that the Deadman River is the most important tributary to the Thompson River for coho and steelhead production. However, in recent years there has been a substantial drop in the escapement numbers of salmonid species, leading to a self-imposed fishing closure by the Skeetchestn Indian Band. Declines have been attributed to the 1 in 500-year flood experienced by the Deadman River in 1990 (ARC Environmental Ltd. 1998) and to the possibility that reductions in upstream nutrient components such as macroinvertebrates and small organic debris have impaired proper watershed functioning. The Kamloops Land and Resource Management Plan (KLRMP) (1995) has defined areas of the Deadman watershed as critical winter range habitat for both deer and moose..

1.3.5 Land Uses

Land uses within the Deadman River watershed include primarily agriculture, forestry and recreation (ARC Environmental Ltd. 1998). Currently there are six forestry service campgrounds within the Deadman watershed, they include; Vidette, Bog, Deadman, Windy, Skookum and Snohoosh Lakes. Provincial parks within the watershed include Bonaparte, Porcupine Meadows, Tsintsunko Lake parks. The area also includes the

Skookum Hoodoos Protected Area (Speed and Henderson 1998). Other recreational users of the area include: snowmobiling, camping, fishing, hunting, hiking and mountain biking (Speed and Henderson 1998).

Forest licensees working within the watershed include; Ministry of Forests Small Business Forest Enterprise Program, West Fraser Mills Ltd, Sk7ain Ventures Ltd., Ainsworth Lumber Co., Tolko Industries Ltd. and Weyerhaeuser Canada Ltd.

1.3.6 Timber Harvesting within the Area

Within the Kamloops Forest Region Timber Supply Area (TSA), only 9.27% of harvesting is done as a selection silvicultural system. Most harvesting is done as clear cutting or clear cutting with reserves, totalling 84% of the total harvest (MOF 2000a). Revenues paid in 1999/2000 from stumpage within the Kamloops Forest Region totalled over $180 million. The productive forested land base of the Kamloops Forest Region is 4,306,000 hectares (MOF 2000a). The Deadman River watershed has 14,950 ha of riparian habitat. 12.2% of this area has already been either clearcut (871 ha, 5.8%) or selectively harvested (954 ha, 6.4%) (Ministry of Water, Land and Air Protection (MWLAP) 2000). According to the MOF (2000a), one opportunity to overcome challenges currently faced in the forest industry is to work with First Nations to advance economic opportunities for aboriginal people in the forest sector.

2 LITERATURE REVIEW

2.1 Riparian Ecology

There are many definitions that surround the term "Riparian Area". Most definitions describe a riparian area as the land that is adjacent to creeks, rivers and wetlands including lakes, marshes and bogs. Riparian areas provide a transition zone or interface between the aquatic and terrestrial ecosystems (Burton 1998, Hennan 1998, MOF 1998b, Bunnell *et al.* 1995, Stevens *et al.* 1995, Belt *et al.* 1992). Particularly, they act as the transition between water dominated low-lying topographic areas and the surrounding upland, generally forest dominated, ecosystems. These areas are generally described as having a plant community that is distinct from those that occupy the drier well-drained area of the upland environment. Riparian areas are also routinely referred to as "Riparian Zones" and "Riparian Ecosystems" and may be used synonymously. In many definitions within the scientific community even wildlife, fish and birds are considered an equal attribute to the components that make up a riparian area (Bunnell *et al.* 1999).

Riparian areas are of important ecological significance as they act as a synergistic network of interactions between the terrestrial and aquatic environments (Koning 1999). While these areas make up only 10% of the land base within British Columbia (MOF 1998b), they are considered the most important aspect of forested ecosystems due to their ability to produce the highest diversity of plant life and attract the greatest number of wildlife species (Cockle and Richardson 2003, Gyug 2000, Haag and Dickinson 2000, Whitaker and Montevecchi 1999). However, research has shown that riparian areas have diminished by as much as 66% in the United States from historical levels (Innis *et al.* 2000). This is of importance as riparian areas maintain part if not all the life stages of approximately 55%-75% of British Columbia's rare, threatened or endangered species (Richardson 2000, Bunnell *et al.* 1999, MOF 1998b). In British Columbia there are 51 vertebrates that are obligatory and 157 opportunistic users of riparian areas (MWALP 2000a). According to Knutson and Naef (1997), similar numbers have been determined for other areas of western North America, as approximately 85% of Washington's terrestrial vertebrate species use riparian habitat for essential life processes and 46 of Oregon's vertebrate species possess an obligatory life stage within riparian areas.

Riparian areas also provide a multitude of other attributes essential to the ecological processes of the natural environment (Figure 1.0). According to Koning (1999), these attributes can be grouped into two main functions; aquatic functions and terrestrial functions. Aquatic functions include; 1) contributing large woody debris (LWD) to maintain channel morphology and create habitat for fish and invertebrates, 2) regulation of water temperature through stream shading, 3) contributing to instream biological production through small organic debris, 4) buffering the stream from fine sediments by intercepting surface flow, 5) regulating instream sediment storage and transport. Terrestrial functions include; 1) providing wildlife habitat features, including coarse woody debris (CWD), wildlife trees, nest and perch sites, and summer and winter dennings, and 2) providing summer and winter forage for terrestrial fauna.

Other attributes of riparian ecosystems are those of importance from an anthropogenic viewpoint and include; cultural, economic, diversity and water. Cultural values include; technological, food, ceremonial, recreational, tourism, medicinal and spiritual purposes. Economic values include; trapping, timber extraction, livestock grazing and sport fishing. Diversity includes; fish, wildlife and plants. Water includes its quality, quantity and reliability (MOF 2002a).

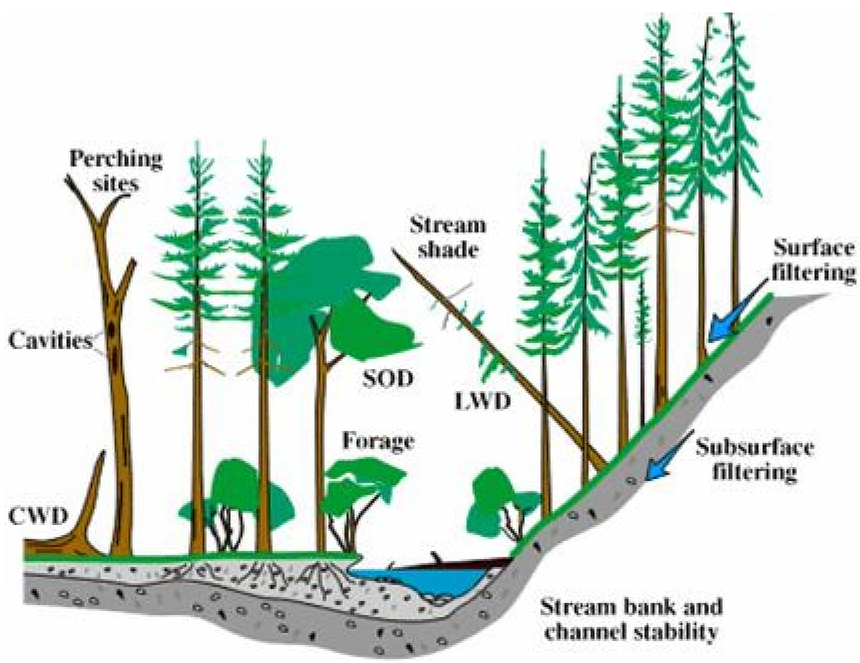


Figure 1.0. Ecological functioning of riparian areas (Taken from Koning (1999)).

2.2 Riparian Management

2.2.1 Riparian Management In British Columbia

The management of riparian areas has received much attention over the last decade in terms of water quality, specifically for its potential impact on fish populations and habitat (Cockle and Richardson 2003, Richardson 2000, Waterhouse and Harestad 1999, Hayes *et al.* 1996). However, due to poor management practices and incomplete information on the effects on other components, research is now progressing to provide greater information on wildlife and bird habitat (Gyug 2000), aesthetics, overall ecosystem functioning (Waterhouse and Harestad 1999) and the cumulative downstream effects not prevalent in past research (Richardson *et al.* 2002, Richardson 2000).

In 1995 the MOF constructed a new classification system to deal with concerns arising around the management of riparian areas. However it is felt that this system was produced mainly to ensure that water quality in community watersheds and fish habitat would be protected from the effects of forest harvesting. The MOF used a classification system that included seven categories of stream characteristics with a varying amount of protection allotted to each (Table 1.0).

Table 1.0. Stream classifications as set forth by the MOF, June 1995.

Riparian Class	Average channel Width (m)	Reserve zone width (m)	Management zone width (m)	Total width (m)
S1 Large rivers	>100	0	100	100
S1 (except large rivers)	>20	50	20	70
S2	>5<20	30	20	50
S3	1.5<5	20	20	40
S4	<1.5	0	30	30
S5	>3	0	30	30
S6	<3	0	20	20

(shaded)	**Fish bearing stream or community watershed**
(unshaded)	**Non-fish bearing and not in a community watershed**

(Modified from Forest Practices Code 1998)

Currently there is great concern that the present system under protects the values of small headwater streams of British Columbia (Gomi *et al.* 2002, Haag and Dickinson 2000). In particular, those streams classified as S4, S5 and S6 streams under the MOF Guidelines. Streams of S5 and S6 classification are those that are determined to be non-fish bearing, and not considered to be within a community watershed. S5 streams are those that have a bankfull width greater than 3m while S6 streams are those with a bankfull width less than 3m (Riparian Management Area Guidelines 1995). Streams of S4 classification are those that are less than 1.5m in width and are either in a community watershed or are fish bearing.

Harvesting within these headwater streams currently accounts for 70% of all harvesting in riparian areas yet harvesting guidelines for these streams provide the least level of protection (Bradley 1997). These streams are also known as Class C (Bradley 1997), first and zero-order streams (Hudson and D'Anjou 2001, Bradley 1997). This is inherently important to watershed management as headwater streams make up over 50% of the total channel length within watersheds (Benda *et al.* 2002, Richardson 2000, Beschta and Platts 1986).

According to Gomi *et al.* (2002) harvesting activities that occur in smaller headwater streams are being inconsistently regulated. They also suggest that the management of these streams has been based on limited scientific research. Gomi *et al.* (2002) suggests that this is due to the absence of fish species within the streams. Another factor may include the fact that riparian habitat of small streams is narrower and less distinct than that associated with large streams or rivers (Knutson and Naef 1997). The influence exerted by the riparian area on the aquatic system is greater in smaller streams than larger ones (Knutson and Naef 1997), and therefore requires equal protection.

Management of these streams is controversial at best due to the management requirements under the Forest Practices Code Act (FPC). All streams within the province require a riparian management area that consists of a riparian reserve zone and/or a riparian management zone (Riparian Management Area Guidelines 1995). Under the current code, S4-S6 streams are required only a riparian management zone and not a riparian reserve zone that is required for those streams of S1-S3 classification (Figure 2.0). Riparian reserve zones and riparian management zones are defined as;

"Riparian Reserve Zone: that portion, if any, of the riparian management area located adjacent to a stream, wetland or lake. Harvesting of trees is not permitted normally in the reserve zone unless approved by government in specific circumstances."

"Riparian Management Zone: that portion of the riparian management area that is outside of any riparian reserve zone or if there is no riparian reserve zone, that area located adjacent to a stream. Harvesting of trees is permitted in the management zone."

(Forest Practices Code 1998)

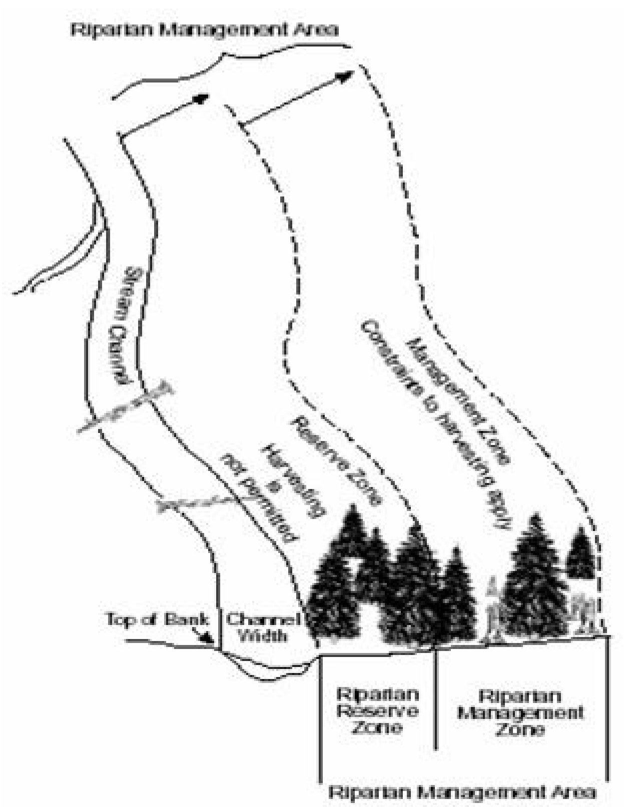


Figure 2.0. Graphical depiction of the riparian management area, riparian reserve zone and the riparian management zone (Taken from Riparian Management Areas Guidelines 1995).

The lack of riparian reserve zone is of great concern because the riparian management zone requirements only suggest the best management practices for these streams and does not provide the same protection that the riparian reserve zone legislation does (Forest Practices Code 1998). Within the Riparian Management Area Guidebook (1995), the

MOF states best management practices for these streams. Best management practices for S5 and S6 streams suggest that riparian management should;

> *" maintain important wildlife habitat and, where needed, a source of LWD and root networks for bank and channel stability, and overall shading for stream temperature control".*
>
> (Riparian Management Area Guidebook 1995)

These are recommended practices only and are not legally binding (Forest Practices Code 1998). That is to say that forest licensees are not legally obligated to follow these practices (Muchow and Richardson 2000). This lack of legislative regulation is of great concern as these smaller streams contribute greatly to the overall length of stream networks and are receiving the lowest legislative protection against harvesting (Gomi *et al.* 2002, Muchow and Richardson 2000).

Even with the fact that these streams may be ephemeral, they are an important part of protecting quality of downstream resources (Gomi *et al.* 2002). Headwater steams are crucial for the transport of organic matter, sediments, water and nutrients to larger downstream reaches. Headwater streams produce a greater amount of coarse particulate organic matter (CPOM) than downstream reaches and obtain their nutrients primarily through onsite riparian vegetation (Gomi *et al.* 2002, Belt and O'Laughlin 1994).

An investigation by the Forest Practices Board (1998) determined that only 39% of S6 streams had the recommended amount of vegetation along the stream bank or within the riparian management area. They attribute this to the forest industry leaving a larger amount of vegetation along a few streams, while leaving smaller amounts vegetation retention along most other S6 streams. They also attribute this to clear cutting and cross-stream yarding which has been shown to increase large woody debris left in streams and reduce standing riparian vegetation.

Based on the findings of the investigation, recommendations have been set as follows;

"Government, working with the forest industry, should provide standards, guidance and training to improve stream inventories, identification and classification. A clear definition of a "stream" is also essential.

Government should develop more specific requirements and recommendations for retention of trees and vegetation in riparian management zones, to meet objectives for biodiversity and habitat management.

Government and the forest industry should work together to improve planning and practices around small streams, particularly to prevent the transport of debris in non-fish streams."

(Forest Practices Board 1998)

It is now becoming apparent that stream orders may be an inappropriate way to classify hydrologic and biological processes (Gomi *et al.* 2002, Bunnell *et al.* 1999). Even the Department of Fisheries and Oceans (DFO) shows concern over the fact that non-fish bearing streams are receiving little or no protection under the FPC. DFO is concerned that current forest practices within S4-S6 streams may be contributing to the harmful alteration and disturbance of fish habitat and therefore may be in contravention of the Fisheries Act. To rectify this, DFO recommends that S5 and S6 streams that are tributaries to fish bearing streams or sensitive spawning areas and S4 streams should have vegetation retention of the riparian management zone of close to 100% unless other more appropriate management issues provide greater ecological significance (J. Guerin. pers. comm).

According to the Ministry of Sustainable Resource Management (MSRM) (2002), concerns have been recently raised with regards to how adequate the legislation under the FPC protects riparian areas, particularly non-fish bearing (S5 and S6 classification) streams and smaller fish bearing streams (S4 classification). The MSRM (2002) has therefore established objectives and strategies for a greater increase in protection of these areas. They include;

"Manage streams less than 1.5m in width with fish (S4), throughout the plan area, by applying a 20m reserve zone and a 20m management zone…

Manage streams greater than 3m in width with no fish (S5)…… by applying a 10m reserve and a 20m management zone…

Manage larger S6 streams (greater than 1.5m bankfull width up to 3m)……by applying a 10m reserve zone and a 10m management zone…

For smaller S6 streams (less than 1.5m bankfull width), use best management practices from the Riparian Management Area Guidebook, September 1995".
(MSRM 2002)

These objectives of the MSRM therefore imply that only those guidelines for small S6 streams under the best management practices are an appropriate protective measure. They therefore suggest that the FPC is inadequate for the protection of all other S4, S5 and large S6 streams.

According to Hogan (2002), the FPC also limits overprotects S1-S3 streams in regards to LWD supply while under-protecting smaller S4-S6 streams. He suggests that these inappropriate levels of protection restrict access to timber around larger streams while smaller streams receive little attention or protection for non-timber resources.

2.2.2 Riparian Management In Other Jurisdictions

Riparian Management in the United States varies significantly from state to state. The primary focus of most states is to provide regulations which sets forth guidelines for minimum riparian zone width, minimum residual trees for the riparian zone, and other guidelines for modifying management practices within the riparian zone (Blinn and Kilgore 2001).

Riparian management in Washington State falls under the direction of the Department of Natural Resources. Riparian areas are regulated under forest practices rules and are termed Riparian Management Zones (RMZ's) (MOF 1995, Belt and O'Laughlin 1994). Under this management protocol, riparian streams are classified into five categories. They include; Type 1-waters including shorelines, Type 2-waters with important fish, wildlife or human use. Type 3-those with moderate fish, wildlife or human use. Type 4-not Type 1,2, or 3 and that are >2 feet (0.6m) wide and Type 5-intermittent streams, temporary ponds and seepage areas (Table 2.0).

RMZ's are only required for Type 1, 2 and 3 waters (MOF 1995, Belt *et al.*1992) and are variable widths ranging from 1.5-33m in western Washington (Belt *et al.* 1992) and 10m-

100m in eastern Washington, depending on stream width. These streams also require that all unmerchantable timber be left and the combination of that timber and merchantable trees provide a minimum of 50% shade. If the stream is characteristic of 7-day average temperatures in excess of 60^{o}F (15.6^{o}C), 75% stream shading must be retained (Belt *et al.* 1992).

Washington State's RMZ's are also required to maintain Riparian Leave Areas (RLA's), a set number of trees/300m. The number of trees/300m is based on stream width, type, material, size of cut block and percent harvest within the RMZ (Belt *et al.* 1992). RMZ's are also required on Type 4 streams for the preservation of small trees and other vegetation to help prevent debris torrents (MOF 1995). RMZ's are primarily focused on maintaining a supply of large organic debris for western Washington streams. Concerns in eastern Washington are more oriented toward wildlife habitat.

Table 2.0. Washington State stream classification and riparian management (Modified from Belt and O'Laughlin 1994).

Stream Class	**Buffer Strip Requirements**		
	Width	**Shade or Canopy**	**Leave Trees**
Type 1, 2, and 3	variable by stream width (5 to 100 feet)	50%; 75% if temperature >60^{o}F	# /1,000 feet dependent on stream width and bed material
Type 4	None	None	25trees/1,000 feet > 6 inches diameter
Type 5	None	None	-

In Oregon State, streams are classified into three size classes and three beneficial use classes (see Table 3.0). Type F streams are those that contain fish and may be used for domestic water uses, Type D are non-fish bearing and are used for domestic water purposes, while all other streams are classified as Type N streams (Oregon Administrative Rules (OAR) 2003).

Classification of the three classes of stream size is based on rates of flow rather than stream widths (Robison *et al.* 1999). Large streams have a flow greater than 2.3 m^3/s, medium streams 0.45-2.3 m^3/s and small streams have a flow of less than 0.45m^3/s (OAR 2003).

Table 3.0. Classification of Oregon State streams (Modified from MOF 1995).

Stream Size	Type of Use		
	Fish Use (F)	**Domestic Use (D)**	**Neither F or D (N)**
Large	100 feet (30m)	70 feet (21m)	70 feet (21m)
Medium	70 feet (21m)	50 feet (15m)	50 feet (15m)
Small	50 feet (15m)	20 feet (6m)	varies

These Riparian Management Areas (RMA's) are not reserves but rather areas that restrict management practices unless otherwise approved. The only streams that have a reserve area are those streams that are classified as large streams. These reserves require a 6m strip in which no harvesting in permitted. The requirements for vegetation retention within RMA's vary according to stream type, size and geographical region. There are seven geographical regions within Oregon (MOF 1995).

Vegetation retention for all Type F and D streams and large and medium Type N streams include the retention of all understory vegetation within 10 feet of the high water level, all trees within 20 feet of the high water level, all trees leaning over the channel and all downed wood and snags that are not safety or fire hazards. In addition vegetation retention must retain a minimum of 30 conifers/300m along large Type D and Type N streams and 10 conifers/300m along medium Type D and Type N streams (OAR 2003).

Smaller Type N streams are not required to have any merchantable timber retained (Robison *et al.*1999). However in certain geographic regions of Oregon understory and unmerchantable trees must be retained if the perennial channels have an upstream drainage of 160 (South Coast), 330 (Interior), and 580 acres (Siskiyou) and all perennial streams in the Eastern Cascades and Blue Mountains (Robison *et al.*1999).

2.2.3 Buffer Strips as a Management Approach

Managing for the protection of riparian areas has been predominantly implemented through the presence and retention of fixed width buffer strips around streams (Cockle and Richardson 2003, Hayes *et al.*1996), wetlands and lakes (Burton 1998, Belt and O'Laughlin 1994, Castelle *et al.* 1992). Buffer strips are areas of protected land adjacent to stream channels that provide a certain level of protection against anthropogenic activities (Whitaker and Montevecchi 1999, Burton 1998, O'Laughlin and Belt 1995). There are many functions of riparian buffers. They contribute to the maintenance of hydrologic, hydraulic and ecological integrity of the stream channel and associated vegetation and soils, protect aquatic and riparian plants and animals against upstream pollution, and protects fish and wildlife by supplying food, cover and thermal protection (Belt *et al.* 1992).

Buffer strips have been studied for their contribution in maintaining high quality rivers in regards to fish habitat and water quality but little attention has been paid to small non-fish bearing headwater streams (Richardson *et al.* 2002). Although buffer strips can afford some protection against the impacts of timber harvesting, these areas of intact land also have the potential to become disconnected from other forests of similar structure surrounded by young forest types, creating fragmentation (Waterhouse and Harested 1999).

If buffer strips are implemented into riparian management they are often too narrow to provide protection (Richardson *et al.* 2002) and may be prone to windthrow (Burton 1998, Moore 1977). It is also suggested that if buffer strips are widened to increase protection, they may take away form the amount of harvestable timber that is available for forest licensees, resulting in a loss of timber resources, and creating a point if contention (Gomi *et al.* 2002, Bunnell *et al.* 1999, Burton 1998). Spatial analysis suggests that if buffer strips of one tree height were required on all perennial streams, 30% of the land base in British Columbia would be excluded from timber supply (Burton 1998) and it is for this reason that small streams are exempt from protection. While areas of the interior of British Columbia do not possess the same magnitude of small order streams as coastal regions, analysis of the interior shows similar tends. The Skeetchestn Indian Band along with Integrated Wood Services mapped out a 100 meter buffer zone around all water features in the Deadman Watershed. It was determined that 20.67% of the land base would be protected under the buffer zone (M. Anderson pers. comm).

Within the scientific community, there is a general consensus that appropriate buffer widths should be based on several variables, including; existing wetland functions and values, sensitivity to disturbance, buffer characteristics, land use impacts, and desired buffer functions (Castelle *et al.* 1992). Due to the fact that riparian areas have such variable patterns of gradients, they cannot be directly linked to one particular width of stream protection or buffer width (Bunnell *et al.* 1999, Burton 1998). Bunnell *et al.* (1999) suggests that by setting specific boundaries or required buffer widths, mangers are suggesting the extent of conductivity with the adjacent upland areas and the appropriate width of management area is easily delineated. However, according to Miller *et al.* (1997), different buffer widths can provide protection for various functions. They suggest that water temperature can be moderated with buffer widths as little as 10m. Sediment removal, nutrient removal and the protection of species diversity have shown to be accomplished by retaining buffer strips of 50, 80 and 90m respectively. However, according to Belt and O'Laughlin (1994), the appropriate buffer strip width will change from site to site based on infiltration rates and slope and suggests that buffer strips are more efficient at controlling overland sediment flows than channelized flows. Research has shown that channelized flow can move over 300m while overland flow is usually limited to less than 100m (Belt *et al.* 1992).

Knutson and Naef (1997) conducted a comprehensive literature review on buffer widths and summarized their findings in Table 4.0 for various riparian habitat functions. There appears to be great variability in the recommended buffer widths between researchers, particularly for wildlife habitat. However, wildlife habitat summaries included all recommended widths for invertebrates, fish, birds and mammals.

Table 4.0. Summary of buffer strip widths ranges and averages for various functions (Modified from Knutson and Naef (1997)).

Riparian habitat function	Range of reported widths (m)	Average of reported widths (m)
Temperature control	11-46	27
Large woody Debris (LWD)	30-61	45
Sediment filtration	8-91	42
Pollution filtration	4-183	24
Erosion control	30-38	34
Microclimate maintenance	61-160	126
Wildlife habitat	8-300	88

Another concern regarding buffer strips is that of creating an edge effect (Burton 1998). Edge effect can be defined as the boundary between two distinct biological communities. In reference to riparian areas, it is the boundary that is created between the riparian vegetation and the vegetation and attributes of the upland area (MOF 1998c). Edge effect becomes more prevalent as buffer strips are created as long and narrow strips of land that lose the influence of the surrounding interior forest (Cockle and Richardson 2003). Harvesting changes this area of transition from a gradation to an abrupt boundary. This abrupt boundary can have severe effects on the population dynamics, through changes in dispersal and predation rates. Over time edge effects can have severe impacts on the composition of vegetation communities (Miller *et al.* 1997). This can occur from blowdown, loss of lichens, alteration of understory vegetation and increased mortality of shade tolerant plant species (Miller *et al.* 1997). Investigation into the effects of increased edges along riparian areas has been minimally researched and requires further investigation into its effect on biodiversity, particularly small organisms (Richardson *et al.* 2002).

Richardson *et al.* (2002) has begun research to look at alternatives to fixed width buffer strips as a form of riparian management. While fixed buffer widths are beneficial for administration simplicity (Belt *et al.* 1992), variable width alternatives would be advantageous as current buffers provide either too much or not enough protection (Belt and O'Laughlin 1994). However, according to Knutson and Naef (1997), there is currently insufficient information to recommend variable width that can adequately protect the high variability of riparian width, land uses, and fish and wildlife communities.

The appropriate buffer width for riparian areas varies according to the protection requirements for different functions. Research has shown that the effectiveness of buffer strips increase as buffer width increases in regards to removing sediments, nutrients, bacteria, and other pollutants from surface water runoff (Knutson and Naef 1997). However, research has shown that the efficiency of sediment removal is disproportionate to the increased widths of buffers. Knutson and Naef (1997), suggest that sensitive or priority species may benefit from these incremental increases.

Huryn (2000), suggests that based on a review of literature, buffer widths should be >30 m to protect the community dynamics of insects within small headwater streams. Huryn (2000) suggests that buffer strips of narrow widths such as the 7.6m width used in 0-order streams in Maine are inadequate for mitigating the effects of harvesting activities for insect communities.

However, buffer strips alone have shown to be insufficient in regulating stream temperature, as stream temperature is also a function of stream width, air temperature, groundwater temperature and slope. According to Teti (2000), stream temperature is a function of reduced shading levels rather than a function of harvesting. Therefore it appears that the effectiveness of stream shading is based on buffer design rather than buffer width, and the more closely a buffer provides shade in proportion to natural shade levels, the more effective the buffer (Teti 2000, Belt and O'Laughlin 1994).

Research is now looking at the effects of partial cutting as opposed to buffer strips within riparian areas to determine what protection this system can provide. While any cutting within riparian areas will alter communities beyond their natural parameters, partial cutting treatments provide greater protection than small headwater streams currently receive. This may also relieve some of the contention that has arisen in concern between full reserve zones and timber extraction.

2.2.4 Partial Retention as a Management Approach

Partial retention of vegetation adjacent to smaller streams has increased in recent years since the imposition of the FPC in 1995. This legislation has lead to an increase in the use of alternative silvicultural systems other than clear cutting. However, there are minimal results available on these silvicultural systems within riparian areas. One research report within British Columbia does however provide insight into the condition of small fish bearing (S4) streams following various riparian management practices.

Chatwin *et al.* (2001) conducted an investigation into 2989 cutblock across British Columbia and determined that 81 blocks contained an S4 stream or S5 and S6 streams that were direct tributaries to an S4. Of the streams, 68% had some type of unharvested riparian reserve, 22% were clearcut and 10% had a partial retention treatment. Study blocks were located in the Merritt (5 blocks), Kamloops (8), Salmon Arm (4), Clearwater (6), 100 Mile House (38) and Williams Lake (20) Forest Districts.

The partial retention treatment varied from 71% retention (% stem/ha) directly adjacent to the streams to approximately 25% tree retention 20-30m from the streams, with cumulative tree retention of approximately 50%. According to Chatwin *et al.* (2001), partial retention treatments possess the highest stream impacts as 33% of streams had moderate impacts due to windthrow and high impacts due to livestock. Boundary and fixed reserves had the least impact on streams with 4.8 and 7.7% streams having moderate to high impacts. Chatwin *et al.* (2001) also found partial cutting to have moderate to high risk of canopy shade loss. They determined shade loss in 42% of partial retention blocks compared to 36% in variable width reserves, 17% in boundary reserves, 31% in fixed-width buffer reserves and 73% in clearcut treatments.

According to Chatwin *et al.* (2001) partial retention has implications as a forestry management practice within riparian areas. It was determined that partial retention had the highest proportion of concerns regarding stream channel stability, windthrow incidence and loss of stream shading. Clear cutting appeared to be a sufficient management practice in regards stream channel stability, and windthrow but appeared to promote high shade loss. Chatwin *et al.* (2001) suggests that boundary reserves and fixed-width buffers provide the most stream protection as they provide the best combination of stream channel stability, shading and windthrow resistance. However, this method may provide increased biological protection but again raises issues of a loss in available timber for harvesting. It should also be noted that while the study results suggests partial retention has many management implications, channel stability is also a factor of cattle use and must be evaluated and managed in conjunction with harvesting treatments.

2.3 Impact Assessment

Removing vegetation from the riparian zone through timber harvesting can cause severe and sometimes indirect effects to the functioning of an ecosystem and cumulative effects many kilometres downstream (Hayes *et al.* 1996). Due to riparian areas being situated within topographic depressional areas, they receive water, soil and organic debris that are affected by upslope land uses (Knutson and Naef 1997). This is particularly true when areas are clearcut to the stream banks, impairing their role of providing the linkage between biological and physical characteristics of the terrestrial and aquatic ecosystems (Koning 1999).

Harvesting can have different impacts on headwater streams due to the high diversity among the size of streams and their gradient, thus affecting the incidence of radiation, current velocity and sediment deposition (Bunnell *et al.* 1999). When harvesting diminishes the vegetation within these ecosystems, riparian areas also lose their ability to influence and moderate the surrounding environments, thus affecting wildlife, water quality and fish habitat. However, different harvesting techniques can affect the magnitude of these detrimental impacts. Studies have also shown that riparian management techniques are required to ensure that water quality concerns do not affect downstream resources (Hudson and D'Anjou 2001).

Alternatives to clear cutting other than buffer strips can include variable retention of merchantable trees or retention of non-merchantable trees within the cutting area. The retention of small groups and individual trees can provide structural complexity, which has been shown to be an important part of forest ecosystem maintenance. These alternative systems tend to have management goals that are broader than solely economic gains and place equal value on all forest resources (MOF 2000b). The retention of small groups and individual trees can provide islands that are characteristic of mature forests and provide an area of refuge for many organisms until the site conditions within the cut block become inhabitable again (MOF 2000b).

The overall impacts of forestry on riparian areas, through vegetation removal, road construction and soil disturbance can include but are not limited to:

- Alteration of site vegetation
- Fish and wildlife impacts
- Water quality and hydrologic (relating to water flow) effects
- Stream temperature increases and a more severe microclimate
- Soil destabilization, erosion, and sedimentation
- Loss of large woody debris
- Increased windthrow
- Cattle grazing

2.3.1 Vegetation

Plant diversity is generally highest in riparian areas. This is due to the gradient of moisture that extends between the influencing water source and the upland area. Plant biomass therefore increases with proximity to the water source (MOF 1998b). Riparian areas are generally dominated by plant species that are both shade tolerant and shade intolerant. Due to the occurrence of flooding, riparian areas at the fringe of the water source generally consist of species that are shade intolerant as crown closure is generally less in these areas. As the gradient of moisture lessens from the water source to the uplands, shade tolerant species become more pronounced due to reduced flooding and increased crown closure (Bunnell *et al.* 1995). Therefore herbaceous shrubs and deciduous species compliment water-loving plants as they diverge from the central water channel to upland areas (MOF1998a).

Riparian vegetation creates a complex rooting system that is usually shallower than vegetation found in upland areas due to the higher water table. These shallow but extensive root systems provide protection against soil erosion, reducing the amount of sediment being deposited into streams and providing an appropriate level of stream bank stability and contribute to the maintenance of water quality and velocity (Stevens *et al.* 1995, Beschta and Platts 1986).

Riparian vegetation also contributes greatly to the recruitment of organic material in the system as it provides leaves, twigs and insects that provide energy to various components of the aquatic environment. Riparian areas also contribute large woody debris that provides habitat structure for numerous aquatic organisms while aiding in maintaining stream bank stability (MSRM 2002, Bunnell *et al.* 1995).

When clear cutting occurs within riparian areas, modification of vegetation layers can occur. For example, clear cutting generally eliminates the moss layer found on the forest floor and replaces it with increased herbaceous cover (Gyug 2000). That increase in shrub cover can occur following the opening of the canopy through clear cutting or partial cutting.

2.3.2 Regeneration of Conifers following Riparian Harvesting

Regeneration of vegetation following harvesting is primarily through the rapid growth of deciduous shrub species. Due to forest management practices within riparian areas generally being lumped with upland harvesting techniques, many streams are harvested to the banks. Because this promotes a flourish of fast growing shrubs that usually give way to the growth of hardwood species, conifers are often poorly represented within the overstory of regenerating riparian stands (Beach and Halpern 2001). This is of importance as conifers are a source of LWD that provides structural integrity to streams for a longer period of time as opposed to hardwoods due to differences in size, structure an decomposition rates.

A major concern with the regeneration of conifer species is the lack of seed availability for natural regeneration following harvesting. If riparian areas are clearcut along with upland areas, the seed bank available to provide seeds for regeneration is often too small or too distant from the stream bank. Due to harvesting practices within the riparian areas of small headwater streams, few riparian areas experience sufficient seed rain for successful conifer regeneration (Beach and Halpern 2001). The method of selectively logging can provide increased seed dispersal in immediate or close proximity to riparian areas.

Research conducted by Beach and Halpern (2001) suggest that regeneration of conifer species is greatest for areas in which seed trees are within a 80m proximity. They also found no regeneration occurred in areas that were in excess of 170m from a seed source. These results suggest that selective harvesting which removes individual trees or groups of trees retains an increased seed bank that is better capable of regenerating harvested areas to conifer stands. Beach and Halpern (2001) also determined that over 50% of conifer regeneration occurs on coarse woody debris. This suggests that conifers are required within riparian areas for perpetual regeneration of stands.

Natural regeneration may also be of concern due to the fact that species such as Douglas-fir are relatively shade-intolerant especially when regeneration occurs under deciduous species. Douglas-fir have shown to rarely establish in stands were shrub cover exceeds 10% (Beach and Halpern 2001). However, MOF (1998a) studies conducted on 31 partially cut stands within the IDF dk3, xm and xw of the Cariboo Forest Region determined that Douglas-fir regeneration was abundant in all stands. Areas were harvested using 13-89% basal removal. Twenty eight of the blocks studied all met MOF stocking standards. The three that did not meet stocking objectives were due to those sites that had steep, southerly slopes with low crown closure (MOF 1998a). This study suggests that natural regeneration is sufficient to meet the stocking standards set forth by the MOF regardless of the amount of basal area removed under partial cutting systems (MOF 1998a).

Other species such as spruce (*Picea*) and sub-alpine fir (*Abies laciocarpa)* have shown varying regeneration success. In a study within the ESSF of the Cariboo Forest Region, it was determined that the natural regeneration of spruce had no relationship to the area of opening harvested, while subalpine-fir was determined to have a greater regeneration success within small (0.03ha) or medium (0.13ha) openings as compared to large openings (1.0ha) (MOF 2000c). However, seven years after harvesting, regenerating spruce and sub-alpine fir were insufficient in height to meeting local stocking standards.

Artificial regeneration through planting may be an alternative method for regenerating partially cut riparian areas. MOF (1997) conducted studies into the artificial regeneration of conifer species within the ESSFwc3. Lodgepole pine, interior Douglas-fir and sub-alpine fir were planted under five treatments; protected sites, natural raised sites, rotten wood, mechanized scarification and standard grid planting. Results determined that seedling diameter and leader growth of all species increased as opening sized increased and elevation decreased. Lower amounts of terminal damage were also noted within large openings. Results also suggest the pine has superior growth but spruce provide better tree form due to slower growth characteristics and lower mortality in higher elevation sites (MOF 1997).

2.3.3 Fisheries

Riparian areas are an imperative aspect of retaining viable fish populations. It is the forest management practices within the riparian zone that can have the greatest effect on fish habitat (Beach and Halpern 2001). Fish have evolved life history strategies that depend on natural conditions found within freshwater streams. Fish have developed behaviours for breeding, feeding, resting, and avoidance of predation that are adapted to natural rates of stream flow, erosion and sedimentation, and inputs of organic materials including food sources and large woody debris (Knutson and Naef 1997).

Four ways in which riparian areas aid in ecosystem function in regards to fisheries include:

- ***Physical and biological filtration:*** *buffering impacts of activities such as logging outside the riparian area by absorbing nutrients and silt produced by those activities;*
- ***Amelioration:*** *reducing variability of physical or chemical characteristics such as water temperatures;*
- ***Biological production:*** *providing the bulk of the aquatic food chain base through terrestrial organic matter and food organisms (insects), specially in small, shaded streams*
- ***Structural protection and renewal:*** *stabilizing banks, minimizing erosion and stream sedimentation, and providing sources of logs, gravel, etc. that provides critical structural elements and variation in stream characteristics*

There are many ways in which forestry can impact a productive fisheries stream directly or indirectly from upstream inputs. Some of the negative impacts may be cumulative and include increased sedimentation, temperature changes, loss of LWD, and changes in hydrology.

Research conducted by Chatwin *et al.* (2001) evaluated 81 harvested areas in 6 forest regions of British Columbia that encompassed or were adjacent to S4 streams to determine the impact of various riparian silvicultural treatments. Treatments included boundary reserves, fixed and variable width buffers, partial cuts and clearcuts.

2.3.4 Wildlife

Riparian areas are of great importance to wildlife throughout British Columbia, primarily due to the attraction of available free flowing and standing water (Waterhouse and Harestad 1999). The variation in plant structure and diversity is also an important attractant of wildlife to riparian ecosystems (MOF 1998b) as the diverse structure provides a source of nutrition while providing rearing and concealment habitat and travel corridors (Bunnell *et al.* 1999, Knutson and Naef 1997, Stevens *et al.* 1995). Most wildlife species use riparian ecosystems at some stage in their lifecycle and are obligatory, while others are only dependent on these areas for opportunistic reasons (Stevens *et al.* 1995). The assemblages of species that rely on riparian ecosystems for various life processes include; birds, fish, amphibians, invertebrates and large and small mammals.

Riparian areas generally have a higher number of wildlife species inhabiting them compared to upland areas due to the presence of free flowing water, greater cover and thus the greater abundance of forage for forest dwelling species. Riparian areas generally consist of both coniferous and deciduous species, therefore providing a greater number of niches than limited structured ecosystems (Bunnell *et al.* 1999).

Due to the greater complexity and biomass of the riparian area, cover is generally greatest in this area. This dense cover allows mammals an environment in which they can hide and take refuge from predation. The greater abundance of shrub species in riparian areas due to wetter conditions and greater sunlight provide an important attribute for mammal populations (Bunnell *et al.* 1999). Research conducted in southern British Columbia has shown that even insectivorous bat activity is more abundant in riparian areas due to greater prey availability and drinking sites (Richardson 2000, Grindal *et al.* 1999).

According to Bunnell *et al.* (1999), riparian areas provide primary habitat for 13 species of rodents that are generally not found in upland forests. Riparian areas within British Columbia are also crucial for mountain beaver (*Aplodontia rufa*), as they are found no where else in Canada and are also limited to the Pacific Northwest of the United States. Ungulates also use riparian areas as a source of concealment and shade while obtaining water and forage as the availability of winter forage is always greater in late-successional stands than in young stands or clearcuts (Bunnell *et al.* 1999)

With most studies looking at the effects of upland harvesting on wildlife species, few have looked at the impact that harvesting may have in riparian areas (Cockle and Richardson 2003). This is an important area that requires greater research, as riparian areas possess a greater abundance of hardwoods than upslope areas. These hardwoods provide cavity nesting for birds and forage for a variety of wildlife (Bunnell *et al.* 1999, Knutson and Naef 1997). Research has also shown that the abundance and diversity of birds that are associated with shrub species can be directly related to harvesting (Bunnell *et al.* 1999). Bunnell *et al.* (1999) found that shrub-associated species tended to increase relative to increased volume removal (basal area) of timber. The research of Bunnell *et al.* (1999) suggests that bird species are influenced least by the selective harvesting of lodgepole pine compared to partial removal or clear cutting. However, the study also shows that elk benefited from clear cutting to stream banks, as they are intermediate grazers and are attracted to increased shrub production.

According to the results of Cockle and Richardson (2003), small mammals, such as shrews (*Sorex*) and red-backed voles (*Clethrionomys gapperi*), tend to decline in species richness after clear cutting even though certain species increased in abundance. Implementing buffer strips around streams also appears to be an effective method of conserving habitat as Cockle and Richardson (2003) determined that small rodent abundance was greater in these areas than adjacent clearcuts, and similar to those sites that remained unlogged. These areas may also prove to be important for the recolonization of regenerating cutblocks (Cockle and Richardson 2003). However, according to Hannon *et al.* (2002) voles were as likely to inhabit cut blocks with at least 10% retention, as they were to inhabit buffer strips left in riparian zones.

According to Bunnell *et al.* (1999), alternatively designed silvicultural techniques may provide a means of ensuring sustainable populations exist within our forested ecosystems. They suggest that the retention of large living trees, snags, and large woody debris can aid in proper ecosystem functioning while ensuring the characteristics of a mutli-aged management regime. However, Bunnell *et al.* (1999) also suggests that any one silvicultural treatment, whether retention or clear cutting will result in winners and losers among vertebrate populations.

Research conducted by Richardson *et al.* (2002) looked at changes in small mammals between clearcuts and buffer strip protected riparian areas. They determined that species richness was greater in buffer strips and controls than clearcut areas. Species diversity also declined with increased alteration by clear cutting and buffer strips. Richardson *et al.* (2002) therefore suggests that while buffer strips appear to have less of an impact on small mammals than clear cutting, changes within species structure and dynamics are still present within buffer strips.

Sullivan *et al.* (2000) conducted studies on small mammal use of Douglas-fir –Lodgepole pine stands within south-central British Columbia under different silvicultural treatments. They determined that red-backed voles were found in higher abundance within old growth stands than young clearcuts or seed tree stands. In contrast, meadow voles (*Microtus pennsylvanicus*) were more abundant in seed tree treatments, and five other species of *Rodentia* were found to be more abundant in both seed tree and recent clearcuts. Deer mice (*Peromyscus maniculatus*), long-tailed voles (*Microtus lingicaudus*) and short tail weasels (*Mustela erminea)* all had similar means among all treatments. Sullivan *et al.* (2000), therefore suggests that seed tree systems are therefore more appropriate for providing natural stand structure and biodiversity than clear cutting treatments.

A study of the effects of group selection on small mammals was conducted within the ESSF of the Cariboo Forest Region (MOF 1997). Treatments included openings of various sizes; 0.03ha, 0.13ha and 1.0ha, each with 30% volume removal and an unharvested control. It was determined that there was no significant difference between the four treatments in terms of species abundance, diversity and evenness. While there was no difference in treatment use, small mammals showed a preference for the forested areas within the various treatments. It therefore appears that partial cutting that create small openings have minor, if any effects on small mammal dynamics two years after harvesting.

The upper Deadman River and Criss Creek valleys provide a wide range of winter habitat for moose populations including riparian shrub habitat and wetland complexes (Lemke 1998). Riparian areas (riparian willow habitat and spruce/sedge meadows) within the Deadman and Criss Creek areas also provide optimum area for moose calving habitat (Lemke 1998) as they provide secluded shelter, high browse availability and close proximity to water. Lemke (1998) also suggests that mature conifers that border riparian and wetlands provide crucial thermal cover throughout the year. Lemke's (1998) research in the Upper Deadman River area on moose habitat suggests that harvesting should be conducted in a manner to minimize damage to understory vegetation. She also suggests that buffer zones of 300meters be established around all riparian and wetland complexes greater than one hectare, 200m for high forage sites, and riparian /wetland edges should retain 75% of its vegetation.

Research has also been conducted into the effects of partial cutting on the abundance of mule deer populations (Armleder *et al.* 1998). Interior Douglas–fir within the Cariboo Forest Region, British Columbia was harvested in a single-tree selection system in which 20% of the volume was removed. Armleder *et al.*'s (1998) results determined that there was no significant difference between mule deer abundance of undisturbed stands and those 20% harvested following track assessments for the winters of 1984-1991. Results suggest that single-tree selection systems may be an appropriate method to harvest interior Douglas-fir at low volumes without having adverse effects on the winter requirements of mule deer populations.

2.3.5 Birds

Riparian areas provide birds with a variety of habitat with distinct attributes for perching and resting and provide snags that ensure ample nesting cavities are available (MOF 1998b). Studies have shown that the abundance of 75% of all perching birds increases within riparian areas as they use hardwoods and shrubs as habitat in preference to conifers (Bunnell *et al.* 1999).

According to Hannon *et al.* (2002), a study comparing buffer width and species composition determined that buffer strips of 20m showed a decrease in the number of bird species inhabiting them as compared to wider buffer strips. They suggest that this may be due to an inability to hold territories within the confined space of the strips. However, the work of Darveau *et al.* (1996) showed that riparian buffer strips increased between 30 and 70% in abundance and composition following adjacent harvesting, but suggest that this was due to dispersal of nesting individuals from the clearcut rather than the quality of habitat. Initial increases dropped to pre-harvest levels within two years.

Hannon *et al.* (2002) suggest that buffer strips may need to be 200m in width to maintain the communities of small passerine bird species. However, they feel that 200m buffer strips are not sufficient to maintain the communities of larger raptor, woodpeckers species or carnivores. This is supported by Whitaker and Montevecchi (1999) who feel that even buffer strips >100m will not support unaltered bird assemblages. Hannon *et al.* (2002) also suggest that buffer strips of < 100m may promote "edge habitat". Whitaker and Montevecchi (1999) also determined that even buffers of 40-50m contained <50% of the bird densities found in adjacent interior forest habitats. Research conducted by Vander Haegen and Degraff (1996) also suggests that small buffer strips contribute to increased nest predation of passerine bird species. Vander Haegen and Degraff (1996) found that riparian areas in unharvested stands (control) have a 15% predation rate while harvested riparian areas with buffer strips of 20-40m and 60-80m had increased predation at 31% and 23%, respectively. Hannon *et al.* (2002) suggests that riparian buffers are insufficient and inappropriate for managing intact vertebrate communities that would be found in older growth forests.

Research has also been conducted into the effects of partial cutting on predation of bird nests. Steventon *et al.* (1999) conducted research into how the removal of 30 and 60% of vegetation affects predation rates of artificial nests. It was determined that a 30% partial cut had no effect on predation rates compared to uncut areas, but data form the 60% partial cut suggest only a moderate increase in predation. They therefore suggest that their results support other studies that indicate that a 30% removal still retains mature forest characteristics (Steventon *et al.* 1999).

Studies from within the ESSF zone of the Cariboo Forest Region found similar results to Steventon *et al.* (1999). MOF (1997) found that following group selection silvicultural trials and fives year post harvest studies, no significant changes in species abundance, richness or diversity have been observed. Again suggesting that a 30% volume removal has minimal impacts on bird species dynamics and maintains bird communities at levels found in mature stands.

2.3.6 Amphibians

Riparian ecosystems are extremely important to the lifecycle of amphibians as these species use water as a medium in which to lay their eggs. Adults also rely on these areas to provide mating sites and foraging areas (Knutson and Naef 1997). Two species of the seven amphibians found within British Columbia are at risk and are found on the red or blue provincial list of British Columbia (Bunnell *et al.* 1999). In Washington 80% of amphibian species are obligates of stream or wetland-related habitats (Knutson and Naef 1997). Due to their reliance on water, amphibians are highly susceptible to changes in stream temperature and increases in sedimentation can impede respiration and interrupt food supply (Bunnell *et al.* 1999). Amphibians may even play a more integral part in ecosystem functioning then previously thought as they contribute up to four times the biomass in riparian ecosystems than salmonids (Stevens *et al.* 1995, Petranka *et al.* 1993).

Amphibians can also be adversely affected by harvesting of riparian areas. The three main effects of harvesting on amphibians inhabiting headwater streams include;

- *changes in cover, aeration, and flow patterns associated with downed wood in streams;*

- *changes in incident radiation, which modifies both periphyton production (through photosynthesis) and stream temperature; and*

- *changes in sedimentation rate*
  (Bunnell *et al.* 1999)

In the research of Richardson *et al.* (2002), there appeared to be no immediate (one-year post-harvest) effect on community structure of aquatic breeding species between controls, buffer strips or clearcuts. However terrestrial breeding species showed lower densities and tended to be smaller in size than those of the buffer strips. Richardson *et al.* (2002) also determined that buffer strips appeared to be movement corridors following harvesting. Contradictory to the findings of Richardson *et al.* (2002), Petranka *et al.* (1993) found dramatic changes in salamander densities as results showed 500% greater salamander densities in mature forests than within recently clearcut stands. Petranka *et al.* (1993) also suggests that up to 80% of salamanders are lost following clear cutting and that their study indicates that in would take approximately 50-70 years for structure to regain pre-harvest conditions.

2.3.7 Invertebrates

Forest harvesting has been shown to alter the population dynamics of many macroinvertebrates. Studies conducted by Muchow and Richardson (2000) within the Malcolm Knapp Research Forest in British Columbia indicate that even ephemeral streams that dry up during the summer may contribute an equal proportion of macroinvertebrates as larger persistent streams. They found that intermittent streams also had an emergence of stoneflies (*Plecoptera*), twice that found in continuous streams over the course of the study. This study provides evidences of the value of small ephemeral streams in their ability to produce invertebrates that provide a food source for downstream predators such as salmonid species. Therefore these riparian areas along ephemeral streams are an integral part of ecosystem functioning (Muchow and Richardson 2000, Richardson 2000).

It is suggested that small headwater streams are major sites for the accumulation of leaf litter that is then processed to organic particles by the feeding activity of invertebrates (Huryn 2000). Shedders are the dominant functional group of macroinvertebrates in small headwater streams as compared to the filterers and gatherers of down stream networks. These shredders provide coarse particulate organic matter (CPOM), an important input to downstream reaches (Gomi *et al.* 2002). The research of Richardson *et al.* (2002), who looked at the effects of riparian buffer widths on invertebrates, found that changes in invertebrate communities appeared to drastic for some species while others had very little changes in community structure following harvesting. Richardson (2000) also suggests that large riparian trees may be important in the aggregation of mating insects.

Research conducted by Heise (2000), used artificial substrate to measure the effects of timber harvesting within three creeks of the Sicamous Creek watershed, British Columbia. Heise (2000) determined that macroinvertebrate abundance decreased in streams adjacent to clearcut harvesting compared to unharvested control streams. He also noted a change in population structure, with the abundances of stoneflies, flatworms and diptera, all showing declining numbers within the harvested stream. However, Batzer *et al.* (2000) had opposing results from his study of 12 small wetlands in Georgia that had been harvested and replanted between 1975 and 1997. He found that there was a direct correlation between smaller streamside vegetation and increased terrestrial invertebrate diversities and numbers. He also found increases in other variables such as water pH, light levels and herbaceous plant cover and biomass. Batzer *et al.* (2000) therefore suggests that harvesting near small wetlands can alter ecological interactions for up to 15 years following vegetation removal.

According to Huryn (2000), protecting of the biodiversity of stream invertebrate communities at undisturbed levels within smaller headwater streams is an essential management practice that is required for maintaining ecosystem functions within drainage networks. Changes though large clearcut harvesting to the edge of stream banks can affect macroinvertebrates through alteration of light levels, sediment input, larval habitat, adult habitat, larval food, summer water temperatures, and inputs of leaf detritus (Huryn 2000).

In a five year study conducted by Erman and Mahoney (1983), on streams with and without buffer strips in California, it was determined that narrow buffer strips had higher macroinvertebrate diversity than those streams with no buffer protection. Diversity in unbuffered streams dropped 12.5% following logging and remained at those levels for five years while narrowed buffered streams dropped 25.2% following harvesting but improved to 9.1% after a five year period (Erman and Mahoney 1983).

2.3.8 Water Quality

The quality of water is extremely important within riparian areas, as it is one of the major determining factors of life for plants, wildlife, fish and humans (Stevens *et al.* 1995). Due to the high abundance of plant material and diversity within riparian areas, these areas can act as a sponge. These areas aid in the infiltration and percolation of surface water into the ground, providing a storage for water that is slowly released into the surrounding area over time (MOF 1998b, Miller *et al.* 1997) Riparian areas also filter out harmful compounds such as nitrogen and phosphorous that may have a detrimental affect on the aquatic system (Bunnell *et al.* 1995).

Harvesting can adversely affect stream quality due to altering the amount and timing of sediment production. Sedimentation can occur due to the exposure of mineral soil due to logging activities (Grace and Carter 2000) or due to wind blowdown of trees that are rooted within or on the stream bank of riparian areas (Hudson and D'Anjou 2001, Moore 1997). In experiments in Demo Creek located on the Sunshine Coast, British Columbia, Hudson and D'Anjou (2001) found that not only did blowdown in riparian areas create sedimentation into the channel but also that the exposed roots and mineral soil will continue to erode and create sedimentation during later periods. This is also suggested by Moore (1997), who determined that while sediment pulses may not be of direct importance of these streams themselves, sediment pulses have a greater effect on downstream reaches that provide domestic water supply or fish habitat. It should also be noted that in silvicultural treatments which shortens the rotation period, harvesting frequency is increased and therefore can accelerate erosion losses and potentially decrease water quality (Grace and Carter 2000).

2.3.8.1 Hydrologic Effects

Riparian vegetation along with upland vegetation moderates stream flow within watersheds (Knutson and Naef 1997). Plant roots can aid in increasing the soil porosity while vegetation interrupts the surface flow of water and promotes onsite infiltration which can then be released over time through subsurface flow (Knutson and Naef 1997), thus decreasing sudden water pulses following rainfall and snow melt events.

Many studies have shown alterations of streamflow due to various forest harvesting practices such as clear cutting (Hicks *et al.* 1991, Keppeler and Ziemer 1990). These alterations of streamflow are due to changes in the rate of interception, evaporation and transpiration following the removal of riparian vegetation (Hicks *et al.* 1991, Keppeler and Ziemer 1990). Alterations may be seen in the form of increased, decreased or temporal changes of streamflow. When decreases in streamflow occur during different periods of the year, they can directly affect fisheries values. This is due to the fact that even small reductions in stream flow can cause increases in stream temperature and promote stress, disease and increased competition among fishes (Hicks *et al.* 1991).

Increases in streamflow can also be seen as a benefit of forest harvesting. However, 90% of streamflow increases generally occur in October to March and therefore do not aid in rectifying any low flow levels indicative of summer periods (Keppeler and Ziemer 1990).

While research conducted by Hicks *et al.* (1991) suggests that logging may actually decrease summer streamflows, they did determine that the practice of patch cutting might actually regulate streamflow at pre-harvest levels or even provide increases in streamflow during the summer. This is supported by research conducted by Keppeler and Ziemer (1990), who evaluated streamflow data from a Californian creek for a 21-year period. They also determined that selective harvesting can increase summer and annual streamflow levels. However studies have shown that a removal of less than 25% basal area tend to show no detectable increase in water yield (Hornbeck and Kochenderfer 2000). Similar research conducted by Hudson (2001) found peak flow of harvested areas was greatest in variable retention treatments of 18% canopy retention compared to shelterwood treatments of 49% retention.

Recovery of hydrologic responses is also a great concern. Keppeler and Ziemer (1990) found that reductions in summer flow still persisted five years after selective logging and is expected to be from increased transpiration of water by residual vegetation. Knutson and Naef (1997) also suggest that partial cutting can alter hydrologic effects for up to 10 years (Table 5.0)

Table 5.0. Recovery period of Hydrologic responses to various treatments.

Hydrologic Response Variable	Treatment	Recovery Period
Water yield – Summer	Clear-cut	2-3 years
Water yield – Annual	Partial-cut (25%-33%)	10 years
Water yield – Annual	Clear-cut	

Modified from Knutson and Naef (1997)

2.3.8.2 Water Temperature

Harvesting can also affect the temperatures of instream water and surrounding soils (Mellina *et al.* 2002, Beschta and Taylor 1988, Beschta and Platts 1986). Literature suggests that increases in stream temperature are predominantly due to the removal of riparian vegetation rather than the harvesting of the surrounding watershed (Mellina *et al.* 2002, Teti 2000, Teti 1998, Knutson and Naef 1997). However, the effectiveness of buffer strips is directly related to how well shading of the stream is maintained at natural levels. It also appears that fixed buffer widths such as those set forth in the Riparian Management Areas Guidebook (1995) are less effective than buffers designed to reduce angular canopy density or sun penetration. Literature also suggests that temperature increases in small headwater streams is minimal but may be of importance as the cumulative effects can have a dramatic change upon entering a S5 stream.

While most literature suggests that stream temperatures increase following the removal of riparian vegetation, the time required for a stream to recover to pre-disturbance levels is still under debate. According to Teti (2000) and Teti (1998), the recovery period of stream temperature increases can be affected by topography, microsite conditions, riparian species and stream morphology. Some studies have suggested that thermal recovery after harvesting may take up to 7 years for coastal regions and up to 20 years for high elevation areas like the Oregon Cascades (Teti 2000). Johnson and Jones (2002) found that recovery to pre-harvest conditions took 15 years following either patch cuts or clear cutting. Other studies suggest that thermal recovery should be based on the regeneration of vegetation rather than a set period of time (Beschta and Taylor (1999). Studies conducted by Beschta and Taylor (1988) also determined that following harvesting, the temperatures of a stream in Oregon increased 6^{o}C over a 30-year period. They suggest riparian vegetation regrowth would take approximately 15 years before a linear decrease in stream temperatures would occur and that the first 5 years growth would not be enough to affect the high maximum stream temperatures. Water temperatures increased directly, and from water flowing over the surface of warmer land eventually reaching streams and further increases water temperatures (Beschta and Taylor 1988).

Recovery of increased temperature following the flow through clearcut blocks is in debate on how long it takes to regain is pre-cutblock temperatures. According to Andrus (1993), a study conducted in Oregon in 1993, established thermographs 90, 180 and 360m downstream in shaded reaches. Results determined that water temperatures within cutblocks were 1-5^{o}F higher than expected under undisturbed canopies. These temperatures decreased as they flowed through undisturbed downstream areas on four of six reaches. Recovery of increased temperatures occurred at its greatest rate in the first 180m down stream (Robison *et al.*1999).

In a study conducted within the Brush Creek watershed, Robison *et al.* (1999), found that temperatures increased 3.8^{o}C after flowing through a clearcut (no streamside vegetation) due to increased exposure to solar radiation. Temperatures recovered to within 0.3^{o}C after flowing through 834ft (254m) of unaltered canopy cover. This recovery is attributed to groundwater exchange and mixing. Robison *et al.* (1999) suggests this recovery is site specific and would depend on the presence of well-connected terraces as those streams that flow over bedrock would be influenced little by groundwater and recovery would not be as quick. Influxes of groundwater into the stream channel can aid in regulating temperature fluctuations, providing thermal stability (Poole *et al.* 2001).

Hornbeck and Kochenderfer (2000) also found that once stream areas are again shaded by shrubs and regrowing trees, stream temperatures decrease and exhibit fairly uniform annual and seasonal variations through the remaining successional stages, or until another disturbance reduces or eliminates streamside shade.

Another reason for variations in recovery period are heat losses to the air within the surrounding riparian areas. Robison *et al.* (1999) suggests losses to air would be insignificant as peak temperatures in riparian areas are often hotter than the heated stream temperatures. Based on studies conducted by Robison *et al.* (1999), is was determined that the rate of recovery ranged form 0.9-2.1^{o}C per 300m of streams and all seven streams recovered to temperatures of 17.8^{o}C (64^{o}F) within 150-360m downstream of clearcuts. 17.8^{o}C (64^{o}F) is the maximum temperature allowed following harvesting in non-fish bearing streams within Oregon.

A study on stream temperature responses to forest harvest conducted in the western Cascades, Oregon, also found that temperatures increase following vegetation removal (Johnson and Jones 2000). According to Johnson and Jones (2000) similar temperatures (summer maximum 23.9^{o}C) were found for clearcut and partial cutting treatments for 16 years following harvesting. Unharvested stream temperatures showed a mean summer maximum temperature of 16.7^{o}C. Temperatures within the first four years after clear cutting and patch cuts were 5.4-6.4^{o}C and 1.6-2.0^{o}C greater than the control.

According to Story and Moore (2002), who conducted research on stream temperature recovery in the Stuart-Takla Fish-Forestry Interaction Project in British Columbia's central interior, determined that stream temperatures showed recovery of temperature within 200m of entering undisturbed vegetation. Temperatures increased an average of 4-5^{o}C after flowing into the partial clearcut. Streams not only showed a recovery but in some instances temperatures returned to temperatures lower than preheated levels. They suggest groundwater mixing, bed infiltration of heated water and heat exchange with cool canopy cover in afternoons and evenings as reasons for temperature recovery but suggest that these attributes are highly variable in time and space, but do suggest harvesting in headwater streams may be of little importance to cumulative down stream effects.

While it appears that thermal recovery not uncommon following harvesting, the debate on recovery times is complex. Recovery time is varied by the amount of downstream dissipation that occurs with the distance required to dissipate heat gains being site specific and dependent on the interactions of the following attributes; topographic shade, upland vegetation, precipitation, air temperature, wind speed, angle of radiation, cloud cover, relative humidity, groundwater temperature and discharge and tributary temperature and discharge (Poole *et al.* 2001).

2.3.9 Microclimate

Due to the complexity of plant life, riparian ecosystems provide dense vegetation that blocks direct radiation from penetrating the floor of the riparian area. This shields direct sunlight and aids in maintaining a constant temperature within the understory (Mellina *et al.* 2002, Knutson and Naef 1997). This in turn ensures that soil temperature and moisture levels are regulated to provide a moist cool environment for amphibians, ungulates and other large mammal species (Knutson and Naef 1997) while producing lush overhanging vegetation that further helps maintain water temperatures (Mellina *et al.* 2002, MOF1998a).

The Itcha-Ilgachuz Alternative Silvicultural systems project, conducted in the MS zone of the Cariboo Forest Region, British Columbia evaluated the effects on microclimate following various harvesting regimes (MOF 2001a). The harvesting regimes included; group shelterwood system at 50% removal (20-30m dia. openings), clearcut and controls. The study determined that clearcut microclimates had a greater proportion (49%) of nights below 0^{o}C compared to partial cutting at 37%. Frost also occurred 18% of the nights in clearcuts compared to 5% in the partial cutting treatments. Summer temperatures were also warmer within clearcuts but edges showed a 1-2^{o}C decrease than the center of openings. All results suggest greater winter characteristics within clearcuts can be detrimental to seedlings. However, greater shading may mean reduced growth in partial cutting as opposed to clearcuts during the growing season.

A similar study on the effects of opening size on microclimate determined that only minor temperature changes occurred between opening sizes except that larger openings tended to be 1-2^{o}C warmer than smaller opening at a soil depth of 15cm (MOF 1997). Similar results were also found by Johnson and Jones (2000) in which temperature under forest canopy was determined to be 5^{o}C lower than those found within forest gaps. This suggests that larger opening sizes are prone to greater soil temperatures, increased growing degree-days and therefore larger openings would become snow free earlier in the season and increase the growing season (MOF 1997).

Hagan and Whitman (2000) conducted studies on microclimate by comparing temperatures with a 22m buffer strip adjacent to a clearcut and an undisturbed site. They determined that daily average temperatures were 5-10^{o}F in clearcuts compared to intact forests. However they determined that air temperatures dropped dramatically just within riparian buffer edge. Temperatures within the buffer strip were $<2^{o}$F higher than temperatures of intact forests. Based on their results it appears that buffer strips of 22m are capable of maintaining microclimate similar to undisturbed forest.

2.3.10 Soils

Soil is a very integral component of the forested and riparian ecosystems for the many functions in which it provides. Soil provides gases, moisture, nutrients and a rooting medium while providing filtered water to aquatic systems (Sutherland 2003). Maintaining the integrity of soils is crucial to ensure proper functioning, as damaged soils can take many years to return to their pre-disturbed state. The major components of soils include mineral and organic particles that are surrounded by pore spaces containing either water or air (Sutherland 2003). It is the texture and moisture content of these components that determine how severe the degradation from harvesting may be (MacDonald 1999).

Harvesting practices can degrade soil through; compaction and puddling, displacement, surface soil erosion, and mass wasting. The two most important forms of degradation of forest soils are through compaction and rutting (Sutherland 2003, Grace and Carter 2000). Compaction occurs when forest machinery compresses the soil beyond its ability to resist the load pressure. Different sites vary in their ability to resist disturbance based on terrain, slope, climate, hydrology, and soil horizons, texture and depth. When compaction occurs in can increase bulk density, convert macropores to micropores, and reduce the infiltration capacity (Keppeler and Ziemer 1990).

While compaction can reduce infiltration rates, scarification of the forest floor through skidding and machine travel can remove surface materials allowing for better infiltration and reduced surface runoff (Grace and Carter 2000). However, Grace and Carter (2000) also suggest that this scarification can lead to increased erosion due to rain splash and surface runoff during higher period of precipitation.

The main practice to limit soil degradation is to limit the amount and timing of travel on soils. The chances of degradation are determined by assessing the hazards to determine how sensitive the site is to soil disturbances (MacDonald 1999). Seasonal logging can also limit the amount of soil disturbance as a thin snow crust or deep snow can protect the ground from compaction and other adverse affects (MacDonald 1999).

Due to the impacts of harvesting on soils, research has been conducted into how different silvicultural systems can mitigate detrimental impacts. The Date Creek study conducted trials to determine site disturbances from harvesting. Treatments consisted of no harvest, light harvest (30% removal of volume in either single tree or group selection), heavy removal (60% removal of volume as irregular shelterwood) and clear cutting in which all merchantable timber was removed (Coates *et al.* 1997). Site disturbance was determined to be consistent between treatments with approximately 10% of disturbance being compacted soils with 50% of that being less than 10cm. Soil bulk density was also consistent between treatments at an increase of 10% from that of undisturbed sites. Soil surface conditions were considered undisturbed for 80.4% of the clearcut treatment, 79.4% for shelterwood, 79.3% of patch cut and 75.5% for the green tree treatment. In all treatments the majority of site disturbance was through excavator tracks. The treatment of shelterwood left the largest woody debris with the small dimensions of woody debris being left in the patch cut. Road densities were found to be at 6.3 % within the treatment areas, similar to the control cutblock with 6.5%.

Conventional hand falling and processing with line skidders (Clarke 664) was compared to that of a mechanical feller-buncher (tracked Cat 325)/grapple skidder (John Deere 748G) harvesting system. On an area basis the impacts of both systems showed similar disturbances of 51%, with the mechanical system being slightly higher in rutting depths and compacted bulk densities at a depth of 200-300mm. Overall both treatments showed that increases to bulk density were non-detrimental to the majority of the area. Excessive compaction and puddling was noted on both sites within wetter areas (Wulfsohn *et al.* 1999).

Research has also been conducted within the Roberts Creek Study Forest, north of Vancouver. Research was conducted in two phases. Phase one occurred between March 1996 and April 1997. Silvicultural treatments included; clearcut with reserves (1 tree per ha), dispersed retention of Douglas-fir and red cedar (95 per ha) and removal of trees (11% of stand volume) in narrow parallel corridors. Phase two occurred between the fall of 1998 and summer of 1999. Silvicultural systems included; variable retention, retaining trees both in groups and individually, strip shelterwood removing trees in strips between 50 and 100 meters in width and removal of trees (18% of stand volume) in narrow parallel corridors. Results showed that soil disturbance from hand falling and cable yarding was low between all harvested blocks. But that the clearcut of phase 1 showed slightly high ground disturbance than the dispersed retention treatment (D'Anjou 2002)

2.3.11 Sedimentation

A study conducted by Kreutzweiser and Capell (2001), looked at the impacts of different silvicultural treatments to determine their effects on fine sediment deposition. The three treatments included; selection-cut of 40% removal, shelterwood-cut of 50% removal and diameter-limit cut of 85% removal. Kreutzweiser and Capell (2001) determined post-sediment increases following logging, they were, 435.3 g/m^2 (selection harvest treatment), 99.9 g/m^2 (shelterwood) and 477.0 g/m^2 (diameter limit harvest). While sediment increases appear to be very high for the selection harvest treatment it was determined that most of the increase was due to the construction of secondary roads and not the disturbance caused be the treatment itself. Kreutzweiser and Capell (2001) therefore suggest that the greatest sediment increase was attributed to high ground disturbance and rutting due to skidder activities within the riparian areas of the diameter limit treatment.

Kreutzweiser and Capell (2001), also determined that the felling, delimbing, and skidding activities within the shelterwood could be done up to the edges of the stream without impacting sediment load. They therefore suggest that riparian buffer strips are not required for select harvesting of up to 50% in regards to sediment increases.

In a study conducted by Grace and Carter (2000), an Alabama stream was monitored to determine the effects of clear cutting on surface runoff and sedimentation supply. They determined that sediment production was higher for the treatment area than for undisturbed controls. Harvesting accounted for an average 360% increase in sediment within treatment areas (0.14 tons/ha compared to 0.03 tons/ha). Runoff was determined also to be greatest for the harvested area in 14 of 17 sampling events. The mean runoff yield increased from 2.1mm to 6.3mm following harvesting, with some increases being as high as 1200%.

2.3.12 Large Woody Debris (LWD)

Large woody debris (LWD), log pieces that are >10cm in diameter and >1m in length, are an important attribute to the proper functioning of a riparian area as they contribute to alterations in channel morphology and are an important component of aquatic ecology (Lassettre and Harris 2001, Belt and O'Laughlin 1994, Beschta and Platt 1986). LWD is of great importance as it represents centers for biological interaction and energy exchange (Arsenault 2002). LWD is introduced to streams through blowdown, stem snapping, bank erosion and landslides (Millard 2001). This LWD tends to obstruct the stream channel as "log jams" and trap sediment that provides habitat for macroinvertebrates and fish (MSRM 2002, Moore 1997) and promotes natural tree regeneration through nurse logs (Arsenault 2002, Lassettre and Harris 2001). Smaller headwater streams are generally characteristic of providing a large portion of LWD that can settle within the stream and provide stability and prevent erosion.

Current legislation that allows clear cutting to the banks of S5 and S6 streams may promote an increase in the amount of LWD entering the system in coastal streams (Millard 2001). However, studies on woody debris determined that logging slash might not necessarily be transported out of a particular reach. The transport of LWD is dependent on the transportability of the stream compared to the resistance of debris to transport and Millard's (2001) results on a study of 42 streams in the Anderson River watershed of British Columbia suggest that lower gradient streams may transport greater amounts of LWD as they are smoother and have less form and are less likely to encounter resistance.

With the majority of streams in British Columbia's interior being lower gradient streams, LWD is therefore more likely to be transported downstream and alter fish habitat in a detrimental way through scarification and sedimentation. Clear cutting adjacent to smaller interior streams may therefore not provide similar amounts of LWD that is seen in steep coastal streams. When LWD are reduced though clear cutting and downstream transport, low instream recruitment of the wood can create a greater chance of erosion and sediment transport (Lassettre and Harris 2001) along with disrupting the habitat of instream organisms such as amphibians and invertebrates. Large woody debris that fall within riparian areas but outside the stream channel also provide habitat for species of small mammals, including bats (MSRM 2002), while providing soil-moisture retention, soil stability, contributing to soil structure and nutrient pools (Arsenault 2002). Clear cutting is also thought to place LWD and wildlife trees below levels that would naturally be found within ecosystems (Gyug 2002). Therefore due to the value of small streams to the recruitment of LWD, management strategies that are based on stream size alone may not meet the best riparian management objectives.

Buffer strips have also been shown to have an equal proportion of LWD to those of unharvested riparian areas and have recruitment levels equal to natural levels in undisturbed forests (Hayes *et al.* 1996). Conifers are also the dominant form of structure for pools as smaller deciduous species are prone to higher decay rates and downstream transport (Hayes *et al.* 1996).

Research conducted by Hogan (2002) on the relationships of LWD, channel morphology and watershed management determined that the volume of LWD supply was dependent on biogeoclimatic zone. However, Hogan (2002) found that the proportion and spacing of LWD stored in logjams was similar within all biogeoclimatic zones. This suggests that logjams are not affected by stream size but rather accumulation of LWD at log jams due to different rates of input.

2.3.13 Windthrow

The success of silvicultural treatments is directly dependant on how much of the stand is subject to windthrow following harvesting (Whitaker and Montevecchi 1999, Coates 1997). There are many factors that affect the success of different harvesting regimes. They can include; stand characteristics such as age, species and dimensions, stand history in regards to fire and harvesting, site condition and climate and wind conditions (Coates 1997, Moore 1977, Stathers *et al.* 1994). The amount of timber lost to blow down is very important to the forest industry as it diminishes the availability of timber for harvest and if salvaged, can be expensive and often dangerous to retrieve (Moore 1977).

According to Huggard *et al.* (1999), there are two mechanisms of wind condition that lead to windthrow; direct blow down by strong winds and structural failure due to harmonic oscillations generated by moderate wind speeds. They suggest that trees next to large openings are subject to sudden strong direct winds and are therefore blown over directly, while trees within small opening or individual tree selection areas will be more prone to structural failure from moderate winds. It therefore appears that in areas of strong short duration winds, uniform and small openings may be a more appropriate management technique. However, success of silvicultural treatments is site specific in regards to windthrow.

While it appears that wind can a be a primary determinant of windthrow, Moore (1977) suggests that wind alone is not the cause of blowdown but rather the interactions of location, local climate, aspect and slope, soil depth and texture, species composition and rooting and stream characteristics.

Windthrow within five treatments were monitored within the Sicamous Creek area of British Columbia. Treatments included; 10ha clearcuts, 1ha patch cuts, 0.1ha patch cuts, individual tree selection and undisturbed controls (Huggard *et al.* 1999). The four cutting treatments were all conducted to remove 33% of the timber volume. Huggard *et al.* (1999) determined that harvesting significantly increased the occurrence of windthrow in comparison to uncut controls following a 2.7 year post monitoring period. A greater portion of windthrow occurred in the individual tree selection treatment due to the increased exposure of residual stand and reduced crown contact. However, windthrow within all systems was determined to be equivalent in volume but variable in distribution. They suggest that the overall distribution of windthrow within the individual tree selection may be more beneficial for a wider array of organisms than areas of concentrated windthrow, although salvage operations may be more appropriate for dense piles near the edge of clearcuts (Huggard *et al.* 1999).

Similar analysis on the effects of harvesting was conducted at Date Creek in northwestern British Columbia. Windthrow damage was assessed following two partial cutting treatments, 30% (light) and 60% (heavy) volume removal through single tree harvesting and group selections up to 0.5ha (Coates 1997). Coates' (1997) results determined that windthrow within the partial cutting areas were 2.2%, 1.1% higher than unlogged areas. Results suggest little difference in windthrow between light and heavy treatments.

Windthrow of the light and heavy treatments was primarily due to the uprooting of trees, accounting for 84.4%. This is due to direct blowdown as suggested by Huggard *et al.* (1999). Stem snapping accounted for 15.6% of windthrow (Coates 1997), which would be due to the harmonic oscillations of moderate winds (Huggard *et al.* 1999). Coates (1997) suggests that partial cutting with a windthrow rate of less than 10% is successful and that as a stand matures it becomes more susceptible to windthrow due to increased levels of decay.

In another study based on a review of buffer strips in 59 Vancouver Island watersheds, Moore (1977) found that blowdown may be attributed to other factors than just the sudden exposure to wind following harvesting. Moore (1977) and Stathers *et al.* (1994) suggest that following harvesting, wind velocities also increase and create greater turbulence due to reduced friction in surrounding clearcuts and are therefore not only subject to increased exposure to wind but also to other increases in wind characteristics. Moore (1977) also suggests that precipitation and soils impact the susceptibility of windthrow. He suggests that heavy rainfall can reduce holding strength due to saturated soils and that roots within finer textured soils are shallower and more prone to blowdown.

In a study conducted within the Blackbear Creek drainage, British Columbia that included small (0.03ha), medium (0.13ha), large (1.0ha) and an uncut control determined windthrow to be greatest in large areas followed by medium, small and uncut treatments. Percentage of blow down was determined to be 4.2, 4.1, 3.2 and 2.6%, respectively (MOF 1997).

Beese (2001) conducted studies within the Montane Alternative Silvicultural systems to evaluate wind damage under clearcut (69ha), patch cut (1.5ha), green tree retention (25sph) and shelterwood systems (70%basal area removal) for montane coastal B.C. forests for six years following harvesting. He determined that green tree retention windthrow totalled 29% of leave trees (8sph).Shelterwood that retained 25% basal area showed the greatest number of blowdown at 10% (21sph). Edge trees of all treatments were less impacted by windthrow within the patch cuts. Patch cut and clearcut lost 6 and 9sph respectively.

Rollerson and McGourlick (2001), who conducted surveys on windthrow within 58 buffer strips on Vancouver Island, determined that on average 21% of the strip was subject to blowdown and found the average distance of penetration into the buffer to be 12 meters. They suggest that two-sided buffer strips are about 100% more vulnerable than one-sided strips and the penetration of windthrow is about 24meters. However, their study suggests that buffer strips that are feathered are subjected to the least windthrow (7%) and that the untreated buffer showed an 18% windthrow rate. They suggest that these feathered strips are less susceptible as they have had the most vulnerable trees removed around the edges, in contrast to uniform cutting or the retention of small trees. Their research also suggests that increases in buffer width decrease windthrow rates up to a maximum of 25-30m buffer width for one-sided buffers and up to 40m for two-sided buffers.

According to Knutson and Naef (1997), the Washington Department of Fish and Wildlife suggests adding 30 m to the outer edge of the windward side of riparian buffer strips where there is high blowdown potential. Stathers *et al.* (1994) also suggests many techniques that can be employed to mitigate the effects of windthrow following harvesting. They include:

- *Edge feathering can be used to reduce the drag force on boundary trees. Trees within the edge buffer should be removed in the following order of preference:*

    1. *Unsound trees, especially if they have a large crown. These include diseased, deformed, forked, scarred, mistletoe infested, and root rot infested trees.*
    2. *Trees with asymmetric or stilt roots.*
    3. *Trees growing on unstable substrates, e.g., rocky knolls, large boulders, nurse logs, poorly drained depressions.*
    4. *Tall non-veteran trees, especially with the above features or with disproportionately large crowns.*

- *Residual trees should be left in the following order of preference:*

    1. *Sound, well-rooted veterans (e.g. snag-top cedars) or deciduous trees.*
    2. *Sound trees (strong roots and good taper) with relatively small, open crowns.*
    3. *Sound snags, when safety is not compromised.*

- *Stem removal should not exceed 15-20% of the trees in a strip 20-30 m in from the edge of the stand.*

- *Excessive thinning will increase windthrow susceptibility. Edge thinning is not recommended in single-storied, high-density stands.*

- *Topping and/or pruning (delimbing) of vulnerable trees along opening boundaries may be necessary to protect and maintain critical areas such as streamside buffers, ungulate ranges, forage areas, and other critical wildlife habitat.*

- *Reducing the crown by 20-30% appears to be adequate to reduce the risk of windthrow for most trees.*

(Stathers *et al.* 1994)

2.3.14 Effects of Cattle Grazing

Within British Columbia, eighty percent of all grazing lands are forested rangeland owned by the crown. It is this forested rangeland that provides the forage base of grasses and forbs that is consumed by cattle and desired by the livestock industry. Riparian areas are a very important source of forage production within these forested rangelands (Powell *et al.* 2000). Similar to a variety of wildlife species, cattle tend to congregate in riparian areas (Belsky *et al.*1999). There are many reasons for this attraction. They can include the lush vegetation and grass species for food sources, shade and water availability (Hennan 1998). However, the presence of cattle within riparian areas can cause adverse affects on the riparian system. They can reduce bank slope and stability, reduce vegetation cover, alter stream channel characteristics, effect plant community structure (Powell *et al.* 2000) and water quality and quantity (Knutson and Naef 1997).

Cattle grazing can also cause many other alterations to riparian areas that may include;

- *Reduction or elimination of the regeneration of woody vegetation.*
- *Alteration of plant species composition (e.g., xeric species and highly competitive exotic species invade, perennials are replaced by annuals, and trees/willows/sedges are replaced by brush and bare soil).*
- *Reduction on overall riparian vegetation.*
- *Reduction in overall plant vigor.*
- *Bank and instream deformation and erosion from loss of protective vegetation, and increases soil compaction and churning by hoof action, which lead to reduced water quality and changes in bank and channel integrity.*
- *Stream channel widening, shallowing, trenching, or braiding because of increased stream bank erosion.*
- *Inability of riparian habitat to trap and filter sediments and pollutants, leading to increased sedimentation and pollution from fecal matter of livestock.*

- *Increased stream temperatures as a result of lost cover provided by both woody and herbaceous plants.*

- *Loss of nutrient inputs, especially invertebrate food sources, to streams.*

- *Decrease in water table, with subsequent loss of riparian vegetation and stream flow.*

- *Increased magnitude of high and low stream flow events.*

- *Reduction in shrub and ground-nesting habitat for songbirds and other wildlife.*

- *Declines of amphibians, small mammals, and other ground-dwelling animals that need herbaceous and woody vegetation for food and cover.*

- *Increased songbird nest predation and brown-headed cowbird parasitism due to loss of shielding vegetation.*

- *Loss of structural and compositional diversity of plant communities, thereby reducing overall wildlife diversity.*

- *Reduction of forage available for wild ungulates and other herbivores.*

(Knutson and Naef 1997)

In British Columbia, riparian health is assessed based on its characteristics of "proper functioning condition". Proper functioning condition (PFC) refers to the ability of the riparian area to filter runoff, store and safely release water, and its ability to withstand normal peak flood events without experiencing accelerated soil loss, channel movement, or bank movement (FPB 2002). If a riparian area lacks one of these attributes it is considered to be either "at risk" or "non-functional" due to its inability to perform certain functions to the functioning of riparian areas.

The FPB (2002), assessed 341 sites subject to cattle grazing within the Kamloops, Penticton, Horsefly and Cranbrook Forest Districts to assess their condition. The assessment consisted of 204 streams and 187 wetlands, with the majority of sites being found within the IDF and MS biogeoclimatic zones. Methods included an assessment of 10 riparian characteristics along 100m transects rather than the standard PFC checklist used by MOF. Results showed that approximately 12% of riparian areas are subject to extensive cattle use with other areas being lightly utilized. FPB (2002) determined that 71% of riparian areas are considered to be properly functioning, while at risk sites and non-functioning riparian areas were determined to be 16 and 13%, respectively. However it should be noted that the somewhat drier zones of the province such as the IDF and MS had a higher proportion (30-40%) of at risk and non-functioning riparian areas. The Kamloops Forest District also showed higher proportions of non-functioning areas than the average for all four districts.

Cattle can alter soils within riparian areas through compaction (Belsky *et al.*1999). According to Krzic *et al.* (1999) and Newman *et al.* (1999), this compaction can alter the penetration resistance of soils and increase soil bulk density. This increased penetration resistance can create hydrophobicity of the soil and surface ponding thus causing conifers to become water deprived underground while their root collar is submersed in water. However, while Newman *et al.*'s (1999) studies showed changes in compaction and bulk density are higher on grazed sites they noted that these increases are far below any limiting threshold for conifer root growth.

In similar studies near Tunkwa Lake, British Columbia, Bromersma *et al.* (2000), determined that a one-month stocking rate of 0.69AUM/ha was not a sufficient enough grazing pressure to significantly alter the soil bulk density of the study sites. However, they did determine that over an eight-year monitoring period, soil bulk density did increase 6% when compared to control exclosures. Soil penetration resistance was increased over most of the soil profile following the eight years of grazing, thus indicating a greater availability of rain water for plant growth on ungrazed sites compared to exclosures. Again there results suggest that soil penetration resistance was above thresholds to be considered root restricting.

Belsky *et al.* (1999) review of literature on cattle grazing in riparian areas found that a major concern is that upland riparian vegetation is removed through livestock while areas adjacent to streams are compacted thus interrupting the infiltration of rainwater.

There are numerous ways to mitigate any detrimental effects that cattle may have on riparian areas. These include; increasing the density and cover percentage of riparian vegetation and promoting plants to maintain root systems thus stabilizing stream banks and reducing sediments (McInnis 1996).

Improper management of livestock grazing in riparian habitat is likely to have significant negative consequences for fish and wildlife (Knutson and Naef 1997). Riparian areas are site specific and therefore no one cattle grazing strategy will work for all sites. According to Knutson and Naef (1997) the proper implementation of a grazing strategy will; 1) incorporate sufficient rest periods to allow plant regrowth, vigor, and energy storage; 2) retain sufficient vegetation during high flow periods to protect stream banks, dissipate stream energy, and trap sediments; and 3) control grazing times and intensity to prevent damage to stream banks from trampling and over-utilization of vegetation.

Kauffman and Krueger (1994) also suggest that well-supervised grazing management within riparian areas, when used in conjunction with resting and restoration of severely damaged areas, can result in decreased stream bank erosion and floodplain losses, increased forage production for both livestock and wildlife, and increases in fish and wildlife resources.

2.4 First Nations Values

Forest management is slowly recognizing the values of forests for their non-timber resources and uses. These non-timber values are therefore now considered part of integrated forest management (Kulshreshtha 1995). Timber resources are continually competed for as they provide an array of monetary values as well as biological, spiritual and cultural values. It is therefore imperative to evaluate the cost and benefits to each user of forest resources. Economic values can be in terms of production, consumption or exchange of goods (Kulshreshtha 1995). Timber uses of forest resources can include woodlands operations, logging activities and primary and secondary wood processing. The non-timber uses of forested resources can include grazing activity, collection of specialty forest products and the production of vegetative foods (Kulshreshtha 1995), as well as spiritual and cultural values.

British Columbia First Nations place high values on forested ecosystems for reasons other than timber values. Non-timber values that are important to First Nations groups are those that are related to their spiritual and ceremonial values, fisheries, plant and riparian values, and wildlife values. Wildlife values can include sustenance while plant values can include those for food, building materials, medicinal, technological, spiritual and ceremonial uses (Moore 2001).

The tie with nature is pronounced in their ceremonial process that is conducted prior to harvesting non-timber products such as forage plants (Blackstock 2002, Teit and Steedman 1930). The spiritual value of plants is therefore evident as they have been used indiscriminately and it is believed that nature's resources represent a spiritual power that can adversely affect their lives if not treated with respect. It is evident that there is spiritual value in plants species through the eyes of first nations people. It is this connection of different values that makes it difficult for indigenous peoples to separate culture, language and spirituality from the land base (Fortier 2002).

Due to this tie with nature, there are many concerns of how current forest management practices can create negative socio-cultural impacts on a community such as the Skeetchestn Indian band. Socio-cultural impacts can include the well-being of a community, social cohesiveness, institutional factors, cultural and religious well being, and a number of factors related to the particular place or resource such as the following:

- *Community well-being and social and family cohesiveness maintained through use of the resource.*
- *Everyday life and material implements derived from the resource.*
- *Living and social activities and practices associated with the place or resource.*
- *Religious, ceremonial well-being gained through use of the place or resource.*
- *Other uses of the site or resource such as education or art.*
- *Intergenerational continuity in knowledge, language, traditions, values, and education related to the place or resource.*
- *Physical integrity of historical or cultural resources located in the place or associated with use of the resource.*
  (Columbia River Comprehensive Impact Assessment 1998).

First Nations communities such as the Skeetchestn Indian band have traditional systems of stewardship that combine cultural uses with local ecosystem values. This promotes sustainability and influences practices that can enhance the productivity, stability and diversity of cultural and non-timber forest resources. Aboriginal land use links spirituality, culture and survival with natural ecosystems to provide a perpetual balance between humans and the environment and promotes environmental husbandry of natures resources (Turner and Jones 2000).

2.4.1 Spiritual values

There are at least twenty-one different plant species presently inventoried within the Skeetchestn traditional territory that are associated with either spiritual or ceremonial uses (Skeetchestn Cultural Heritage Resource Inventory).

2.4.2 Fisheries and Riparian Values

Skeetchestn has suspended their fishery in Deadman River since 1985 due to deceased salmon stocks. They have been monitoring and evaluating salmon stocks in the system in co-operation with D.F.O. for this same time period. Thompson river Coho salmon of which the Deadman stocks are an important component have been recently listed as an endangered species on the Federal governments Species At Risk Act (SARA) list. Skeetchestn Indian Band has initiated the implementation of Cultural Resource Management Zones throughout their Traditional Territory not just the Deadman watershed.

The Skeetchestn Indian band perceives riparian areas as being crucial to the health of their community. It is felt that water is the linkage between all users of the ecosystem including its human, plant, soil, wildlife and spiritual components (Blackstock 2002). Many first nations groups of the Interior Plateau also rely heavily on the availability of pacific salmon as a means of sustenance (Turner 1997). However, this dependence has been declining due to a decrease in the populations of returning salmon. In 2004, Thompson River Coho and Steelhead were taken out of the fishery due to critically low population levels. This concern over sustainable management of water, fisheries and forest resources has led the Skeetchestn Indian band to initiate watershed restoration projects and the implementation of Cultural Resource Management Zones adjacent to water features within the Deadman Valley.

2.4.3 Wildlife Values

There are many wildlife species that are of great importance to many First Nations groups. In particular the Skeetchestn Indian Band has noted the following as having significant cultural values; great blue heron, woodpecker, crow, raven, hawks, owls, cougar, bear, grouse, rabbit, deer and moose among others. Moose and deer are the most important wildlife species that are hunted by the Skeetchestn Indian band and are used for clothing, medicine and manufacturing items for sale or trade. Hunting and trapping within the Deadman watershed is currently conducted by the Skeetchestn Indian band along with other first nation bands.

The Skeetchestn Indian band has also expressed concern over a number of species that are endangered or vulnerable and which reside within their traditional territory of the Deadman watershed. These species include:

- Great basin spadefoot toad
- Painted turtle
- Rubber boa
- Great Basin Gopher snake
- Racer snake
- American Bittern
- Peregrine falcon
- Sharp-tailed grouse
- Long-billed curlew
- Flammulated owl
- Lewis woodpecker
- Spotted bat
- Townsends big-eared bat
- Western small-footed myotis
- Short eared owl
- American Avocet
- American Badger
- Western Rattlesnake
- Timber Rattlesnake
- Grizzly bear
- Sandhill crane
- Great blue heron
- Coho Salmon
- Steelhead Salmon
- Screech Owl
- Sage Thrasher
- Monarch Butterfly
- Wolverine

- Western toad
- Northern Goshawk

2.4.4 Plant Values

Research has shown that there are long standing relationships between First Nations people and the vegetative components of surrounding forested land (Turner *et al.* 1990). Plants have been used by First Nations for many purposes including medicinal, subsidence and spiritual purposes. In terms of medicinal purposes, plants have been used for the treatment of stomach disorders, colds, wounds, venereal diseases, cramps and menstrual disorders and were primarily obtained through the collection of roots, stems and leaves (Turner *et al.* 1990, Teit and Steedman 1930). In particular, food within the area was generally obtained from roots and fruits. Plants and their parts were also used for chewing, non-medicinal drinks and smoking (Turner 1997).

Plants were also heavily used in manufacturing. Vegetative material was used for weapons, making canoes, snowshoes, baby carriers, roofing, fishhooks and drums (Turner *et al.* 1990, Teit and Steedman 1930). Plants were also used for making paints, dies and scents and in many cases used as a form of trade between First Nations people of adjacent areas (Turner 1997).

Many spiritual values, religious beliefs and mythical traditions are also linked with plants due to the great reliance on them for everyday survival (Turner *et al.* 1990). Plants were used as drinks, washes and baths and many plants were believed to have a magical purifying power. Many of these drinks and washes were used for success in hunting and war, and various puberty ceremonies. Under aboriginal religious tradition, plants were also viewed as having souls that are capable of thought and feeling and therefore viewed them with reverence and respect and were not to be exploited or used without appreciation (Turner 1998). Plants have also been a predominant part of First Nations culture for their use as charms, which were used to ensure long life, friendship, love, wealth and success in the hunt (Teit and Steedman 1930). Plants have also been an important part of First nations cultural and social status and are also thought to have a relationship to animals. This can be through dietary requirements or through mythology origins (Turner et al 1990).

To date the Natural Resources Department of the Skeetchestn Band has identified 148 species of plants within their Traditional Territory that are of cultural significance. Many of these plants are still being used on a regular basis for medicine, food and other components of everyday life within the community. Of the 148 plants inventoried so far, 90 have medicinal uses, 53 are used for food , 11 have structural value, 13 are used spiritually, 12 are used in ceremony and 17 have other cultural uses not previously listed. During the course of this project Skeetchestn Indian Band was able to identify approximately 15 more plant species than they had previously inventoried (pers. comm. M. Anderson).

3 METHODS

3.1 Literature Review

An in depth literature review was carried out to provide background information on issues and concerns of forestry operations within riparian areas. Literature review focused on riparian ecology, riparian management and current studies on impact of harvesting on fish, amphibians, invertebrates, avian and wildlife, hydrology, vegetation, microclimates, soils, windthrow, water quality, regeneration and cattle grazing. A literature review analysis was also carried out on current large and small-scale harvesting operations to evaluate the benefits and limitations of various types of equipment and mechanicals. Socio-economic literature was also sited to determine productivity and costs for other forestry operational experiments in British Columbia and Canada. Literature on non-timber Aboriginal values was assessed to provide information on the significance of riparian attributes to their cultural, social and spiritual well-being.

3.2 Aboriginal Values

To provide and account for aboriginal values for the purposes of this study, The Skeetchestn Indian Band carried out Cultural Heritage Overview and Archaeology Overview Assessments in the four study sites. The information obtained from these assessments was used to determine presence of plant, wildlife and other significant attributes that are of social and cultural concern to the Skeetchestn Indian Band.

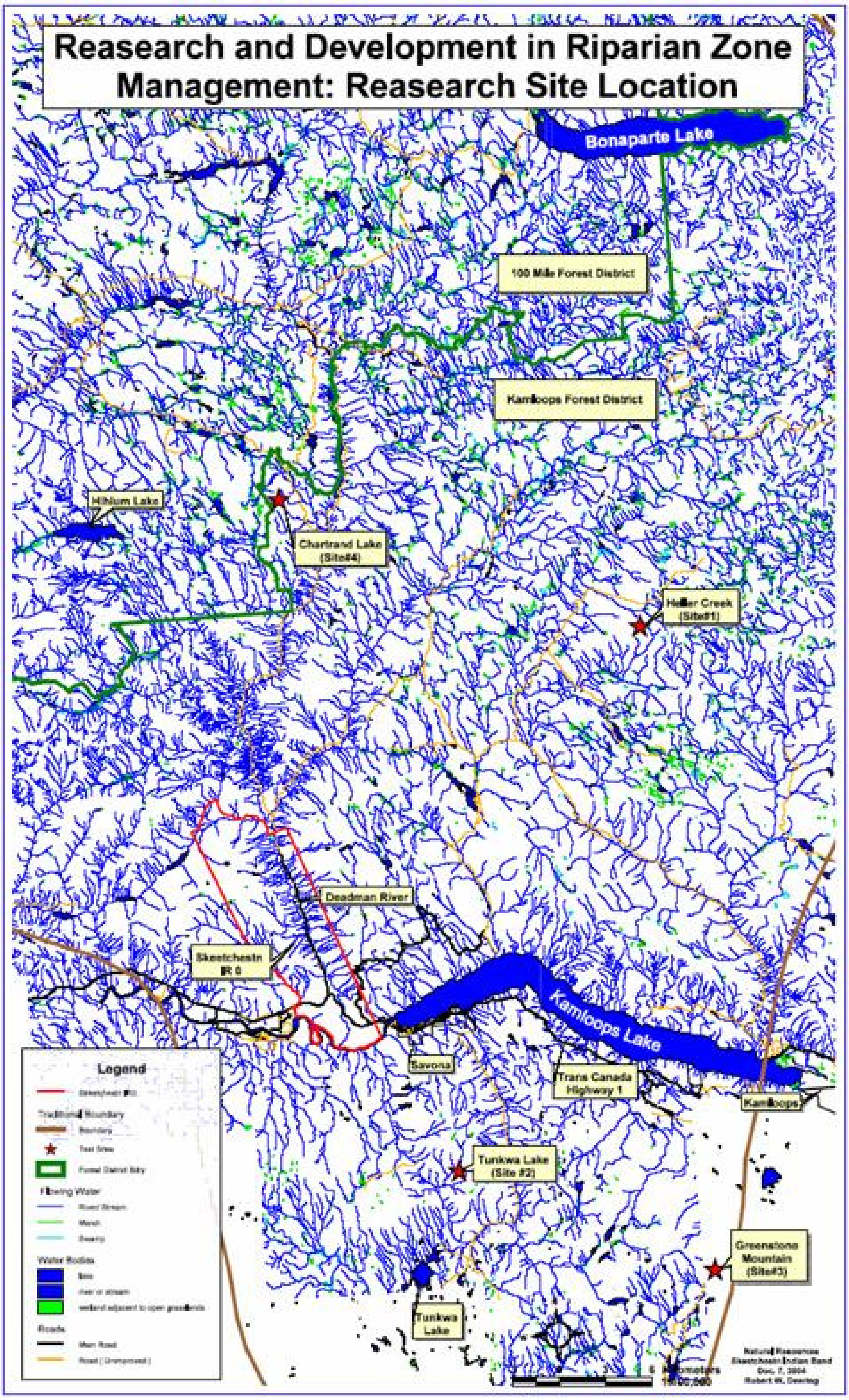
3.3 Research Plan and Design Limitations

Site selection for the research plan was heavily dependant on both Weyerhaeuser Company Limited (Weyerhaeuser) and West Fraser Mills Ltd - Chasm Sawmills (West Fraser) accommodation in terms of site selection and availability. Due to the high occurrence of mountain pine beetle (MPB) (*Dendroctonus ponderosae*) and recent wild fire activity in the Kamloops Timber Supply Area, research was required to follow along with the existing operations of the licensees. Therefore site selection was limited to MPB blocks under the licensees current forest development plans (FDP).

Also the riparian areas within these MPB blocks were limited in size and uniformity, this further limited options for plot size and location. Plot size was intended to be one hectare in size to represent minimum clearcut requirements, however, the site limitations dictated that plot sizes be .25 ha or smaller. Overall operation feasibility placed further limitations on research design. Due to safety requirements of harvesting personnel's and horses random treatment assignment was compromised. Weather and early break-up altered and extended harvesting schedules. An additional constraint that was encountered was the lack of easy access to anything but conventional harvesting equipment. Small scale equipment was very hard to locate and access. Both crews and equipment had to be brought in from Prince George thus adding significantly to the costs experienced for this treatment.

3.4 Study Area

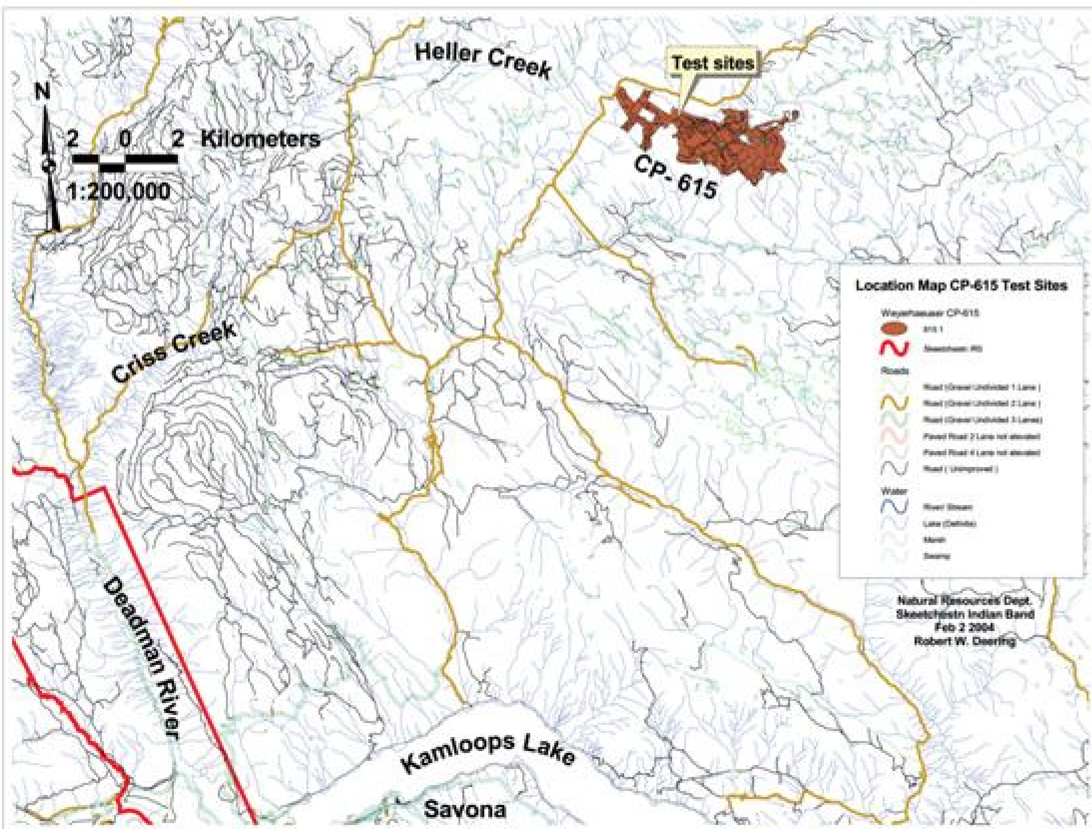
The study area consisted of four individual sites; Heller Creek (Site #1), Tunkwa Lake (Site #2), Greenstone Mountain (Site #3) and Chartrand Lake (Site #4). All four sites are located within the southern interior plateau, within a one and a half hour radius of Savona, British Columbia (Map 1). Heller Creek and Chartrand Lake are located within the Fraser Plateau while Tunkwa Lake and Greenstone Mountain are located within the Thompson Plateau. All four sites, except for a portion of the Chartrand Lake site which is in 100 Mile Forest District, fall within the Kamloops Forest District and Kamloops Timber Supply area. All sites are within the traditional territory of the Skeetchestn Indian Band, whose reserve is located within the Deadman River valley, 20kms northwest of Savona, B.C. Harvesting of the Heller Creek and Tunkwa Lake research sites occurred during the winter of 2003/2004 and Greenstone Mountain and Chartrand Lake in the winter of 2004/2005.



Map 1. Overview of Research and Development in Riparian Zone Management study area.

3.4.1 Site #1 – Heller Creek

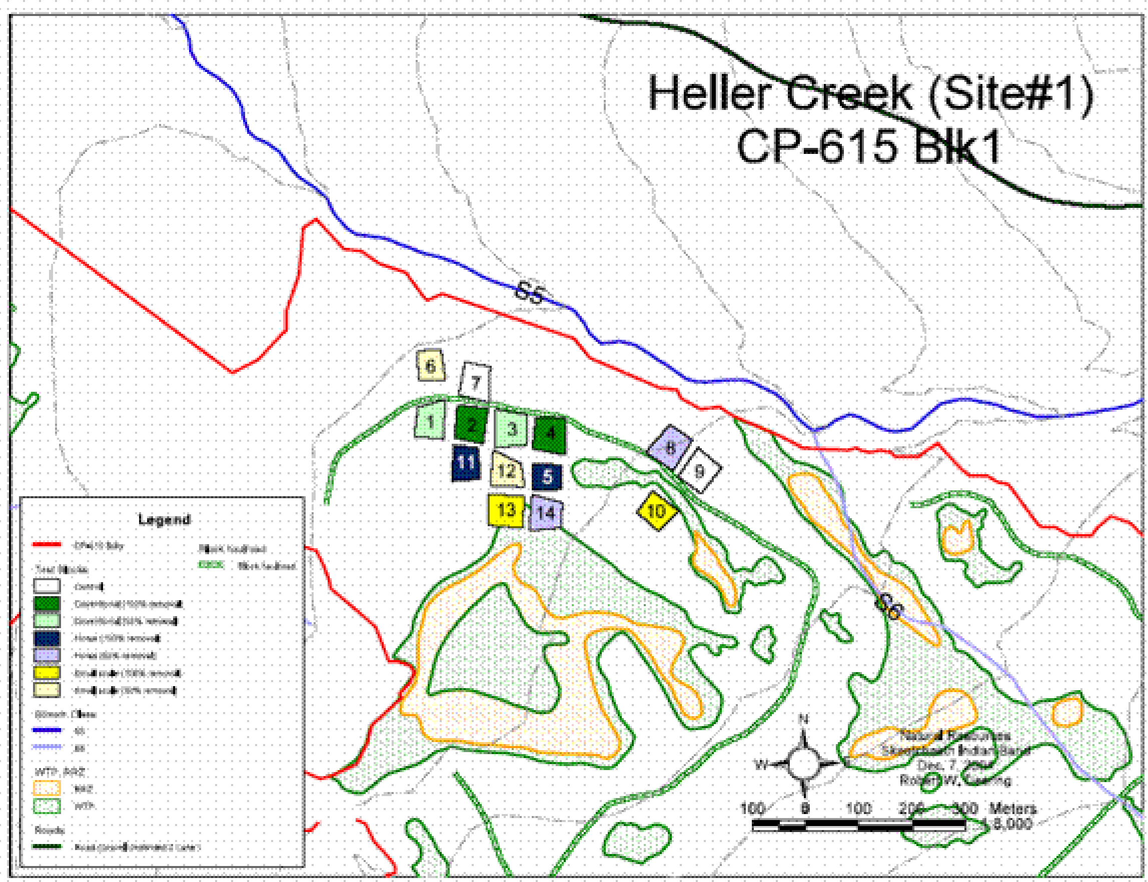
Site #1 is located directly adjacent to Heller Creek within the Deadman watershed. The research area is located within Weyerhaeuser's operating area, cutting permit 615. One third of cutting permit 615 is located within the Tranquille Community Watershed with the remainder forming the headwaters to Criss Creek via Heller Creek (Map 2). Harvesting of the site was conducted in November 2003.



Map 2. Site #1 - Heller Creek.

Heller Creek falls within the Montane Spruce (MS) biogeoclimatic (BGC) zone (Table 6.0) and is found at an elevation of approximately 1640m. This site is typical of the characteristics that are found in most montane spruce forests within the southern interior. The MS zone occurs at mid elevation in the plateaus of B.C. The area is dominated by lodgepole with a mix of various other species. This area is indicative of short cool and dry summers and cold winters.

The topography of Heller Creek is represented by low undulating hills with various types of water features surrounding all sample plots within the Heller Creek site (Map 3). The site is bordered by Heller Creek on the North (an S3 classified stream that acts as a water source for the Deadman River), a wetland (W5) on the south boundary and an S6 on the east that flows west, emptying into depressional areas within the sample plots. All three features within the area and topography contribute to the site being characteristic of high groundwater tables throughout the entire growing season.



Map 3. Location of the treatment plots in Site #1 - Heller Creek.

One in block road transects the research area from east to west. Plots 6,7,8 and 9 are located north of the road, closest to Heller Creek, with the remainder of the plots being situated between the road and the classified wetland.

Table 6.0. Biogeoclimatic information for Site #1 - Heller Creek.

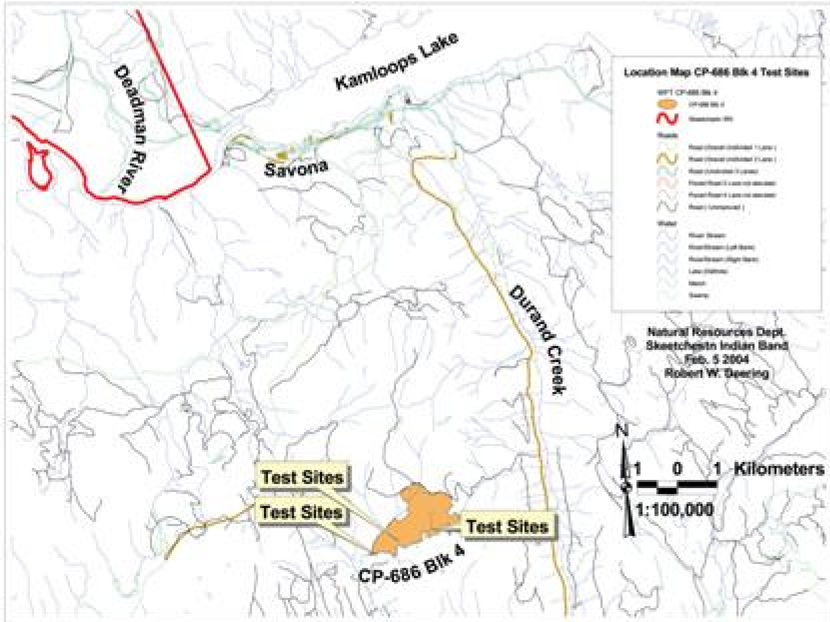
BGC Zone	Subzone	Variant	Site Series
MS	xk	01	$01_{50}07_{40}06_{10}$

Geology and Soils

Heller Creek as well as the remainder of the Deadman watershed is located within the Thompson plateau. Heller Creek is characteristic of plateau lava and basalt flows and is dominated by ablation moraine, morainal (glacial till) and organic deposits. It is characteristic of being 90% gravelly, coarse and moderately coarse textured ice-contact (ablation moraine) deposits that are moderately to excessively stony. The prodominant soil (90%) within the area is Orthic Humo-Ferric Podzols. Well-drained soil moisture normally exceeds field capacity for a significant part of the year and has a moderately rolling to hilly topography that is associated with basic bedrock. The remaining 10% of soil is undecomposed, mainly moss derived organic deposits (Fibrisol), which is very poorly drained with free standing water remaining at or within 30 cm of the surface for most of the year and is nearly level to gently undulating topography (Young et al. 1992). The soil moisture regime of the research area ranges from mesic to subhygric and has a very poor to rich soil nutrient regime.

3.4.2 Site #2 – Tunkwa Lake

Site #2 is located in the Tunkwa Lake area of the Kamloops Forest District and is within the Kamloops Timber Supply Area. In particularly, West Fraser's cutting permit 685, block 4, located just north of Tunkwa Provincial Park (Map 4). The site falls within the Interior Douglas-fir (IDF) BGC zone (Table 7.0) and is characteristic of warm, dry summers and moderately cool winters.

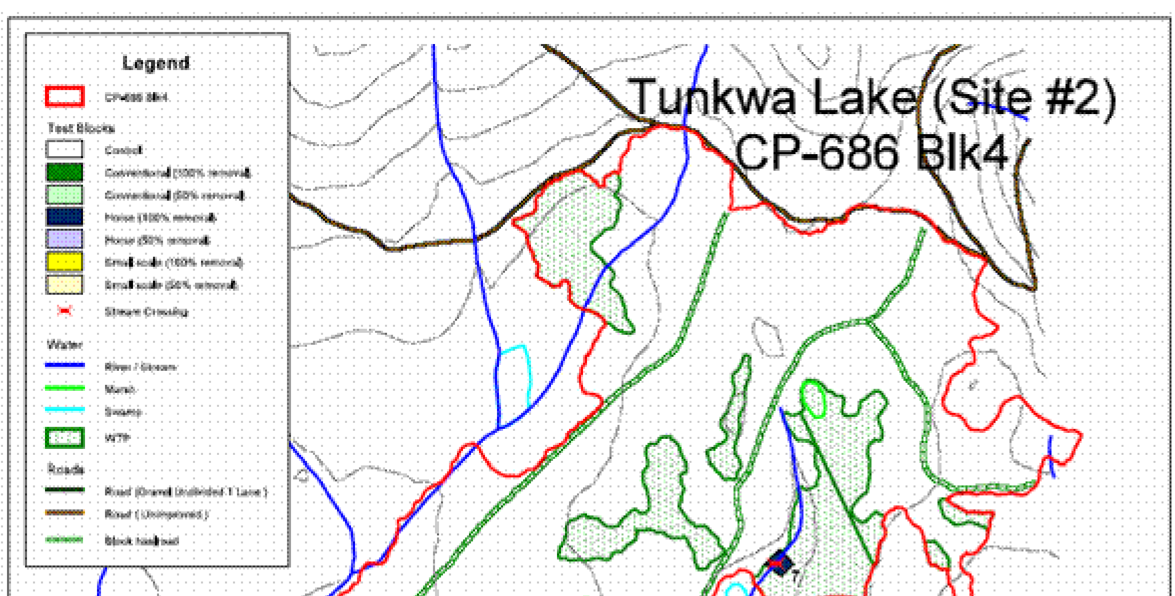


Map 4. Site #2 – Tunkwa Lake

Table 7.0. Biogeoclimatic information for Site #2 – Tunkwa Lake

BGC Zone	Subzone	Variant	Site Series
IDF	dk	1	$06_{80}05_{10}01_{10}$

The research site encompasses two streams that are classified as S6 and borders two wetlands that are classified as W3 and W1 (Map5). The two S6 streams are located within the center portion of the block for plots 2-11 and 13, while plots 1,12 and 14 are located in depressional areas that are moisture receiving sites and are within 10 meters of an S6 stream. Plots 1,7,8,14,10 and 11 are located in areas along the S6 that are highly incised, creating two distinct microsites that differ in terms of moisture availability.



Geology and Soils

The Tunkwa lake site is found on the Thompson plateau and consists of a generalized extrusive volcanic bedrock group with minor sedimentary portions. It is characteristic of andesite, basalt, rhyolite associated tuff and breccia and is dominated by morainal (glacial till) deposits. The soils of the Tunkwa Lake site are generally dominated by Orthic Gray Luvisols (Young et al. 1992). Parent materials and texture of the area are generally characteristic of silt loam or loams that are mildly alkaline and slightly to very stony. The soil moisture regime of the research area ranged from subhygric to mesic with a predominately medium to very rich soil nutrient regime.

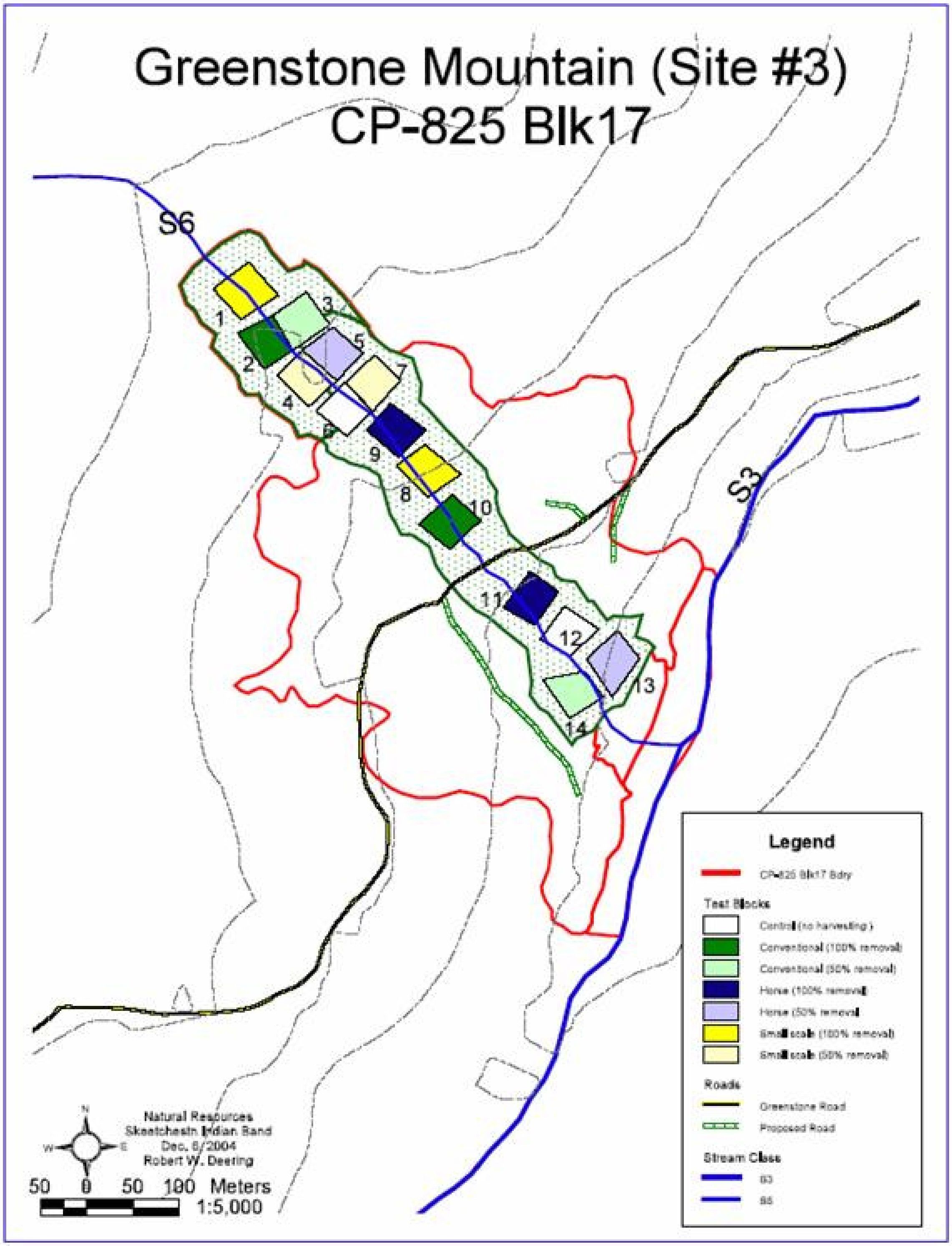
3.4.3 Site #3 – Greenstone Mountain

Site #3 is located on Greenstone Mountain within the Kamloops Forest District and is within the Kamloops Timber Supply Area. The site falls within the IDF BGC zone is typical of the variety of vegetation and forest type within that zone (Table 8.0). The Greenstone Mountain site is similar to that of Tunkwa Lake, with many sample plots having a fairly abrupt transition between moisture receiving areas and adjacent drier areas.

Table 8.0. Biogeoclimatic information for Site #3 – Greenstone Mountain

BGC Zone	Subzone	Variant	Site Series
IDF	dk	1	$01_{60}05_{40}$

All sites are influenced by a single dominating S6 stream that flows either through the sample plots or directly adjacent to them (Map 6). This S6 stream empties into Cherry Creek (S3), approximately eighty meters south of the research area. Sample plots 2,3,4,5,7,8,13 and 14 are directly adjacent to the S6 stream, while plots 1,8,9,10 and 11 have the S6 situated within the center of the plot. Harvesting of Greenstone Mountain occurred in November of 2004.



***N.B. Plot # 13 has not been completed yet due to weather conditions**

Map 6. Site #3 – Greenstone Mountain.

Geology and Soils

The geology and soils of Greenstone Mountain are also similar to those found within the Tunkwa site. The Greenstone Mountain site belongs to the Tunkwa soil association and consists of medium textured morainal deposits and is slightly to very stony. Common soils of the area consist primarily of Orthic Gray Luvisols. The topography of the area is gently sloping to strongly rolling and is associated with basic bedrock. The soil moisture regime is predominately mesic with a soil nutrient regime ranging from very poor to very rich.

3.4.4 Site #4 – Chartrand Lake

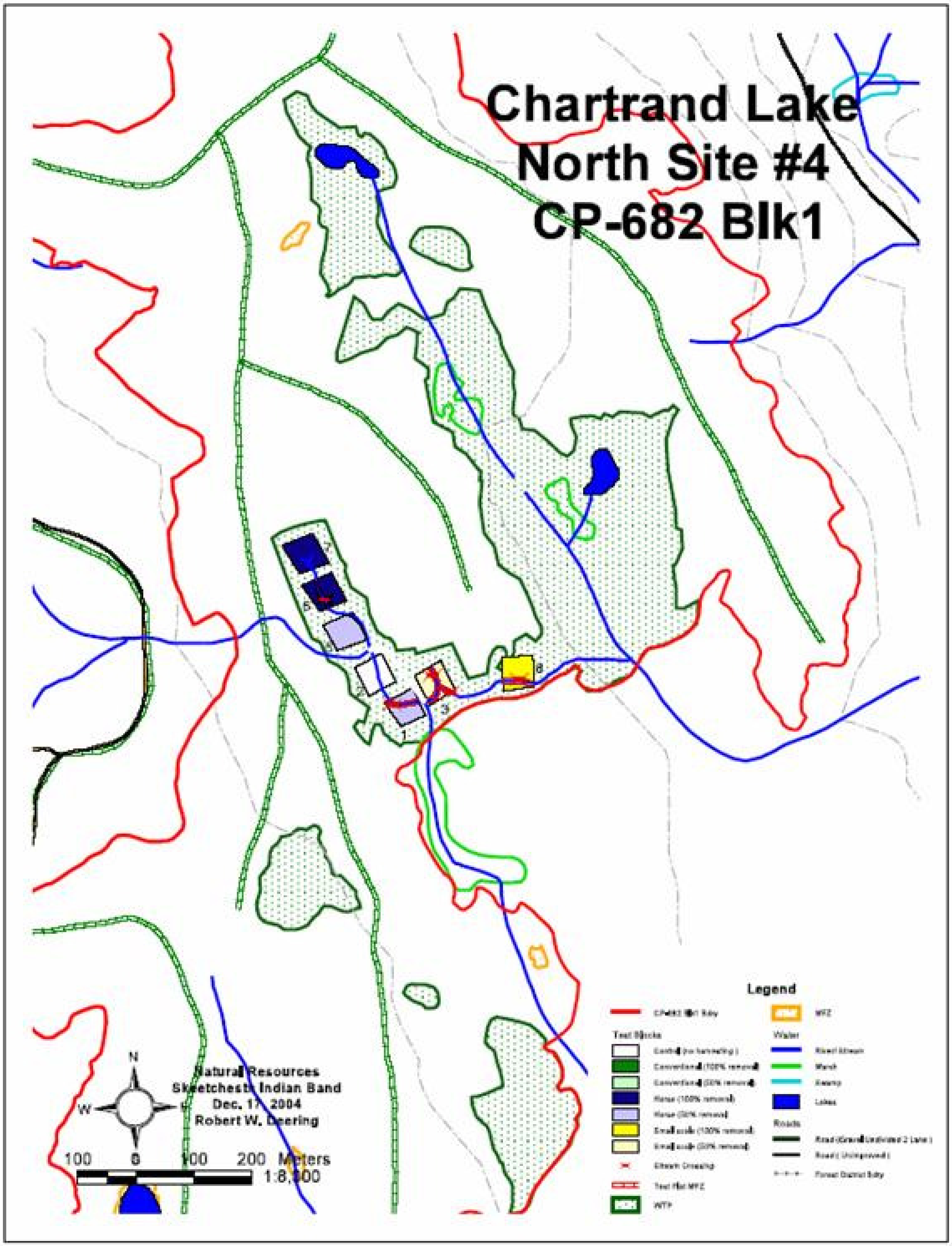
Site # 4 is located within the 100 Mile Forest District and is within the 100 Mile Timber Supply Area. Site #4 is under authority of block 01 of West Fraser's cutting permit 682. The site is described as being part of the Interior Douglas fir BGC zone (Table 9.0). The research area encompasses four different S6 streams and is surrounded my numerous wetlands and moisture receiving sites (Map 7 and Map 8). All sample plots within the research area have one S6 stream the flows through the center of the plot. As per the BGC site series, the area is characterized as permanent and temporary seepage areas with a topography of plateaus and gentle slopes.

Table 9.0. Biogeoclimatic information for Site #4 – Chartrand Lake

BGC Zone	Subzone	Variant	Site Series
IDF	dk	3	$08_{60}07_{25}01_{15}$

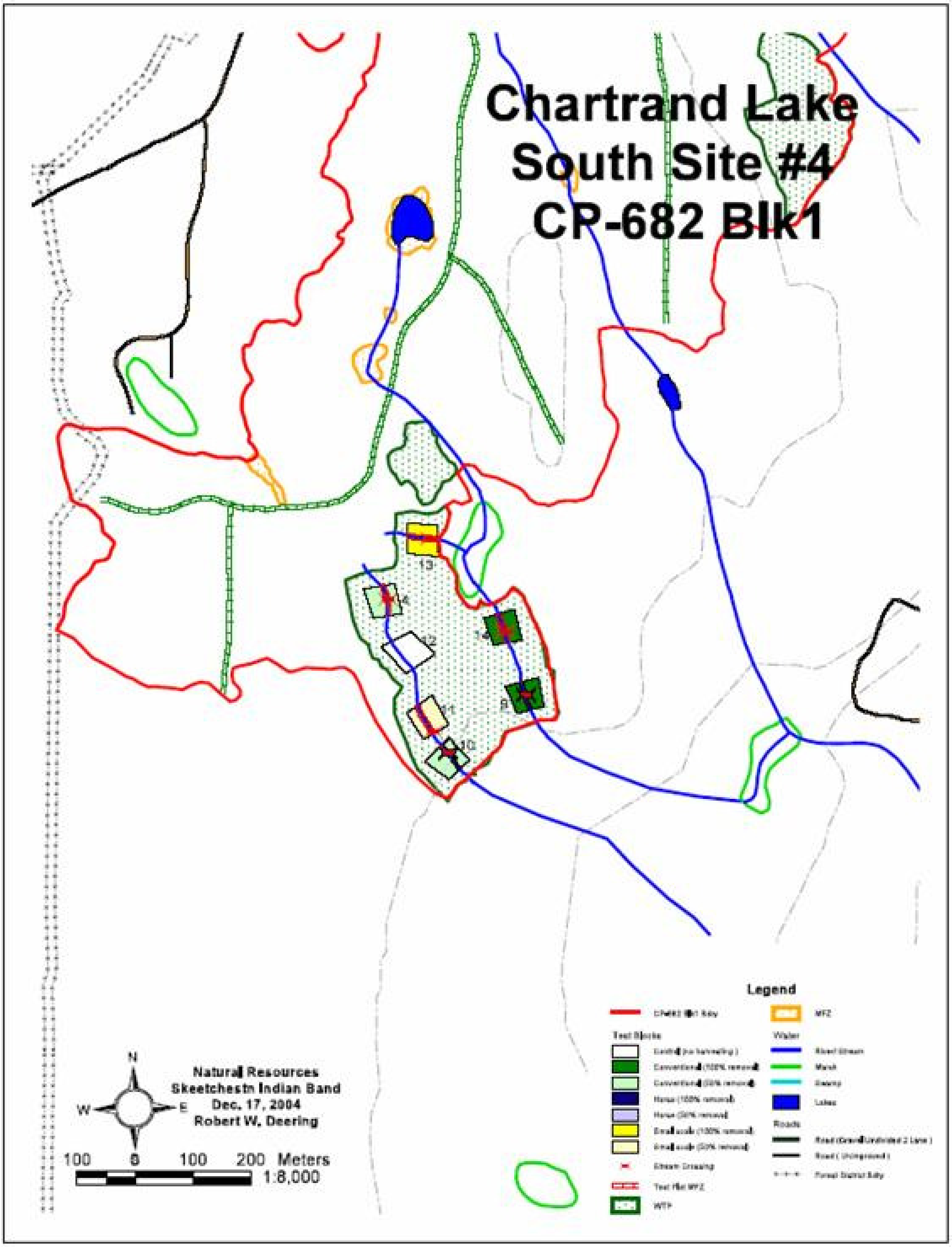
Geology and Soils

The soil moisture regime of the area ranges from mesic to subhygric and is characteristic of areas that maintain a water table within 25 cm of the soil surface for the majority of the year. This site is also characteristic of having a soil nutrient regime that varies between very poor and very rich. Soils in the area are commonly classified as Dystric or Eutric Brunisols and Gray Luvisols.



***N.B. Horselogging treatments are not yet completed due weather conditions**

Map 7. Site #4 – Chartrand Lake North



Map 8. Site #4 – Chartrand Lake South

3.5 Treatment plots

Treatment plots were laid out as 50x50m squares in July and August of 2003 for sites #1 and 2. Treatment plots were laid out in July and August of 2004 for sites #3 and 4 at 40x40m and 50x50m, respectively. Treatment plots were positioned along various bearings within the riparian area to allow for increased homogeneity between the riparian attributes of the area and to lessen any ecological variability between treatment plots. Treatments plots were laid out in a manner to ensure that all treatments had a minimum of a fifteen meter buffer strip surrounding the plot to minimize the effects of adjacent harvesting treatments and stand structure. However, treatments plots along roadsides were not given a buffer area along the side directly adjacent to the road. Treatment plot layout patterns (bearings) varied from site to site due to the topographical locations of the different streams in the areas.

3.6 Sampling Techniques

3.6.1 Vegetation Assessments

Three transect lines were laid out within each treatment plot at intervals of 12.5m for sites #1, 2, and 4 and at 10m intervals for site #3 (Figure 4.0). Along each transect line five sample plots were conducted, giving a total of 15 sample plots for every one treatment plot. Distances of sample plots along the transect lines were determined using a random number generator, thus allowing for a stratified randomization approach for sampling design. To further control for external influences, no sampling plots were conducted within the outer 10m of the treatment plots. This was implemented by limiting the randomization of sample plots to between 10 and 40m for sites #1,2 and 4 and between 10 and 30 for site #3. Sampling therefore occurred within the inner 900m^2 of the 2500m^2 treatment plots and within the inner 400m^2 for plot #3. Vegetation assessments therefore covered 8.3% of the assessment area per plot for #1,2 and 4 and 18.8% of the assessment area for plot #3.

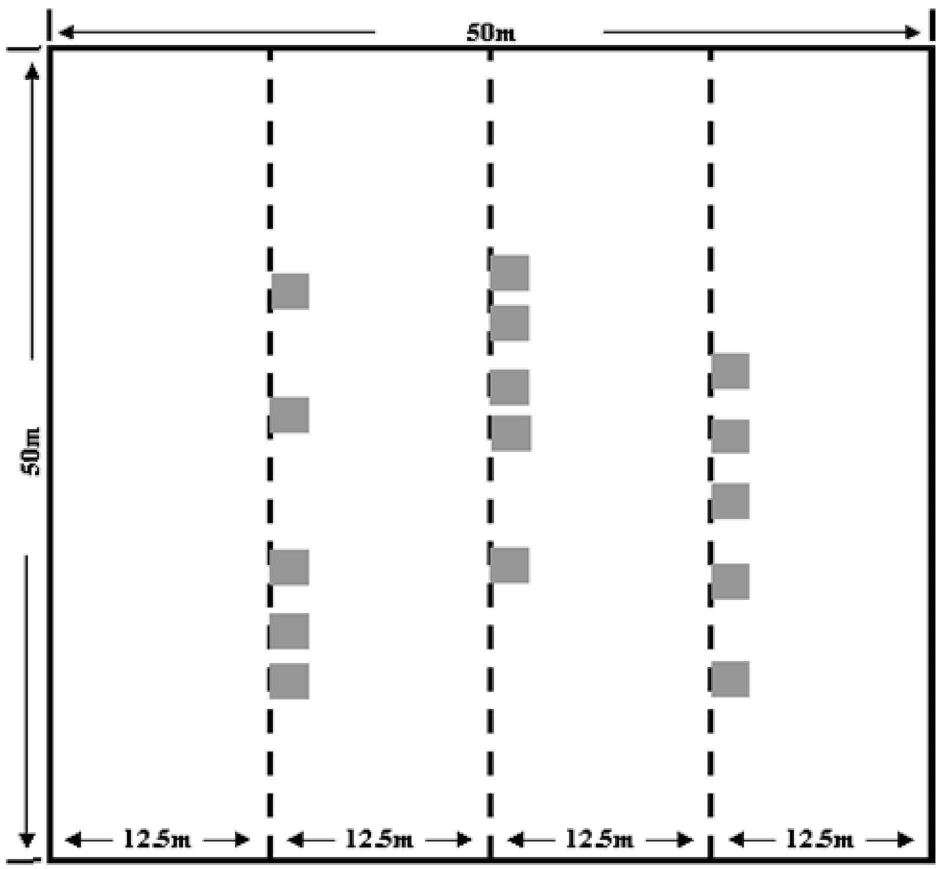

50m
50m
12.5m
12.5m
12.5m
12.5m

Figure 3.0. Graphical depiction of field assessment process. The squares represent the vegetation sample plots ($5m^2$) randomly located along the three lines (5 sample plots per line).

3.6.2 Pre harvest Stand Characteristics

Timber values and characteristic sampling were conducted congruently with pre-harvest vegetation assessments. One plot was conducted within each treatment plot for a total of fourteen timber plots per site. Timber plots consisted of a circular plot of a radius of either 5.64 or 7.98 meters in radius, totalling an area of 100 and 200 m^2, respectively. The different sized circular plots were used based on the average density of the area (i.e. in areas that contained a large number of stems per hectare the smaller radius was used).

3.6.3 Post Harvest Stand Characteristics

Post harvest timber values and characteristics surveys were conducted congruently with vegetation assessment surveys. One plot was conducted within each treatment plot for a total of fourteen timber plots per site. Timber plots consisted of a circular plot of a radius of either 5.64 or 7.98 meters in radius, totaling an area of 100 and 200 m^2, respectively. The different sized circular plots were used based on the average density of the area (i.e. in areas that contained a large number of stems per hectare the smaller radius was used).

3.6.4 Soils

Soils sampling was conducted for both pre and post harvest years to determine the impact of harvesting on soil bulk density. Samples were taken using a sampling unit obtained from Agriculture and Agri-Food Canada, Kamloops Range Research Unit (Figure 4.0). Five soil samples consisting of $393.9cm^3$ were extracted from each treatment plots, thus totaling 70 samples per research site. Soils were then dried for a minimum of 24 hrs and weight to the nearest $^1/_{100}{}^{th}$ gram. Soil bulk density is referred to as the mass of dry soil per unit of bulk soil. Increases in bulk density correspond to increased soil compaction following harvesting.

Figure 4.0. Soil sampling unit for determining soil bulk density.

3.7 Treatments

Two site treatments were established to represent differing amounts of tree removal while using various harvesting methods. It was the objective of this project to establish areas of 100% removal to represent current harvesting practices and to implement areas of alternative harvesting through selection cutting (50% removal).

Three forms of harvesting operations were further established giving a total of six different treatments plus one control (Table 10.0). All treatments were replicated, totalling fourteen treatment plots per research site. The objectives of the 100% removal were to harvest all merchantable timber within plot boundaries, while retaining all unmerchantable timber, regeneration and alternate species where operationally feasible. The objective for the select harvesting blocks where to harvest all marked (pink ribbon around bole) timber while retaining all unmarked merchantable timber, regen and alternative species. All danger trees within all areas were to be harvested to comply with Workers Compensation Board regulations.

Timber designated to be harvested under the select cutting treatment (pink ribbon around bole) were selected using the following criteria, in order, up to a 50% canopy removal:

1. Removal of all dominant/mature pine type to decrease future pine infestations within the research plots.

2. Remove mature spruce overtopping current stand to decrease susceptibility to blowdown following gap opening

3. If required, remove merchantable pine then spruce of various D.B.H. to ensure a 50% canopy removal.

Table 10.0. Harvesting methods used for various treatments.

Treatment #	Harvesting method (Prescription)
1	Small-scale harvesting (100% removal)
2	Small-scale harvesting (50% removal)
3	Conventional harvesting (100% removal)
4	Conventional harvesting (50% removal)
5	Horse Logging (100% removal)
6	Horse Logging (50% removal)
7	Control (no harvesting)

3.8 Harvesting Techniques

3.8.1 Horse Logging

Horse logging consisted of two draft horses, one teamster, one hand faller and one buckerman (Photo 1)..

Photo 1. Skeetchestn horse logging operation

3.8.2 Small-scale Mechanical

Small-scale mechanical harvesting consisted of a low-pressure hydrostatic skidder (Berfor Forcat 2000) with one hand faller and one buckerman. The Berfor Forcat 2000 is manufactured and used primarily in eastern Canada for applications on smaller woodlots and commercial thinning (Photo 2).

Photo 2. Berfor Forcat 2000 skidding within Site #1 - Heller Creek.

3.8.3 Conventional Large-scale Mechanical

Representation of conventional large-scale mechanical harvesting was through the use large skidders, feller bunchers and processors. The equipment used had been previously utilized within the operating area of Weyerhaeuser and West Fraser as their primary harvesting equipment. West Fraser's equipment consisted of a Prentiss 630 feller buncher, John Deere 748 skidder, Hitachi 200 processor and a Hitachi Zaxis 200 loader for West Fraser. Weyerhaeuser's equipment consisted of similar machines of similar size and horsepower (Photo 3).

Photo 3. Conventional stroker / delimber and skidder working within Site #1 - Heller Creek.

3.9 Socio-Economic Analysis

A socio-economic analysis was used to monitor the harvesting operation to determine harvesting productivity and costs enabling assessment of the operational suitability of using low impact systems as alternative to conventional harvesting for selection cutting in riparian areas. Three areas were harvested in Tunkwa Lake area and ranged from 8.1 to 14.0 ha. Data from these harvesting operation was used to evaluate man hours contributed, total labour costs, maintenance cost and total logging cost on per m^3 basis.

This evaluation was used to determine the overall impact that harvesting practices have on local employment and income.

4 RESULTS

4.1 Pre-harvesting Vegetation and Soil Assessments

The purpose of pre-harvesting vegetation and soils assessments was to gather baseline data to enable comparison of pre and post harvest site characteristics. Assessments included compiling data on overstory stand structure, shrub, forbes and moss species and soil bulk density.

4.1.1 Site # 1 - Heller Creek

Overstory Stand Characteristics

The overstory of the Heller Creek site is representative of most montane biogeoclimatic zones of the southern Interior (Photo 4) and includes lodgepole pine (*Pinus contorta* var. *latifolia* (Pl)), spruce (*Picea engelmannii* hybrid (Sx)) and sub-alpine fir (*Abies lasiocarpa* (Bl)). The overall stand of Heller Creek consists of an average of 664 stems/ha and is comprised of a species composition of PlSx(Bl) mix. Average tree age within the Heller Creek site was determined to be 70yrs with an average volume of 393m^3/ha. Canopy closure of the area was 67% (Table 11.0).

Photo 4. General view of the Site #1 - Heller Creek prior to treatments.

Table 11.0. Average Pre-harvest Stand Characteristics of Site #1 – Heller Creek

Crown closure (%)	Basal Area (m^2/ha)	Volume (m^3/ha)	Age (yrs)	Species Composition	Total Stems/ha
67	30	393	70	$Pl_{61}Sx_{30}(Bl_{09})$	664

Vegetation Characteristics

The understory vegetation within Heller Creek was dominated by those species that are indicative of the montane spruce BGC zone. Low lying shrubs and forbes such as grouseberry (*Vaccinium scoparium*), bunchberry (*Cornus Canadensis*) and wild strawberry (*Fragaria virginiana*) were the most common species occurring throughout the site (Table 12.0). These species are also indicative of sites that contain nitrogen-poor soils. Red stem feather moss (*Pleurozium schreberi*) and broom moss (*Dicranum scoparium*) constituted the highest occurrence within the moss community.

Table 12.0. Fifteen highest cover rates Site #1 – Heller Creek

Latin Name	Frequency (%)	Cover (%)	Height (cm)
Ledum glandulosum	88	24	51
Pleurozium schreberi	75	12	3
Vaccinium scoparium	97	8	10
Dicranum scoparium	87	6	2
Abies lasiocarpa	70	5	59
Cornus canadensis	93	5	6
Valeriana sitchensis	87	5	20
Calamagrostis rubescens	75	4	35
Linnaea borealis	71	3	2
Elymus glaucus	24	2	50
Festuca occidentalis	46	2	17
Fragaria virginiana	90	2	9
Hylocomium splendens	15	2	3
Lonicera involucrata	75	2	41
Lupinus arcticus	67	2	27

Trapper's tea (*Ledum glandulosum*) dominated the shrub community within the Heller Creek site (Table 13.0). Trapper's tea occurred on nearly ninety percent of all vegetation plots and was used as the base species to compare uniformity throughout the Heller Creek site, ensuring that all sample plots were homogenous. Trapper's tea also indicates higher moisture levels and occurs in coniferous forests on acidic soils and in bogs and wet depressional areas. The ground water table in the area remains within thirty centimetres of the soil surface throughout the entire year. In all, seventy-eight species were identified within the Heller Creek site prior to harvesting.

Table 13.0. Fifteen highest frequency rates for Site #1 – Heller Creek

Latin Name	Frequency (%)	Cover (%)	Height (cm)
Vaccinium scoparium	97	8	10
Cornus canadensis	93	5	6
Fragaria virginiana	90	2	9
Ledum glandulosum	88	24	51
Dicranum scoparium	87	6	2
Valeriana sitchensis	87	5	20
Calamagrostis rubescens	75	4	35

Lonicera involucrata	75	2	41
Pleurozium schreberi	75	12	3
Linnaea borealis	71	3	2
Abies lasiocarpa	70	5	59
Petasites frigidus var. palmatus	70	1	12
Lupinus arcticus	67	2	27
Senecio pseudaureus	67	1	12
Epilobium angustifolium	64	1	38

The trapper's tea (Photo 5) also has great cultural value to the Skeetchestn Indian Band and to other bands in the area, as it is one of two major traditionally recognized tea beds within the Southern Interior (M. Anderson pers. comm.).

Photo 5. Site #1 – Heller Creek's understory is dominated by *Ledum glandulosum* (Trapper's tea).

Soil Classification and Bulk Density

The Heller Creek soil has developed on ablation till underlain by basil till and has a horizon sequence of L, FH, Bgi, Bg and Cg (Photo 6). The soil is an Orthic Gleysol and displays mottling from the surface down (Photo 7) indicating a strong fluctuating water table that is generally near or at the soil surface during the spring and early summer period. Because of the seasonally high water table, the rooting depth is limited to 20 cm resulting in shallow-rooted trees which are susceptible to windthrow. Coarse fragment content for the Bgj is 80%, and 10% for the Bg and Cg horizons. Structure ranges from very coarse subangular blocky to coarse subangular block for the three mineral horizons with a sandy clay soil texture.

Photo 6. Site #1 – Heller Creek, major soil horizons.

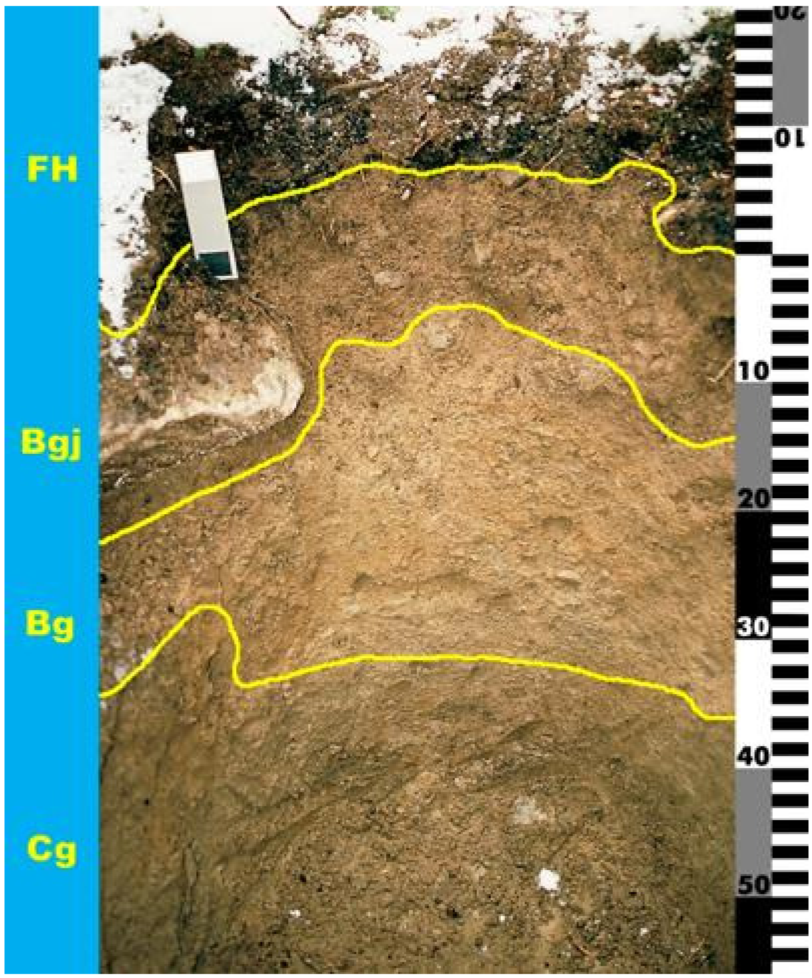


Photo 7. Site #1 – Heller Creek soil profile (Orthic Gleysol).

Soil bulk densities of the site were categorized into; 1) mostly mineral, 2) mostly organic and 3) mineral and organic mix. Pre-harvest assessments determined bulk density to range from 0.102 g/cm^3 to 0.997 g/cm^3 with a site mean of 0.380 g/cm^3.

4.1.2 Site #2 - Tunkwa Lake

Overstory Stand Characteristics

The overstory of the Tunkwa Lake site consists of a spruce, trembling aspen (*Populus tremuliodes* (At)), pine mix (Photo 8 and Table 14.0). Spruce comprises over ninety percent of composition due to the higher moisture levels directly adjacent to the S6 streams. The pine component of the species composition is due to the influence of the drier micro sites above the highly insized channel areas. Crown closure within the site averages eighty-two percent. Average stems per ha and volume of the site are 1107 stems/ha and 476 m^3/ha, respectively. Stems per hectare within the site range from 400 to 1700 stems/ha throughout the research plots (Appendix 1).

Photo 8. Site #2 – Tunkwa Lake general overview prior to harvest treatments.

Table 14.0. Average Pre-harvest Stand Characteristics of Site #2 – Tunkwa Lake

Crown closure (%)	Basal Area (m^2/ha)	Volume (m^3/ha)	Age (yrs)	Species Composition	Total Stems/ha
82	56	476	123	$Sx_{91}(At_{06}Pl_{03})$	1107

Vegetation Characteristics

The dominating S6 stream within the Tunkwa Lake site is highly incised in many of the research plots resulting in two distinct plant communities within the individual sample plots. The dominating species within the moisture deficit areas is pinegrass (*Clamagrostis rubescens*), which is indicative of the IDF, and dominates in dryer areas due to its ability to survive at low moisture levels during the growing season. Within the deeply insized area bottoms and throughout the rest of the sample plots the area is a moisture-receiving site. The most common forb species of the wetter areas are common horsetail (*Equisetum arvense*) and meadow horsetail (*Equisetum pratense*) (Photo 9 and Table 15.0) and are generally abundant in nitrogen-medium to rich sites (Klinka et al. 1989). Soft-leafed sedge (*Carex disperma*) also occurs on the sites indicating a very moist soil moisture regime in which the water table remains at between 30 and 60 cm (Lloyd et al. 1990), providing rooting zone moisture throughout the growing season.

Photo 9. Site #2 – Tunkwa Lake dominated by *Equisetem* (horsetail) .

Red stem feather moss (*Pleurozium schreberi)* and trailing leafy moss (*Plagiomnium medium*) are the dominating moss species (Table 15.0 and Table 16.0). Leading shrubs within the area include prickly rose (*Rosa acicularis*) and northern black current (*Ribes hudsonianum*), although both species occur at low levels (percent cover). Tunkwa represented the most diverse research site in terms of species, containing a total of 125 different species.

Table 15.0. Fifteen highest cover rates for Site #2 – Tunkwa Lake

Latin Name	Frequency (%)	Cover (%)	Height (cm)
Equisetum arvense	59	16	30
Equisetum pratense	73	15	40
Calamagrostis rubescens	48	7	49
Hylocomium splendens	24	4	2
Linnaea borealis	60	4	3
Muhlenbergia cuspidata	47	4	2
Rosa acicularis	70	4	43
Carex disperma	18	3	25
Oryzopsis asperifolia	22	3	24
Pleurozium schreberi	35	3	3
Aulacomnium palustre	21	2	2
Cornus canadensis	59	2	10
Lonicera involucrata	42	2	53
Rubus pubescens	45	2	33
Sphagnum squarrosum	8	2	2

Table 16.0. Fifteen highest frequency rates Site #2 – Tunkwa Lake

Latin Name	Frequency (%)	Cover (%)	Height (cm)
Mitella nuda	81	1	4
Equisetum pratense	73	15	40
Rosa acicularis	70	4	43
Fragaria virginiana	61	1	11
Linnaea borealis	60	4	3
Cornus canadensis	59	2	10
Equisetum arvense	59	16	30
Calamagrostis rubescens	48	7	49
Muhlenbergia cuspidata	47	4	2
Aster Subspicatus	45	1	13
Rubus pubescens	45	2	33
Lonicera involucrata	42	2	53
Peltigera canina	38	1	2

Pleurozium schreberi	35	3	3
Plagiomnium medium	33	1	2

Soil Classification and Bulk Density

The Tunkwa soil has developed on a fluvial floodplain and has a horizon sequence of Of, Ahg, Bg, and Cg. The soil is an Orthic Humic Gleysol (Photo 10) and displays mottling from the surface down. The water table is at or near the soil surface during most of the growing season but can fluctuate down to approximately 60cm in the late summer/early winter period. Due to the relatively high water table, rooting depth is restricted to 36cm resulting in a shallow rooted stand that is prone to windthrow. The coarse fragment content is less than 10 % with all horizons classified as massive (structureless) with a clay soil texture. The mineral horizons contain high organic matter content and are classified as a nutrient rich (after Klinka et al. 1989). The high clay content and high water table make this soil susceptible to soil compaction.

Soil bulk densities of the site were categorized into; 1) mostly mineral, 2) mostly organic and 3) mineral and organic mix. Assessments determined bulk density to range from 0.088 g/cm^3 to 0.990 g/cm^3 with an overall site average of 0.405 g/cm^3 .

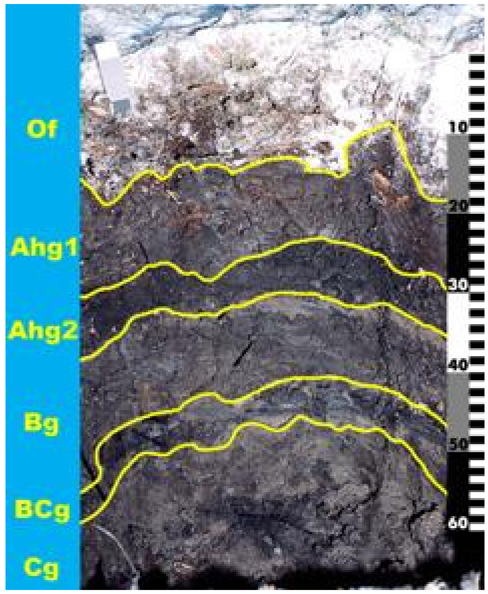


Photo 10. Site #2 – Tunkwa Lake soil profile (Orthic Humic Gleysol).

4.1.3 Site #3 - Greenstone Mountain

Overstory Stand Characteristics

The overstory of Greenstone Mountain varies throughout the site in terms of species composition, incorporating interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), spruce and lodgepole pine (Appendix 1). Overall species composition for the site consisted of SxPlFd (Table 17.0). While having a fairly uniform mix of species by average, plots 13 and 14 consisted of a pure spruce composition. This may be attributed to the change in slope within plots 13 and 14, thus creating a moisture level higher than that of the other plots.

Total stems per hectare and volume of the stand were, 1150 stems/ha and 960 m^3/ha, respectively. Plots within the research area ranged in stems per hectare from 800 and 2100 stems /ha, and in volume from 325 to 1933 m^3/ha. Average crown closure of the area is ninety-six percent with the average age being ninety-six years.

Table 17.0. Average Pre-harvest Stand Characteristics of Site #3 – Greenstone Mountain

Crown closure (%)	Basal Area (m^2/ha)	Volume (m^3/ha)	Age (yrs)	Species Composition	Total Stems/ha
96	57	960	96	$Sx_{38}Pl_{37}Df_{25}$	1150

Vegetation Characteristics

Due to the topographical attributes of some of the sample plots, pinegrass is again a dominating species (Table 18.0), indicating a medium to dry soil moisture regime with rooting zone groundwater being absent within the growing season. Aside from the drier areas, the majority of the Greenstone Mountain site consists of a multitude of various species occurring uniformly throughout the site at low abundances. Wheeler's bluegrass (*Poa wheeleri*) and twinflower (*Linnaea borealis*) are also represented throughout the majority of the area indicating moderately dry to fresh sites, however neither species are typical of high abundances (Table 19.0). In all, Greenstone Mountain consisted of 108 different species within the research area.

Table 18.0. Fifteen highest cover rates for Site #3 – Greenstone Mountain

Latin name	Frequency (%)	Cover (%)	Height (cm)
Calamagrostis rubescens	66	17	35
Poa wheeleri	61	10	2
Sheperdia canadensis	29	4	57
Equisetum pratense	8	3	32
Linnaea borealis	81	3	3
Arnica cordifolia	58	2	10
Rhytidiadelphus loreus	29	2	1
Ribes lacustre	39	2	31
Symphoricarpos albus	14	2	40
Aster foliaceus	56	1	12
Equisetum scirpoides	27	1	7
Fragaria virginiana	71	1	10
Orthilia secunda	63	1	5
Osmorhiza chilensis	60	1	16
Peltigera canina	43	1	1

Table 19.0. Fifteen highest frequency rates for Site #3 – Greenstone Mountain

Latin name	Frequency (%)	Cover (%)	Height (cm)
Linnaea borealis	81	3	3
Fragaria virginiana	71	1	10
Calamagrostis rubescens	66	17	35
Orthilia secunda	63	1	5
Poa wheeleri	61	10	2
Osmorhiza chilensis	60	1	16
Arnica cordifolia	58	2	10
Aster foliaceus	56	1	12
Rosa asicularis	52	1	28
Peltigera canina	43	1	1
Thalictrum occidentale	42	1	20

Aulacomnium palustre	39	0	1
Ribes lacustre	39	2	31
Senecio pseudaureus	39	1	11
Lilium columbianum	38	0	18

Soil Bulk Density

Soil bulk densities of the site were categorized into; 1) mostly mineral, 2) mostly organic and 3) mineral and organic mix. Assessments determined bulk density to range from 0.174 g/cm^3 to 1.178 g/cm^3.

4.1.4 Site #4 - Chartrand Lake

Overstory Stand Characteristics

The overstory of Chartrand Lake site is more indicative of areas that might be found within the MS zone. This is primarily due to the site occurring in wetter depressional areas and thus resulting in a higher component of spruce than may be characteristic of the IDF. The stand consists of a spruce-pine mix at 1471 stems/ha (Photo 11 and Table 20.0). With a basal area of 50 m^2/ha and an average volume of 390 m^3/ha, the average tree size within the sample plots is smaller than any of the other three research sites. This is primarily due to plots 1 and 2 having total stems/ha of 3200 and 2200, respectively. While basal area of these plots is similar to others within the area, overall volume per tree is therefore reduced beyond that of the other research plots. Average age and canopy cover for the Chartrand Lake site are 106 and 93%, respectively.

Photo 11. Site #3 – Chartrand Lake general over prior to harvest treatments.

Table 20.0. Average Pre-harvest Stand Characteristics of Site #4 – Chartrand Lake

Crown closure (%)	Basal Area (m^2/ha)	Volume (m^3/ha)	Age (yrs)	Species Composition	Total Stems/ha
93	50	389	106	$Sx_{73}Pl_{27}$	1471

Vegetation Characteristics

Prickly rose is the most commonly found species within the area (Table 21.0) while pinegrass (Table 22.0) is the most abundant within the entire site. Both species are characteristic of the IDF zone. Common horsetail is also a predominant species throughout the site in depressional areas, further indicating a wetter soil moisture regime (Photo12). In all, the Chartrand Lake site is characteristic of having a high species variety that mostly occurs at low abundances. Species variety was 113 different species throughout the research area. Species of the area occur in abundances no higher than six percent, indicating a uniform and homogenous site in which there are no true dominating species.

Table 21.0. Fifteen highest frequency rates for Site #4 – Chartrand Lake

Latin Name	Frequency (%)	Cover (%)	Height (cm)
Rosa asicularis	74	1	28
Cornus canadensis	69	2	9
Mitella nuda	67	1	2
Equisetum arvense	64	5	35
Petasites frigidus var. palmatus	59	1	13
Aster foliaceus	57	2	19
Fragaria virginiana	54	1	10
Rubus pubescens	54	1	10
Linnaea borealis	52	1	3
Equisetum scirpoides	49	1	8
Pleurozium schreberi	49	5	2
Calamagrostis rubescens	46	6	41
Epilobium angustifolium	45	0	34
Orthilia secunda	45	0	5
Osmorhiza chilensis	40	0	17

Table 21.0. Fifteen highest cover rates for Site #4 – Chartrand Lake

Latin Name	Frequency (%)	Cover (%)	Height (cm)
Calamagrostis rubescens	46	6	41
Carex disperma	37	5	24
Equisetum arvense	64	5	35
Pleurozium schreberi	49	5	2

Aster foliaceus	57	2	19
Cornus canadensis	69	2	9
Scenecio canus	12	2	67
Alnus incana ssp. tenuifolia	12	1	71
Equisetum scirpoides	49	1	8
Fragaria virginiana	54	1	10
Linnaea borealis	52	1	3
Lonicera involucrata	30	1	49
Mitella nuda	67	1	2
Petasites frigidus var. palmatus	59	1	13
Plagiomnium medium	27	1	2

Photo 12. Site #4 – Chartrand Lake understory dominated by *Equisetum* (horsetail).

Soil Bulk Density

Soil bulk densities of the site were categorized into; 1) mostly mineral, 2) mostly organic and 3) mineral and organic mix. Assessments determined bulk density to range from 0.097 g/cm^3 to 1.255 g/cm^3.

4.2 Post-harvest Vegetation and Soil Assessments

4.2.1 Site #1 – Heller Creek

Understory Vegetation Characteristics

Species composition did not change significantly one year following the harvest treatments (Tables 22.0 and 23.0). Trapper's tea (*Ledum glandulosum*), along with *Vaccinium scoparium*, *Cornus Canadensis and Fragaria virginiana*, maintained a relatively high frequency - > 85% (Table 23.0). However, percent vegetation cover declined in all harvest treatments following one year of post-harvest (Table 22.0 and Photo13). Percent cover of Trapper's tea declined significantly on all harvesting treatments and ranged from 11 – 25% reduction in cover (Figure 5.0).

Table 22.0. Site #1 – Heller Creek listing of the top fifteen species by percent cover, frequency and height. Species are listed in descending order based on percent cover.

Latin Name	Frequency (%)		Cover (%)		Height (cm)	
	Pre	Post	Pre	Post	Pre	Post
Ledum glandulosum	88	85	24	8	51	37
Pleurozium schreberi	75	69	12	4	3	2
Vaccinium scoparium	97	88	8	2	10	7
Dicranum scoparium	87	46	6	1	2	1
Abies lasiocarpa	70	49	5	2	59	55
Cornus canadensis	93	88	5	1	6	5
Valeriana sitchensis	87	90	5	2	20	14
Calamagrostis rubescens	75	14	4	1	35	43
Linnaea borealis	71	54	3	1	2	2
Elymus glaucus	24	11	2	0	50	72
Festuca occidentalis	46	62	2	1	17	14
Fragaria virginiana	90	89	2	1	9	9
Hylocomium splendens	15	15	2	1	3	2
Lonicera involucrata	75	60	2	1	41	36
Lupinus arcticus	67	69	2	1	27	22

Table 23.0. Site #1 – Heller Creek listing of the top fifteen species by frequency, percent cover, and height. Species are listed in descending order based on frequency.

Latin Name	Frequency (%)		Cover (%)		Height (cm)	
	Pre	Post	Pre	Post	Pre	Post
Vaccinium scoparium	97	88	8	2	10	7
Cornus canadensis	93	88	5	1	6	5
Fragaria virginiana	90	89	2	1	9	9
Ledum glandulosum	88	85	24	8	51	37
Dicranum scoparium	87	46	6	1	2	1
Valeriana sitchensis	87	90	5	2	20	14
Calamagrostis rubescens	75	14	4	1	35	43
Lonicera involucrata	75	60	2	1	41	36
Pleurozium schreberi	75	69	12	4	3	2
Linnaea borealis	71	54	3	1	2	2
Abies lasiocarpa	70	49	5	2	59	55
Petasites frigidus var. palmatus	70	70	1	1	12	8
Lupinus arcticus	67	69	2	1	27	22
Senecio pseudaureus	67	65	1	1	12	11
Epilobium angustifolium	64	78	1	1	38	28

Photo 13. Site #1 - Heller Creek understory following harvesting treatments. The percent cover of *Ledum glandulosum* (Trapper's tea) was significantly reduced following harvesting within all harvesting treatments.

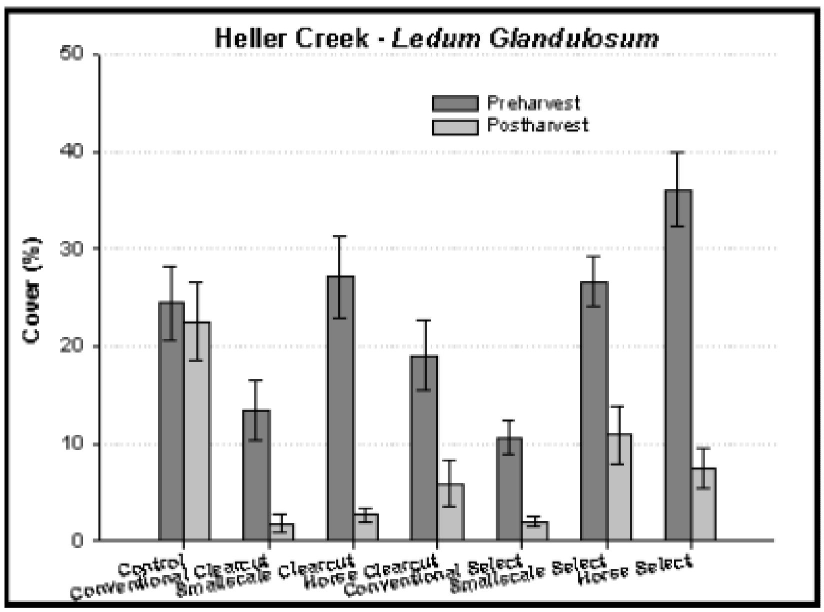


Figure 5.0. Site #1 – Heller Creek percent cover changes of Ledum glandulosum (Trapper's tea) following one year of harvesting treatments within the Heller Creek site. Error bars represent one standard deviation.

Soil Bulk Density

Figure 6.0 shows the mean bulk density between treatments prior to harvesting and one year post-harvest. No significant differences were measured between most of the pre- and post- harvest, however, there was a significant increase (albeit small) in soil bulk density within the 100% removal treatments.

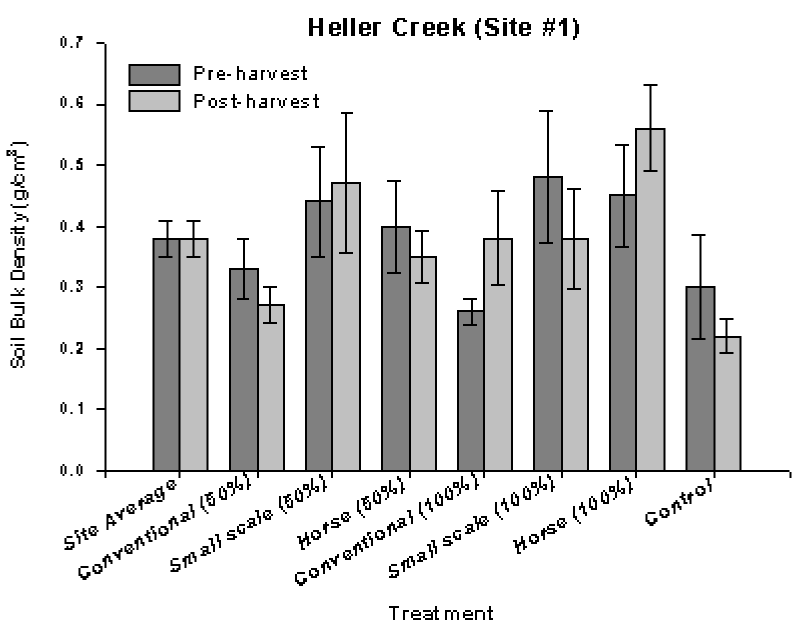


Figure 6.0. Soil bulk density (g/cm3) pre- and post harvesting within each of the 7 treatments and control on the Heller Creek site. Error bars represent one standard deviation.

4.2.2 Site #2 – Tunkwa Lake

Understory Vegetation Characteristics

Post-harvest vegetation decline was most evident with *Equisetum* species. In most cases, all harvesting methods resulted in a 20 – 25% reduction in percent cover of *Equistem arvense* and *E. pratense*. (Figure 7.0 and Photo 14). However, there was little change in % cover for *Carex disperma*, *Rubus pubescens* (Table 24.0), *Mitella nuda*, *Fragaria virginiana*, *Aster foliaceus* and *Plagiomnium medium* (Table 25.0). These species represented less than 7% in both the pre- and post-treatment sites.

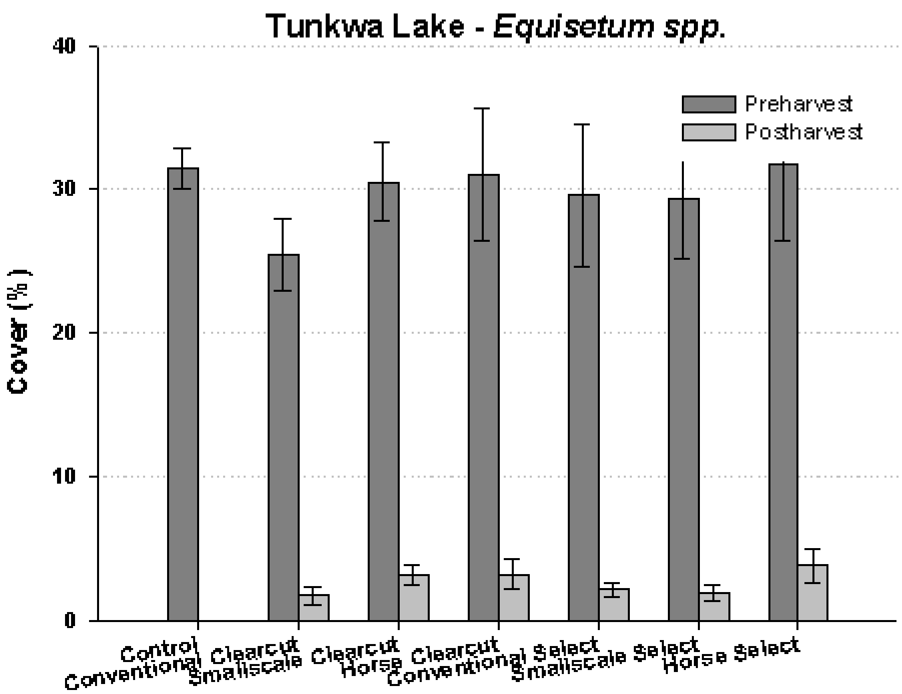

Tunkwa Lake - *Equisetum spp.*
40
30
20
10
0
Cover (%)
Preharvest
Postharvest
Control
Conventional Clearcut
Smallscale Clearcut
Horse Clearcut
Conventional Select
Smallscale Select
Horse Select

Figure 7.0. Site #2 – Tunkwa Lake percent cover of Equisetum species pre- and one-year post-harvesting. Error bars represent one standard deviation.

Photo 14. Site #2 – Tunkwa Lake understory characteristics following harvesting.

Table 24.0. Fifteen highest cover rates for Site #2 (2003) – Tunkwa Lake

Latin Name	**Frequency (%)**		**Cover (%)**		**Height (cm)**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Equisetum arvense	59	50	16	2	30	24
Equisetum pratense	73	69	15	1	40	29
Calamagrostis rubescens	48	37	7	2	49	33
Hylocomium splendens	24	11	4	0	2	2
Linnaea borealis	60	51	4	1	3	2
Muhlenbergia cuspidata	47	-	4	-	2	-
Rosa acicularis	70	76	4	1	43	31
Carex disperma	18	47	3	3	25	20
Oryzopsis asperifolia	22	-	3	-	24	-
Pleurozium schreberi	35	27	3	2	3	2

Aulacomnium palustre	21	1	2	0	2	2
Cornus canadensis	59	60	2	1	10	8
Lonicera involucrata	42	46	2	1	53	38
Rubus pubescens	45	67	2	2	33	12
Sphagnum squarrosum	8	8	2	0	2	1

Table 25.0. Fifteen highest frequency rates for Site #2 (2003) – Tunkwa Lake

Latin Name	Frequency (%)		Cover (%)		Height (cm)	
	Pre	Post	Pre	Post	Pre	Post
Mitella nuda	81	69	1	1	4	2
Equisetum pratense	73	69	15	1	40	29
Rosa acicularis	70	76	4	1	43	31
Fragaria virginiana	61	58	1	1	11	8
Linnaea borealis	60	51	4	1	3	2
Cornus canadensis	59	60	2	1	10	8
Equisetum arvense	59	50	16	2	30	24
Calamagrostis rubescens	48	37	7	2	49	33
Muhlenbergia cuspidata	47	-	4	-	2	-
Aster foliaceus	45	55	1	1	13	14
Rubus pubescens	45	67	2	2	33	12
Lonicera involucrata	42	46	2	1	53	38
Peltigera canina	38	11	1	0	2	1
Pleurozium schreberi	35	27	3	2	3	2
Plagiomnium medium	33	36	1	1	2	2

Soil Bulk Density

Soil bulk density did not significantly change following the harvest treatments (Figure 8.0). Post- harvesting soil bulk density ranged from 0.220 – 0.670 g/cm^3 and was within the pre-treatment range (0.088 – 0.990 g/cm^3).

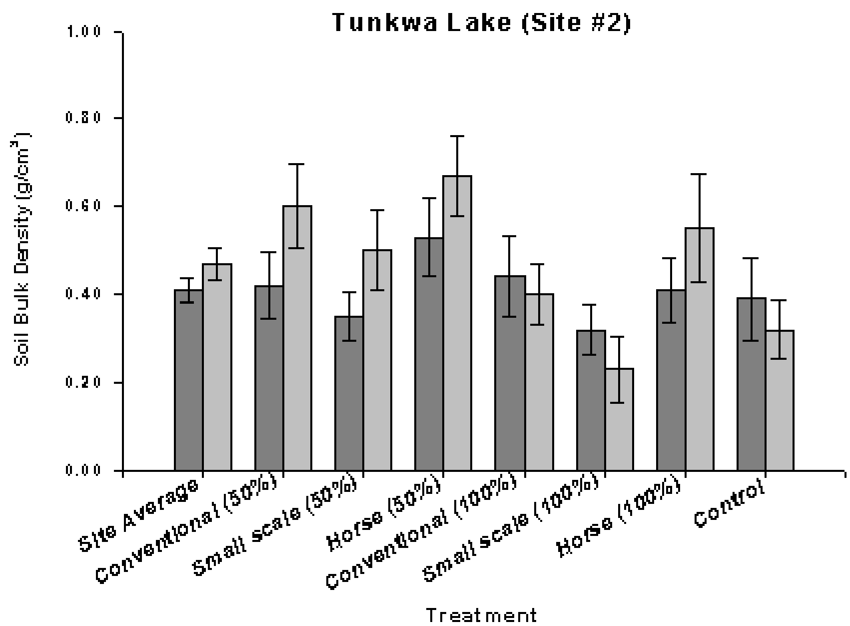


Figure 8.0. Site #2 – Tunkwa Lake soil bulk density.

4.3 Socioeconomic Impact Assessment

A socio-economic analysis was conducted to determine the economic feasibility of alternative harvesting practices and the overall impact that harvesting practices may have on local employment and income. The analysis included an evaluation of harvesting operations for harvesting productivity, costs and operational suitability of using low impact systems as an alternative to conventional harvesting in riparian areas. Data for this assessment was gathered and analysed from the records of the participating contractors and the Skeetchestn Indian Band on a per job basis and studies conducted by Forest Engineering Research Institute of Canada (FERIC).

The total logging costs were lowest for conventional machinery at \$15.42/m^3. Logging costs for horse logging and small-scale machinery were higher than conventional logging costs by 160% (\$24.57) and 247% (\$38.03), respectively (See Table 26.0). These logging costs are representative of costs reported in the literature, horse logging \$17.00 to \$24.29 (Hamilton 1998, Thibodeau et. al 1996) and conventional \$13.15 to \$17.21 (Thibodeau et. al 1996, Gillies 2002). It should be noted that these logging costs include ownership costs that are based on the volume harvested. Increases in volume harvested over the life span of machinery can greatly effect the \$/m^3 cost of ownership.

The majority of logging costs for conventional harvesting were ownership costs at \$7.30/m^3, which amounted to 47% of total logging costs. Ownership costs for small-scale and horse logging were \$1.85/m^3 and \$.70/m^3, respectively. The majority of ownership costs are generally transferred out of the immediate community in terms of purchase price, interest on loans and insurance. With small-scale and horse logging over 95% of logging costs are retained within the local economy.

Table 26.0. Summary of Labour and Harvesting Activity Costs.

	Conventional	Small-scale	Horse
Site Characteristics			
Volume Harvested (m^3)	1682	1220	1104
Area Harvested (ha)	14.0	11.8	8.1
Volume/ha	120	103	136
Man hours contributed			
Felling	0.03	0.15	0.23
Skidding	0.03	0.14	0.32
Processing	0.05	0.74	0.32
Forwarding	-	0.21	0.11
Loading	0.03	0.02	0.02
Logging Supervision	0.08	0.01	0.11
Maintenance	0.09	0.01	-
Total man hours (m^3)	**0.15**	**1.36**	**1.11**
Wages Paid	$4.41	$26.41	$19.35
Benefits Paid	$0.88	$5.03	$2.32
Total Labour Costs (m^3)	**$5.29**	**$31.45**	**$21.67**

Maintenance Costs			
Felling	$0.63	$0.42	$0.66
Skidding	$0.39	$2.13	$0.17
Processing	$0.95	$2.10	$0.90
Loading	$0.29	-	$0.39
Total maintenance costs	**$2.26**	**$4.64**	**$2.11**
Ownership Costs [a]	**$7.30** [b]	**$1.85** [c]	**$0.70** [d]
Low bedding costs	**$0.57**	**$0.09**	**$0.09**
Total Logging Costs	**$15.42**	**$38.03**	**$24.57**
Wages as percentage of costs	**34%**	**82%**	**88%**
Wages as percentage of contract price	**32%**	**66%**	**67%**
m^3/Man hour	**6.53**	**0.73**	**0.90**
Average wage/hr	**$34.54**	**$23.09**	**$19.58**

[a] Costs were determined using FERIC's Standard costing methodology for determining machine ownership costs for new machines converted from a per hour basis to a per m^3 basis on actual volume harvested for each trial.

[b] Based on machine costs of John Deere 748G skidder (Gillies 2002), average of Timberjack 850 and TigerCat 845 Feller-buncher (Kosicki 2000), average of Denharco DM 3500 processor on Komatsu PC 200 carrier and Lim-mit 2000 processor on John Deere 690E-DL carrier (Kosicki 2000).

[c] Based on machine costs and expected life of machine from TDB Consulting Ltd, January 2005.

[d] Based on costing assumptions for horse logging operations (Thibodeau *et. al* 1996)

Labour costs for small-scale and horse logging accounted for at least 82% of all logging costs, while only 34% of total costs were attributed to labour under conventional harvesting. Increased employment in greater labour intensive harvesting activities contributes to the local area through job creation, local spending, and income taxes. An analysis conducted by Cirque Resource Associates Ltd. (2002), determined that provincial revenues of horse logging generate $2.90/$m^3$ in direct and indirect employment taxes, compared to $0.63/$m^3$ for conventional harvesting. However, it should be noted that although Federal revenue from direct and indirect employment income tax was significantly higher ($4.62/m3) provincial revenues through stumpage and rent are 39% lower for horse logging than conventional harvesting.

5 DISCUSSION

Forest practices throughout the world, and particular in British Columbia, have changed significantly over the last two decades, mainly due to public pressure. Forest mangers have been asked, and in some cases legislated (e.g. the Forest Practices Code/Results Based Forest and Range Practices of British Columbia), to re-evaluate present forest practices and to propose new and innovative silvicultural systems that best meet society's concerns about past forest practices, specifically alternatives to large clearcut harvesting of forest stands.

Up until recently, the majority of forests in British Columbia were harvested using the clearcut method; a system that removes most if not all of the merchantable timber from a site (during one period) leaving an area devoid of standing trees. This method has been viewed as the most economical way of harvesting trees and the most effective system for regenerating a new crop of trees. In most ecosystems this has been an efficient and economical method of harvesting and ensuring efficient regeneration (specifically via planting). Alternatives to the clearcut system have also been used in British Columbia, especially in parts of the southern interior. These alternative systems have included; single-tree selection, which results in uneven aged stands; group-selection, which creates a series of small openings in a forest stand (this allows several trees in a group to reach maturity at the same time); and, strip-selection, a method of harvesting trees along long, narrow strips. Other methods that are also utilized are shelterwood systems which maintain a portion of the existing stand during the seedling establishment stage.

Within each of the above silvicultural systems the objective is to extract timber while still maintaining some of the structural characteristics and ecological attributes of the pre-disturbed (harvested) forest. This approach may be the most effective method for managing forested ecosystems within riparian areas, specifically around S6 and S5 streams. Keppeler and Ziemer (1990) conducted research in California indicating that selective harvesting can help maintain summer and annual streamflow levels and mitigate low summer flow indicative of clearcut response. Research conducted in Oregon by Hicks et al. (1991) also indicate that patch cutting can regulate stream flow at preharvest levels. As well, the use of smaller low impact equipment may allow forest managers to economically extract timber from these areas while at the same time maintaining ecological integrity.

Preliminary results have shown that understory vegetation cover is significantly reduced regardless of the harvesting treatments used or site location. However long-term monitoring is needed to determine whether any of the post-harvest treatments will recover to pre-treatment levels. Unlike the understory vegetation, soil bulk density was not significantly changed as a result of the harvesting treatments and can be attributed to harvesting over snow cover and frozen ground. All sites, including Greenstone and Chartrand, were harvested during the winter period when all sites were covered with a significant level of snow (greater than 30 cm). The snow cover, along with freezing temperatures, provided a protective layer which significantly reduced soil compaction from both the conventional and small-scale harvesting equipment. As well, the snow cover provide a stable base for horse logging allowing the horses and the teamster a safe working environment.

Our study has established permanent research/monitoring plots within four sites located within the Skeechestn Indian Band Traditional Area/West Fraser TSA/Weyerhaeuser TSA. The establishment of these permanent research plots create an opportunity for the Skeetchestn Indian Band and partners such as UCC to pursue further monitoring which will better identify long term trends. In order to obtain accurate trends overtime, monitoring of these research plots must continue for minimum for three to five years. The continuation of this riparian zone management study and monitoring of the established plots will further enhance benefits associated with this study.

5.1 Socio-Economic Analysis

Extenuating circumstances arose for small-scale and horse logging activities that appear to have inflated the total logging costs. Lack of easy access to anything but conventional harvesting equipment also added another constraint. Small scale equipment was very hard to locate and access and choices were very limited. Both crew and equipment had to be brought in from Prince George thus adding significantly to the costs for small scale harvesting treatments. In this study the piece size (m^3/stem) was not assessed, however, according to observations the piece size of the study areas logged drastically reduced productivity. The affect of piece size on productivity was examined by Hamilton (1998), who determined that piece size ranging from 0.26 to 0.34 m^3/stem affected overall productivity, with largest piece size contributing to highest productivity. Holtzscher and Lanford (1997) also determined that as diameter of harvested trees increases manual and mechanical felling and processing becomes more productive. Larger piece size has also been shown to contribute to a decrease in cost per m^3.

In the case of small-scale harvesting, additional decreases in productivity were also experienced due to the harvesting of timber below specified log diameter limits that could not be accounted for in harvested volumes. This harvested amount could not be separated from total logging costs. Other factors affecting productivity are noted by Bolgiano (2001) as horse logging productivity can vary considerably due to differences in slope, terrain and tree size and can range from 4.72-14.16 m^3/day. According to Hamilton

(1998), studies within New Brunswick determined average productivity of horse logging teams (one horse, one teamster) to be between 3.0 and 3.7 m^3 per hour. However, this study was based on skidding distances of only 30 meters.

All conventional logging in this study took place over frozen ground, however due to the increased length of harvesting time for small-scale and horse logging, these activities carried through into periods of unfrozen ground (break-up). The weather, as well as differences among skidding distance, slope and crew experience will also impact productivity (Hamilton, 1998; Renzie and Han 2002). These authors also concluded that logging costs are less influenced by silvicultural treatments than they are from tree and terrain characteristics (Renzie and Han 2002).

Other factors that affect productivity but were not evaluated in this study are costs for planning and layout. According to Renzie and Han (2002), costs for planning and layout for clearcuts, group selection (30% retention) and group retention (70%) treatments were \$0.45/m3, \$1.16/m3 and \$1.73/m3, respectively. This equated to an overall increase of 250% for 30% retention treatment and 380% for 70% retention treatment over clear cutting costs.

Research into the productivity and costs in varying harvesting methods and silvicultural treatments are not comprehensive and individual studies reviewed had particulars that could not directly be applied or compared with the productivity findings of this study. However, these studies are important as individual components can act as a comparison and provide valuable information indicating socio-economic feasibility (see Table 27.0).

Table 27.0. Literature Research on Productivity Findings in British Columbia

	Mitchell (2000)	**Renie and Han (2002)**			**Phillips (1996)**	**Thibodeau *et. al* (1996)**		
Prescription	**Clearcut**	**Group Selection**	**Group Retention**	**Clearcut**	**Clearcut**	**Clearcut**	**Clearcut**	**Selection cut**
Layout (m^3)	-	\$1.73	\$1.16	\$0.45	-	\$0.71	\$0.61	\$4.66
Falling (m^3)	\$2.65 (1.81-3.44) Manual	\$3.42 Manual	\$3.21 Manual	\$2.52 Manual	\$3.74	\$2.84	\$4.11 Manual	\$9.71 Manual

Processing (m^3)	-	$1.08 Manual	$1.05 Manual	$1.21 Manual	-	-	-	-
Skidding (m^3)	$5.32 (3.79-6.98)	$5.00	$3.53	$5.46 Tired	$3.45 Tracked	$2.30	$4.88 Line	$14.58 Horses
Total (m^3)	**$7.97**	**$11.23**	**$8.95**	**$9.64**	**$7.19**	**$5.85**	**$9.60**	**$28.95**

Due to the high variability between silviculture treatments, Cirque Resource Associates Ltd. (2002) conducted a comparative cost analysis of the three silvicultural treatments of the Date Creek Study (1996). They developed coefficients that would compare three different logging systems and prescriptions; mechanical felling/skidding clearcut, hand falling/mechanical forwarding selective prescription and a selective tree prescription involving hand falling and horse skidding. All three treatments consisted of a hypothetical harvest of 6354 m^3 from a 20.6 ha site.

Results of this analysis determined that costs for mechanical felling/skidding was $12.66/$m^3$. Harvesting costs for hand falling/mechanical forwarding selective prescription and hand falling/horse skidding selective prescription were determined to be $22.76/$m^3$ and $28.70/$m^3$, respectively. However, these costs only include the activities of falling, skidding and loading.

A comparison of the findings from this Skeetchestn socio-economic analysis and Cirque Resource Associates Ltd (2002) is shown in Table 28.0.

Table 28.0. Comparison of Harvesting Costs

	Conventional	**Small-scale/Mechanical**	**Horse**
Skeetchestn	$15.42	$38.14	$24.68
Cirque Resource	$12.66	$22.76	$28.70
Cost Difference	$2.76	$15.38	($4.02)

One major contributing factor of the cost differences is that harvesting costs of this Skeetchestn project includes ownership costs and it is unclear to what extent ownership costs were considered in the Cirque Associates/Date Creek study. The large cost difference between the small-scale/mechanical treatment of both projects may be due to variability between machine size used for skidding and other extenuating circumstances as previously discussed.

It was important to consider ownership costs (purchase, financing and maintenance) for the purposes of this study and how they impacts overall harvesting costs. The proportion of costs above ownership costs indicate the amounts available for wages and income that are retained in the community. For example, horse logging ownership costs are only 2.8%, while ownership costs for conventional harvesting are 47.3% of total harvesting costs. The majority of these ownership costs leave the community and are therefore contributing little to economic development within the area.

Results indicate that horse logging can generate 7.4 jobs for every job created through conventional logging. Results form this study suggest that small-scale logging can create up to 9 jobs for each job created through conventional logging. However, this number does not take into account the additional costs incurred, as previously discussed, and therefore, the number of jobs created for small-scale logging would fall between conventional and horse logging.

The benefits of increased employment and revenues through small-scale and horse logging can provide rural communities such as the Skeetchestn Indian Band with a means to rectify high unemployment rates and seasonality of employment opportunities. These alternative harvesting activities can provide the Skeetchestn Indian Band and other small rural communities with the ability to shift attitudes towards sustainable economic development. Benefits of these alternative harvesting practices can also help maintain and promote ecosystem functionality and stewardship. With harvesting techniques that deviate from industry standards for clear cutting, local communities are insured forestry resources are available for future generations while maintaining other traditional non timber forest products.

5.2 Literature Review Findings

Riparian Ecology

1. Riparian areas make up only 10% of the land base within British Columbia (MOF 1998b) but are considered the most important aspect of forested ecosystems due to their ability to produce the highest diversity of plant life and attract the greatest number of wildlife species (Cockle and Richardson 2003, Gyug 2000, Haag and Dickinson 2000, Whitaker and Montevecchi 1999).

2. Riparian areas maintain part if not all the life stages of approximately 55%-75% of British Columbia's rare, threatened or endangered species (Richardson 2000, Bunnell *et al.* 1999, MOF 1998b).

3. In British Columbia there are 51 vertebrates that are obligatory and 157 opportunistic users of riparian areas (MWALP 2000a).

Riparian Management

4. Under the current code, S4-S6 streams require only a riparian management zone and not a riparian reserve zone that is required for those streams of S1-S3 classification.

5. Only 39% of harvested S6 streams have the recommended amount of vegetation within the riparian management area (Forest Practices Board 1998).

6. The Department of Fisheries and Oceans (DFO) shows concern over the fact that non-fish bearing streams are receiving little or no protection under the FPC and that current forest practices within S4-S6 streams may be contributing to the harmful alteration and disturbance of fish habitat.

7. Spatial analysis suggests that if buffer strips of one tree height were required on all perennial streams, 30% of the land base in British Columbia would be excluded from timber supply (Burton 1998) and it is for this reason that small streams are exempt from protection. However, Skeetchestn Indian Band conducted a spatial analysis and reported that placing of a 100 meter buffer in all streams and lakes in their traditional territory only effected 20.67% of the land base (IWS, 2002).

8. According to scientific community, appropriate buffer widths should be based on several variables, including; existing wetland functions and values, sensitivity to disturbance, buffer characteristics, land use impacts, and desired buffer functions (Castelle *et al.* 1992).

9. According to Belt and O'Laughlin (1994), the appropriate buffer strip width will change from site to site based on infiltration rates and slope and suggests that buffer strips are more efficient at controlling overland sediment flows than channelized flows (Table 29.0).

Table 29.0. Appropriate buffer strip widths.

Riparian habitat function	**Range of reported widths (m)**	**Average of reported widths (m)**
Temperature control	11-46	27
Large woody Debris (LWD)	30-61	45
Sediment filtration	8-91	42
Pollution filtration	4-183	24
Erosion control	30-38	34
Microclimate maintenance	61-160	126
Wildlife habitat	8-300	88

10. Huryn (2000), suggests that based on a review of literature, buffer widths should be >30 m to protect the community dynamics of insects within small headwater streams.

11. Research is now looking at the effects of partial cutting as opposed to buffer strips within riparian areas to determine what protection this system can provide. While any cutting within riparian areas will alter communities beyond their natural parameters, partial cutting treatments provide greater protection than small headwater streams currently receive.

12. According to Chatwin *et al.* (2001) partial retention has implications as a forestry management practice within riparian areas. It was determined that partial retention had the highest proportion of concerns regarding stream channel stability, windthrow incidence and loss of stream shading. Clear cutting appeared to be a sufficient management practice in regards stream channel stability, and windthrow but appeared to promote high shade loss.

Vegetation

13. Removing vegetation from the riparian zone through timber harvesting can cause severe and sometimes indirect effects to the functioning of an ecosystem and cumulative effects many kilometres downstream (Hayes et al. 1996).

14. Riparian areas also contribute large woody debris that provides habitat structure for numerous aquatic organisms while aiding in maintaining stream bank stability (MSRM 2002, Bunnell *et al.* 1995).

15. When clear cutting occurs within riparian areas, modification of vegetation layers can occur. For example, clear cutting generally eliminates the moss layer found on the forest floor and replaces it with increased herbaceous cover (Gyug 2000).

Regeneration of Conifers following Riparian Harvesting

16. Harvesting to stream banks promotes a flourish of fast growing shrubs that usually give way to the growth of hardwood species, conifers are often poorly represented within the overstory of regenerating riparian stands (Beach and Halpern 2001).

17. Due to harvesting practices within the riparian areas of small headwater streams, few riparian areas experience sufficient seed rain for successful conifer regeneration (Beach and Halpern 2001). The method of selection logging can provide increased seed dispersal in immediate or close proximity to riparian areas.

18. Selection harvesting which removes individual trees or groups of trees retains an increased seed bank that is better capable of regenerating harvested areas to conifer stands (Beach and Halpern 2001).

Wildlife

19. Bunnell et al. (1999) suggest that the retention of large living trees, snags, and large woody debris can aid in proper ecosystem functioning while ensuring the characteristics of a mutli-aged management regime.

20. Lemke's (1998) research in the Upper Deadman River area on moose habitat suggests that harvesting should be conducted in a manner to minimize damage to understory vegetation. She also suggests that buffer zones of 300 m be established around all riparian and wetland complexes greater than one hectare, 200m for high forage sites, and riparian /wetland edges should retain 75% of its vegetation.

Birds

21. Hannon *et al.* (2002) suggest that buffer strips may need to be 200m in width to maintain the communities of small passerine bird species. However, they feel that 200m buffer strips are not sufficient to maintain the communities of larger raptor, woodpeckers species or carnivores.

Amphibians

22. Petranka et al. (1993) also suggests that up to 80% of salamanders are lost following clear cutting and that their study indicates that in would take approximately 50-70 years for structure to regain pre-harvest conditions.

Invertebrates

23. Changes though large clearcut harvesting to the edge of stream banks can affect macroinvertebrates through alteration of light levels, sediment input, larval habitat, adult habitat, larval food, summer water temperatures, and inputs of leaf detritus (Huryn 2000).

24. In a five year study conducted by Erman and Mahoney (1983), on streams with and without buffer strips in California, it was determined that narrow buffer strips had higher macroinvertebrate diversity than those streams with no buffer protection. Diversity in unbuffered streams dropped 12.5% following logging and remained at those levels for five years while narrowed buffered streams dropped 25.2% following harvesting but improved to 9.1% after a five year period (Erman and Mahoney 1983).

Water Quality

25. Many studies have shown alterations of streamflow due to various forest harvesting practices such as clear cutting (Hicks et al. 1991, Keppeler and Ziemer 1990). These alterations of streamflow are due to changes in the rate of interception, evaporation and transpiration following the removal of riparian vegetation (Hicks et al. 1991, Keppeler and Ziemer 1990).

26. Literature suggests that increases in stream temperature are predominantly due to the removal of riparian vegetation rather than the harvesting of the surrounding watershed (Mellina et al. 2002, Teti 2000, Teti 1998, Knutson and Naef 1997). It also suggests that buffer strips adjacent to clearcuts can minimize the effects of these stream temperature increases (Belt and O'Laughlin 1994).

27. Literature suggests that stream temperatures increase following the removal of riparian vegetation, however, the time required for a stream to recover to pre-disturbance levels is still under debate. The recovery period of stream temperature increases can be affected by topography, microsite conditions, riparian species and stream morphology (Teti 2000, Teti 1998).

Soils

28. The two most important forms of degradation of forest soils are through compaction and rutting (Sutherland 2003, Grace and Carter 2000). Different sites vary in their ability to resist disturbance based on terrain, slope, climate, hydrology, and soil horizons, texture and depth. When compaction occurs in can increase bulk density, convert macropores to micropores, and reduce the infiltration capacity (Keppeler and Ziemer 1990).

29. While compaction can reduce infiltration rates, scarification of the forest floor through skidding and machine travel can remove surface materials allowing for better infiltration and reduced surface runoff (Grace and Carter 2000).

Large Woody Debris

30. Current legislation that allows clear cutting to the banks of S5 and S6 streams may promote an increase in the amount of LWD entering the system in coastal streams (Millard 2001).

31. Clear cutting is also thought to place LWD and wildlife trees below levels that would naturally be found within ecosystems (Gyug 2002).

6 OTHER ACHIEVED OUTCOMES

6.1 Partnerships

In the preparatory phases of the project, partners were recruited and asked to sign an agreement to assist in the project as follows:

Partner	Responsibilities
Ministry of Forests	Ease the passage of requested plan amendments; provide policy advice and knowledge of process for change.
Treaty Negotiation Office	Funding, assistance in agency coordination
Weyerhaeuser Canada	Assistance in planning and provision of research areas for harvest
West Fraser	Assistance in planning and provision of research areas for harvest
FORREX	Extension of research information and advice on equipment
University College of the Cariboo	Research and data management
Skeetchestn Indian Band	Project guidance
Cirque Resource Associates	Project Management

Roles were accepted and responsibilities carried out completely.

6.2 Training of Staff and Information Management

Skeetchestn Indian Band needed to develop and upgrade their information management system to support this project and the band's Natural Resources Department. In total 12 members from the community received 12 days training in Arcview and GIS. Hardware and software requirements were identified and the band's systems were updated accordingly. These upgrades and training enabled the Natural Resource Department to create all the required overview and treatments maps for the purposes of this project. Field technicians were also trained in forest mensuration and soil sampling techniques, preliminary study design and pre and post harvest vegetation survey and data entry. The Skeetchestn Indian Band provided all the support by conducting Cultural Heritage Overviews and related archaeology work for the four study sites.

6.3 Knowledge Transfer

Knowledge transfer was conducted throughout the duration of this project. Initial objectives, research design and socio-economic methodology was presented to the licensees partners for their comments and review. A community meeting and a visit to the Tunkwa Lake research site was arranged after first and second year of harvesting and pre harvest assessment. The meeting was attended by Ministry of Forests, Ministry of Attorney General and Ministry of Treaty Negotiation, licensee partners, UCC, Skeetchestn's Chief and Council, Natural Resource Department and community members. A final knowledge transfer session will be organized in April 2005 to present final research findings, provide an update on the project and a presentation on the final report. Skeetchestn will also make the report available on their web site and will make it available for peer review.

6.4 Policy Changes

As a result of heightened awareness of Skeetchestn values, the Ministry of Forests inserted new clauses in a recent Forest Licence, awarded within Skeetchestn traditional territory.[1] The clauses recognize the need to manage for wildlife and fisheries habitat, and for maintaining ecosystems for traditional medicine and plants. Restrictions on species removal, and the imposition of a 2 zone reserve system, will protect Class 6 streams and swamp complexes greater than 0.25 hectares in size.

7 NEXT STEPS

1. It is recommended that the post harvest assessments and monitoring continue at a minimum for the next 5 to 10 years to obtain more precise data to evaluate long term post harvest impacts.

2. To further enhance the value of this study, it is suggested that other attributes such as hydrology, vertebrate and invertebrate habitat, microclimate and windthrow be included to evaluate the interrelationships of the riparian ecosystem.

3. To further their business interests, the Skeetchestn Indian Band should further develop their alternative logging activities and develop a business plan for small-scale harvesting. The existence, availability and suitability of other small scale equipment needs to be researched more fully and attempts to encourage its use in suitable sites should be made by all parties involved.

4. Skeetchestn Indian Band is encouraged to continue gathering the socio-economic data to develop a business case for small-scale and alternative logging and to demonstrate benefits of low impact logging in riparian areas. In order for the socio-economic analysis to be representative it should be carried out at an operational scale that is more representative of average cutting volumes and area.

5. Skeetchestn Indian Band should continue to work with Ministry of Forests and licensee partners to include CRMZs in their policy development for the management and harvesting of all riparian areas.

6. In view of the increased harvesting pressures on watersheds due to Mountain Pine Beetle attack, research should be conducted specifically into the effects of beetle harvesting in C.R.M.Z.s. Viable alternatives to present clearcutting silvicultural practices in beetle attacked C.R.M.Z.s should also be explored and encouraged.

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