A STUDY OF

UNEVEN-AGED STAND GROWTH AND DEVELOPMENT

IN RELATION TO

RESIDUAL BASAL AREA DENSITY

UNDER A SPRUCE - SUBALPINE FIR SELECTION SYSTEM

SUMMIT LAKE PROJECT

WORKING PLAN

Silvicultural Systems Research Project SS015

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SUMMARY

Well-documented scientific trials of selection systems are needed in the white spruce-subalpine fir forest types of the Prince George Forest Region, to meet research, demonstration, and integrated resource management objectives. In recent decades, there has been little research into this topic, and no trials have been attempted. Such trials would provide new opportunities for the testing of silvicultural and biological concepts relating to selection (or 'uneven-aged') management. The planning and execution of selection stand entries would also allow the development of local expertise in partial-cutting methods.

Determination of an appropriate level of post-harvest stand basal area density, or *residual basal area,* is a fundamental concept in the silvicultural regulation of stands under selection management. In order to achieve stand management objectives with the selection system, it is necessary to understand and reliably predict the effects of a specific stand entry on long-term stand development and growth. At present, however, the detailed, quantitative data that would be required for this purpose is largely lacking for Northern Interior forest types.

The overall objective of this study, therefore, is to determine the relationship between the long-term growth and development of uneven-aged white spruce-subalpine fir stands and the residual basal area density left after a selection stand entry. Specifically, this study will examine the relationships between residual basal area and post-harvest rates and patterns of:

1) stand volume and basal area growth;

2) diameter and height post-harvest release of various size-classes of spruce and subalpine fir;

3) natural regeneration establishment and species composition;

4) possible mortality and blowdown, and;

5) incidence and long-term effects of logging damage on individual tree growth and quality.

A 70.0-hectare Ministry of Forests Small Business cutblock near Summit Lake, B.C., was identified for a single-tree selection trial. The stand, which was previously diameter-limit logged about 1954, has good access and generally well-drained sandy soils. The immediate surrounding area has high recreational values. The stand is multi-storied, with a relatively open overstory of dominant, 175- to 225-year-old white spruce and scattered Douglas-fir; there is a vigorous, well-developed intermediate layer of 30-to 90-year-old subalpine fir and spruce.

In order to develop a systematic, well-justified selection prescription for the area, long-term stand management objectives were determined. These included:

- Timber management objectives;
- Protection and maintenance of aesthetics, and species and structural diversity, and;
- Scientific research into selection systems.

A total of 30 50mX50m (0.25 ha.) *experimental* units were located within the 70 hectare cutblock area. Three target residual basal area treatments (*10 m2/ha residual, 20 m2/ha. residual*, and an *uncut control)* were prescribed and each of the 3 treatment types were randomly allocated to 10 of the 30 treatment units. Target maximum residual diameters, q-values, and % basal area removal are summarized below:

Target Residual Basal Area (m^2/ha.)	**Maximum Residual Diameter** (cm)	**Mean q-value**	**% Basal Area Removal**
10	40	2.04	71 %
20	45	1.75	42 %
Uncut (35)	50-95	1.77	0 %

One 0.05 ha. (12.6 m radius) growth-and-yield permanent sample plot (PSP) will be established in the center of each experimental unit. These PSP's will be measured and described immediately post-harvest, and at 3, 6, 10, 15, and 20 years after harvest. Four 0.005 ha. (3.99 m radius) regeneration subplots within each PSP will be permanently established and marked to monitor regeneration release or establishment.

Based on the broad stand management objectives, short-term (post-harvest) residual stand goals were developed. For *non-experimental* areas of the block, a residual 'B-level' basal area stocking goal of approximately 20 m^2/ha., and cutting cycle of 25 years was recommended (to maintain optimal levels of stand increment). Also, marking guidelines for mark-to-cut removal of individual trees (specifying maximum residual diameter, definition of unacceptably defective trees, and priorities for species retention) were developed. This prescription is designed to improve the overall species composition, quality, and stocking of the residual stand for future stand entries. Both experimental and non-experimental areas of. the stand were marked-to-cut according to these guidelines.

In general, the selection prescription will involve the harvest of many senescent, older overstory trees and defective trees. There will be retention of many of the younger, thrifty subalpine fir and spruce in all canopy layers. Individual trees which are within a diameter-range from 25 cm up to a maximum residual diameter (40 to 45 cm) will be either marked-to-cut or retained, based on the overall basal area goal, and on acceptability criteria such as species, types of defects, live crown ratio, and stem distribution. A target of approximately 50% of the standing volume between 25 and 45 cm dbh will be retained, and 50% cut. All trees greater than the maximum residual diameter of 45 cm will be harvested. All trees less than 25 cm will not be taken for harvest, although a post-harvest sanitation cutting will remove damaged trees.

Partial-cutting operations in this block are expected to remove approximately 150 m^3/ha., 16 m^2/ha., and 203 stems/ha., while approximately 71 m^3/ha., 20.5 m^2/ha. and 1807 stems/ha. will be retained as crop trees for a future stand entry.

Linear regression and graphical analysis techniques will be used initially to derive statistical and predictive relationships between residual stand basal area stocking and the response variables of interest.

This study site will provide several ancillary benefits:

1) • extension and demonstration of operational selection-cutting and uneven-aged stand management;

• operational field testing and implementation of tree-marking procedures;

2) improved scientific understanding of stand growth and development for refinement of future prescriptions, and;

3) protection of local scenic viewscapes.

Keywords: *Basal Area, Residual Basal Area, Selection, Uneven-aged management, White spruce, Subalpine fir, growth and yield*

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1.0 INTRODUCTION

1.1 Single-tree Selection Management in Spruce-Subalpine fir Stands

During the last two decades in northern British Columbia, clearcutting followed by planting has become the most common method of timber-harvesting and forest regeneration. However, interest in partial-cutting techniques and 'alternative' silvicultural systems has increased among both foresters and the general public in recent years. Selection, shelterwood, and seed-tree systems (Smith, 1986) require one or more partial-cutting stand entries over the lifespan of a single stand. The partial cuts are designed to create the kind of stand characteristics (e.g. - amount of natural regeneration, species composition, stand structure) that would meet a pre-specified set of management objectives.

It is desirable to develop a range of partial-cutting methods and silvicultural systems for many northern forest types. Their development would allow regional foresters to consider a greater variety of stand treatment options during the pre-harvest silvicultural prescription (PHSP) process. A wider range of proven silvicultural options would provide more flexibility in the planning of timber-harvesting activities, preparation of regeneration prescriptions, and protection of non-timber forest values.

In the Sub-boreal Spruce (SBS) biogeoclimatic zone of B.C.'s Central Interior, there are some good opportunities for selection (or 'uneven-aged') management of mixed stands of white spruce (*Picea glauca*) and subalpine fir (or 'balsam'; *Abies lasiocarpa* (Hook.) Nutt.). There are, of course, many factors that influence the choice of the most appropriate silvicultural system for any given stand and site. However, the silvical and structural characteristics of many SBS spruce-balsam stands that potentially make them good candidates for selection management are:

- moderate- to high shade-tolerance of both tree species, and demonstrated ability to establish and grow in canopy gaps;
- variable, and often multistoried stand structures which contain a wide range of intermingled diameter and height classes, and;
- relatively open, multilayered canopies, which suggest moderate to high windfirmness of individual leave-trees after partial stand removal.

While broad generalizations are difficult, these characteristics are frequently found in both mature/overmature old-growth stands and diameter-limit 'selectively-logged' stands. Similar stand conditions and partial-cutting opportunities are also found frequently in the higher-elevation Engelmann spruce (*Picea engelmannii*)-subalpine fir (ESSF) zone.

The selection system is a particularly useful silvicultural option in areas such as visually-sensitive highway corridors and recreational viewscapes, wildlife habitats requiring maintenance of mature forest cover, sensitive riparian zones, or sites where extreme climatic conditions inhibit survival and growth of planted stock. In contrast to even-aged plantation regimes, selection management can provide constant canopy coverage on a site, encourage natural regeneration by retaining numerous overhead seed sources, reduce competing vegetation by shading from overstory trees, and ameliorate micro-environmental extremes on harsh sites. Theoretically, this system can provide the opportunity for relatively frequent, periodic harvests of high-quality volume (Alexander, 1987).

It should be emphasized that selection management is NOT equivalent to simplistic diameter-limit selective logging or 'high-grading' which was common in many Interior spruce-balsam forest types between about 1910 and the early 1960's. Unfortunately, many diameter-limit cuts were poorly-planned and regulated. These methods often resulted in irregular, poor-quality stands with a heavy proportion of scarred and damaged subalpine fir advance regeneration and residual hardwoods. Common arguments made against the use of any kind of partial-cutting in spruce-balsam stands (e.g. - that it will result in widespread blowdown, prohibitive logging damage to residuals, and degraded, 'non-productive' stands) are based on observations of such high-graded stands (Weetman *et al*, 1990).

Many silviculturists in the Central Interior recognize that a modified type of selection system is desirable for protection of non-timber values in suitable spruce-balsam stands. At present, however, silviculturists face three basic problems in attempting to prepare well-founded, justifiable prescriptions for selection systems:

1) Because little data is available from *managed* uneven-aged stands in the region, local operational guidelines for selection management are poorly developed at present. Quantitative, field-tested guidelines are needed to prepare reliable selection prescriptions. Basic components of these prescriptions which need to be better understood and quantified under northern B.C. conditions include:

   - optimum post-harvest residual basal area stockings;
   - recommended maximum tree sizes;
   - recommended diameter distributions for specific product objectives;
   - post-harvest volume increment and its distribution among different sizes of trees;
   - expected cutting cycles, and;
   - expected species and amount of regeneration.

   Silvicultural system manuals for forest types in other parts of North America (Anderson et al, 1990; Alexander, 1987; Johnston, 1986) are useful as rough guides, but may prove ureliable if applied untested and *ad hoc* in northern B.C. forest types;

2) There are very few planned and carefully-monitored examples of partial-cutting techniques and uneven-aged management systems in local spruce-balsam forest types.

Currently, new opportunities for research and demonstration of operational selection management are limited. And;

3) The impacts of selection management on stand-level yields are not well understood. There is only limited data on periodic volume growth in uneven-aged stands in the region. Current Ministry of Forests growth and yield estimates for spruce-balsam forest types are based on analyses of homogeneous *even-aged* stands.

Partial-cutting techniques and related silvicultural systems should be customized to the combination of forest types, terrain, soils, climate, and available logging technology in a given area. Carefully planned and evaluated partial-cutting trials are an important part of this process. There is no substitute for direct field testing of operational harvest methods, and for long-term monitoring and evaluation of their biological effects. More such trials are urgently needed.

1.2 Silviculture of Subalpine Fir in Partially-cut Stands

In the SBS zone, fire has historically played a dominant role in the renewal of forest stands; the structure and composition of existing mature stands reflects this influence (Bloomberg, 1950; Kneeshaw, 1991, unpublished data). White or Engelmann spruce, which can establish in abundance on freshly burned or mineral seedbeds, often forms the overstory in mature fire-origin stands. The highly shade-tolerant subalpine fir, however, often tends to establish in the understory later in the development of such stands. As a result, many natural spruce-fir stands possess two-storied or multi-storied stand structures; spruce dominates the overstory, and younger subalpine fir tends to occupy intermediate and understory crown classes.

Past attempts at partial cutting of Interior spruce-balsam types have been widely criticized (e.g. - Stettler, 1958; Monchak, 1982; Smith and Clark, 1974). It is felt that the simplistic diameter-limit removal of all overstory trees in a stand, with no site preparation and reliance upon natural and advance regeneration, will simply accelerate the ecological succession of a stand from spruce to subalpine fir. This is often viewed to be undesirable, because:

- Subalpine fir is presently a less valuable timber tree species than spruce;
- Retention of advance regeneration with little soil disturbance (i.e. - winter logging on snowpack) tends to heavily favor regeneration of subalpine fir;
- Subalpine fir is very prone to stem decay *if* scarred during logging activities;
- Large, old subalpine fir in many overmature stands have a high incidence of defects and decay, and;

- Subalpine fir has gained a reputation (albiet generally anecdotal) of being "less productive" than spruce on any given site.

Few topics in Interior silviculture have initiated more sustained controversy, studies, and discussion than the question of the long-term reliability of subalpine fir as a timber crop species. Major studies and assorted reviews relating to this topic include Griffith (1931), Barnes (1937), Pogue (1946), Bier et al (1948), Hornibrook (1950), Smith (1955), Stettler (1958), Parker and Johnson (1960), Smith and Craig (1968), Herring (1977), Herring and McMinn (1980), Aho (1981), Monchak (1982), Smith and Clark (1974), Bergstrom (1983), Vankka (1983), David (1987), Mather (1987), Laing and McCulloch (1988), Jull (1990b), and Filip and Schmidt (1990).

Most studies, however, have focussed on the growth performance and quality of advance regeneration released and damaged during diameter-limit cuts which have seldom if ever had subsequent sanitation treatments. Only a relatively few studies have collected long-term data on the growth and quality of undamaged subalpine fir residuals (Herring, 1977; Bergstrom, 1983; Coopersmith and Coates, 1987). These studies have shown that well-formed, undamaged advance regeneration of subalpine fir growing on suitable sites (mesic or moister) are capable of rapid relase and vigorous growth after an initial period of post-harvest 'check'. A recent handbook which provides a synthesis of silvicultural options for true fir stands (Filip and Schmidt, 1990) recommends that, to minimize damage caused by stem decay fungi in true firs, it is critical that:

- Cambial scarring and wounding of the tree stem be prevented, and;

- True firs should be managed on short rotations, less than 150 years maximum.

It is explicitly recognized that, in the short-term, selection management of the Summit Lake stand will tend to increase the proportion of subalpine fir in the stand (at least for the next stand entry). Therefore, the prescription for this stand will manage for improved *quality* of subalpine fir advance regeneration through 4 key practices:

1) Harvest cutting of existing defective subalpine fir;

2)) Minimizing damage to residuals during logging through careful planning, skid road layout, and consultation with the logging contractor;

3) Favoring retention of spruce and Douglas-fir (wherever possible) to provide a mix of alternative species in the stand;

4) Sanitation removal of damaged trees during harvest and sanitation spacing of non-merchantable stems after harvest, and;

Long-term monitoring of permanent sample plots will allow assessment and evaluation of the above objectives.

1.3 General Approach

The primary thrust of this study is to improve our understanding of of the biological basis of uneven-aged stand management. The relationship of residual stand density to subsequent long-term growth of trees and stands, changes in stand structure, volume and basal area increment, regeneration abundance and composition, and possible mortality, will be documented and analyzed. This study will aid future prescriptions by improving our ability to predict the nature of these basic stand responses to selection management. A secondary thrust of the Summit Lake selection project is the development and testing of operational methods and guidelines for the planning and implementation of single-tree selection prescriptions in previously logged spruce-balsam stands.

As a trial of the selection system in the SBSmk1 (formerly the SBSe2) subzone, this project will complement and add to the pioneering long-term research on spruce-balsam selection management at the Aleza Lake Research Forest in the adjacent SBSwk1 (formerly SBSj1) subzone.

2.0 SITE SELECTION

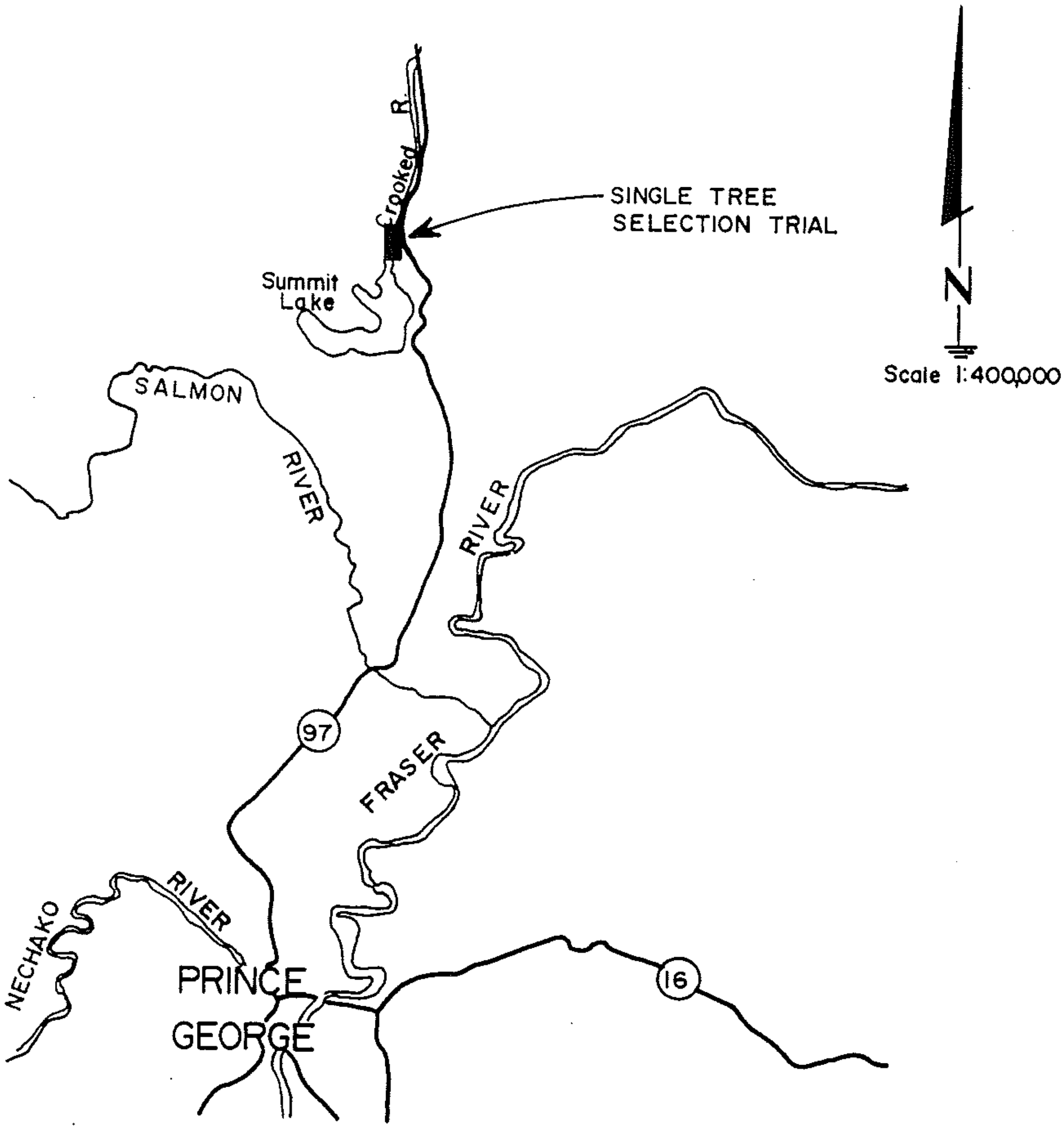
Use of the single-tree selection system is generally appropriate in stands containing species of moderate to high shade-tolerance (Smith, 1986; Klinka and Carter, 1991). Often, if influenced by past natural stand disturbance or partial-cutting, stands of tolerant conifers contain a complex mixture of tree sizes and age-classes. If stand and site conditions are appropriate, selection systems can be directly applied to the existing stand.

Based on the preceding considerations, a Small Business cutblock at the north end of Summit Lake (approx. 55 km north of Pr. George on Hwy. 97) was identified for the single-tree selection trial. The stand is of fire-origin, but has had a subsequent history of 43 cm (17") diameter-limit cutting (circa 1954). The stand has moderate merchantable volume, variable stand structure, and good road access. It is close to a heavily-travelled highway, and there are high recreational values in the immediate surrounding area.

A detailed description of the block's stand and site characteristics, and its silvicultural history, was obtained from:

1) a 1989 operational cruise of the area;

Figure 1: Geographic Location of, and Highway Access to the Summit Lake Single-Tree Selection Trial



2) 1990 mapping of ecological site types on the area;

3) a retrospective study (Jull, 1990a) of post-logging stand characteristics and subsequent stand growth after the 1954 diameter-limit cut, which also included sampling of non-merchantable diameter-classes, and;

4) original 1954 Timber Sale documents from Ministry archives.

The proposed selection block, approximately 55 km north of Prince George on Hwy. 97, is accessed from the Tallus Road, 1 km north of the northern Summit Lake turnoff (Figure 1). The south end of the block is at 3 km on the Caine Creek Forest Road, just east of the Crooked River bridge. The 69.9-hectare block includes Small Business Timber Licenses A28480 and A28481 (Figure 2).

The area is partially visible from the main highway, and is prominent in the immediate foreground from viewpoints on the hiking trail on the 923-meter elevation Teapot Mountain. The block is less than 1 km north of the Summit Lake Forest Service Recreation Site on the Caine Creek Road. The Crooked River bridge just 250 m west of the cutblock is a popular summer fishing spot and canoe launch area.

The site is in the SBSe2 (Fraser Basin Moist Cool Central Sub-boreal Spruce; more recently termed the SBSmk1) biogeoclimatic subzone (DeLong *et al*, 1987), at an elevation of about 700 meters. The terrain consists of low morainal ridges, and the slope of the area ranges from 5 to 30 %. The site is most generally characterized by a mesic (01) association, but there are pockets of drier, submesic (02 and 03) associations on coarse-soiled knolls, and some areas of a subhygric (08) association. Soils are generally well-drained Ferro-humic podzols on coarse, poorly-sorted sandy loam tills; rooting depth on these soils is often 50 cm or more. The limited 08 association, however, has areas of finer-textured silty loam soils with high water-tables in spring, and somewhat more restricted rooting of about 30 cm.

The stand is largely composed of white spruce and subalpine fir, although there are significant pockets of Douglas-fir (Pseudotsuga menziesii) and/or lodgepole pine (Pinus contorta var. contorta). Parts of the study site and some surrounding adjacent areas were partially-cut for large spruce in the mid-1950's. Skid roads from this original stand entry are still evident within the block, both on the ground and from aerial photographs. This selective logging was quite patchy, and a number of much larger trees still remain in some pockets.

Currently, the stand has an average merchantable volume of 216.0 m^3/ha., with a range of 137.0 to 255 m^3/ha. Overall, the composition of white spruce, subalpine fir, Douglas-fir, and lodgepole pine in the stand is 33, 61, 2, and 4% (by stems-per-hectare greater than 17.5 cm), and 54, 38, 4, and 4% by total merchantable volume.

As can be seen from the stand and stock tables presented in Figures 3 and 4, the stand contains a wide range of tree sizes. The 1954 diameter-limit logging in the original stand left a

Figure 2: Location of the Summit Lake Single-Tree Selection Research trial. (Boundaries of Individual Timber Sales are indicated)

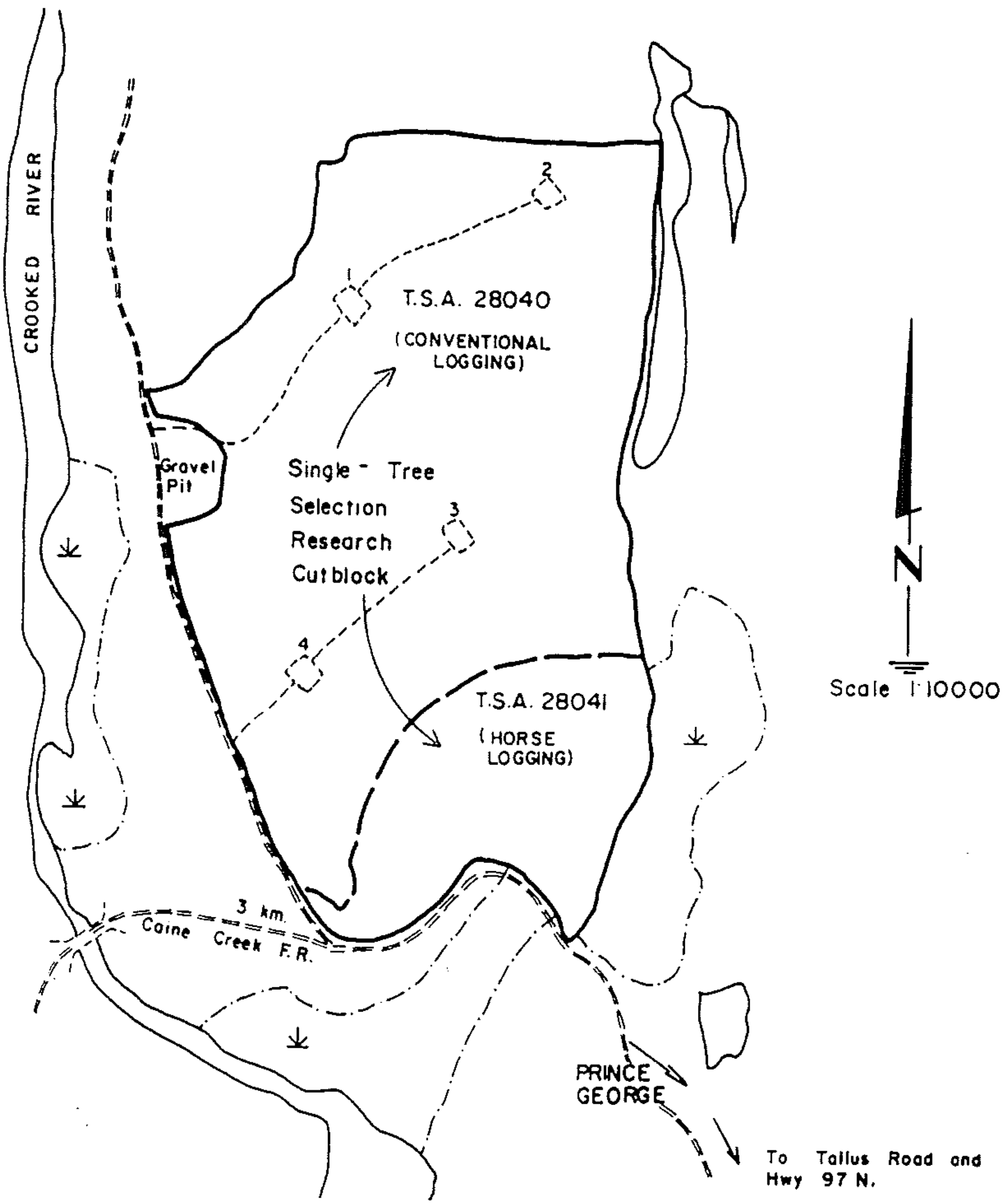


Figure 3 :

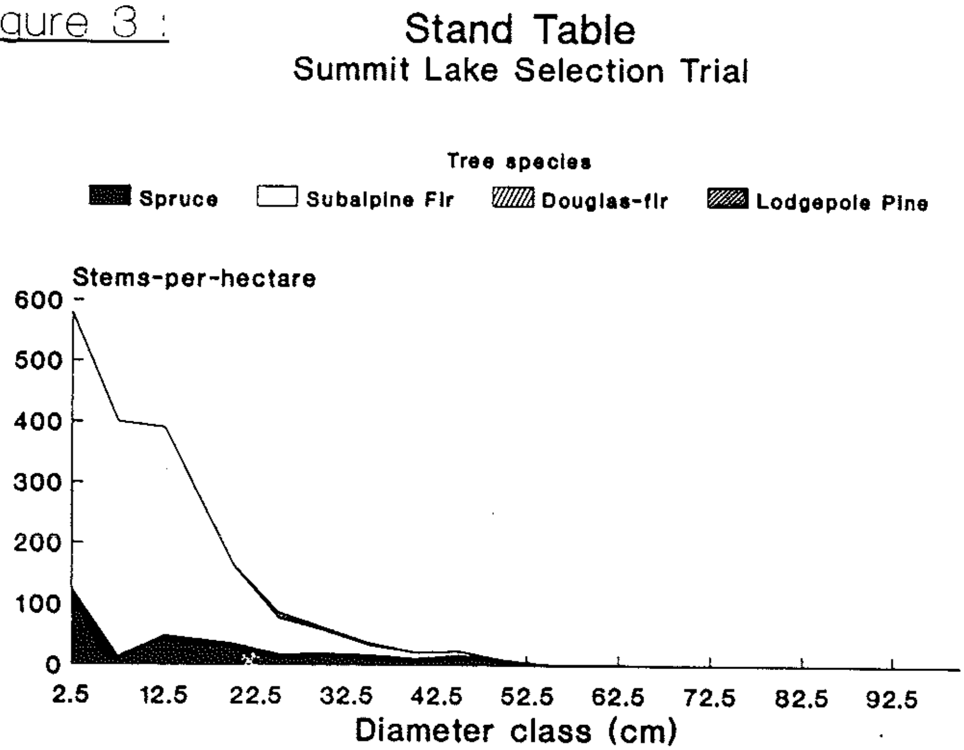
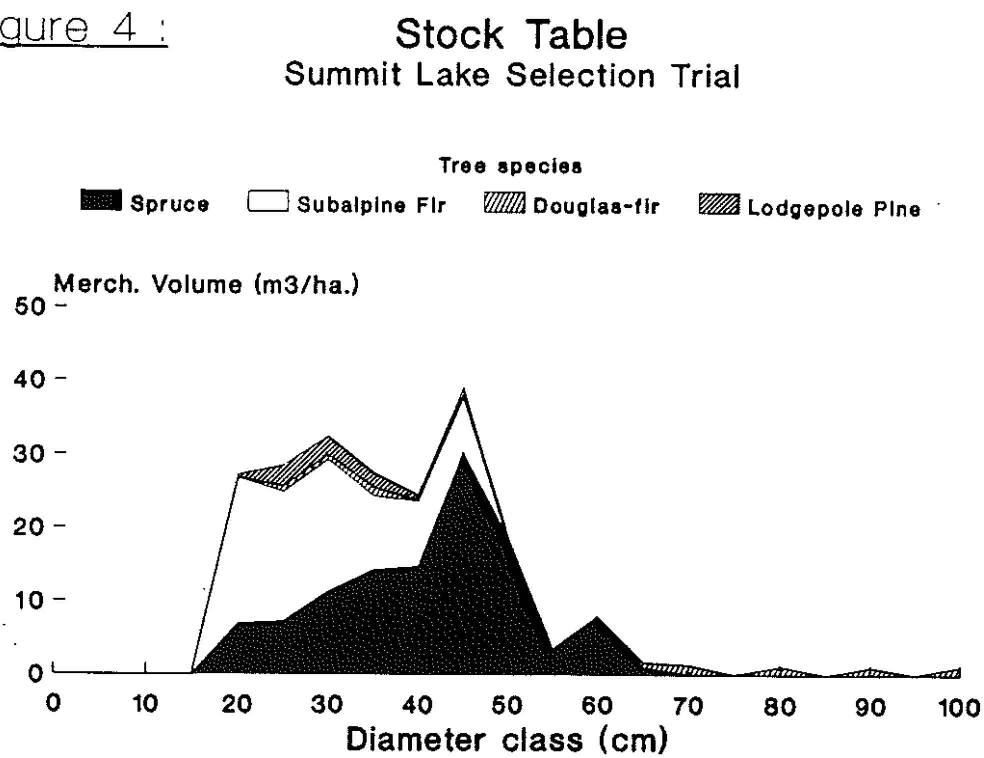


Figure 4 :



relatively open overstory of larger spruce and scattered Douglas-fir, under which a vigorous and abundant intermediate subalpine fir-spruce layer has developed. This initial stand entry apparently released the originally-small subalpine fir advance regeneration and stimulated some new spruce and fir regeneration in the understory. While many of the older, 200- to 250-year-old overstory veterans have only marginal rates of 35-year diameter increment (i.e. - 1 to 4 cm) since the stand entry, many of the smaller (10 to 30 cm) and younger (30 to 90-year-old; average age 70) intermediate trees have had more vigorous rates of increment (4 to 16 cm, depending on the degree of release). The stand now appears to be ready for the harvest of some overstory trees, and for the sanitation release and spacing of younger, more vigorous trees (Jull, 1990a).

3.0 OBJECTIVES

The overall objective of the study is to examine differences in long-term patterns of uneven-aged stand development and growth patterns over a wide range of possible residual basal area densities. Specifically, this study will examine the influence of residual basal area on post-harvest rates and patterns of:

1) stand volume and basal area growth;

2) diameter and height release of spruce and subalpine fir in all canopy layers;

3) natural regeneration establishment and species composition;

4) possible mortality and blowdown, and;

5) incidence and long-term effects of logging damage on individual tree growth and quality.

This study site will provide three ancillary benefits:

1) • extension and demonstration of operational selection-cutting and uneven-aged management;

   • operational field testing and implementation of tree-marking procedures;

2) improved scientific understanding of stand growth and development for refinement of future prescriptions, and;

3) protection of local scenic viewscapes.

4.0 METHODS

4.1 Selection-cutting Prescription Development

4.11 Long-term Stand Management Goals

The following long-term stand management goals were developed to guide present and future prescription development:

1) *Timber Management* :

- Create and maintain high-quality sawtimber stocking (> 50% of stand basal area in dbh-classes 25 cm or greater) over an approximately 25-year cutting cycle, with a maximum diameter *at harvest* of 50 to 65 cm. To attain and maintain a sustainable supply of the desired quantity of large, good-quality stems in the stand in the long-term, individual trees must be protected and enhanced in the stand for 3 to 6 cutting cycles (to a minimum of 75 years of age and a maximum of about 150 years);

- Protect and maintain healthy, good-quality residual trees, of a range of size classes, which are as free as possible from defects and/or decay, and;

- Increase the proportion of Douglas-fir and white spruce in the stand by the next cutting cycle through preferential retention of spruce and Douglas-fir residuals (within a given dbh-class) and protection of young regeneration .

2) *Protection of Aesthetic Values*:

- Maintain a well-developed, multi-storied canopy on site, and;

- Retain the Douglas-fir veterans on the gravel ridges for seed sources, wildlife habitat and perches, and appearance;

3) *Scientific and technical research into selection systems*

(As discussed in Sections 3.0 and 4.0).

4.12 Stand-Entry Prescription Goals

To prepare a prescription which would achieve the preceding broad stand management goals, three more focussed short-term goals were also developed:

1) *Target Residual Basal Area*

Within the 62.4 ha. (89 %) of the cutblock *outside* of the experimental treatment units, a 'B-level' stocking of about 20 m^2/ha. of residual basal area will be protected during harvest. Similar residual basal area levels for partial-cutting in spruce-balsam types are recommended by Alexander (1987), Johnston (1986), Smith (1986), and Jull (1990b). The residual stocking within each of the experimental units will be be randomly assigned to one of 3 target residual stocking levels (10 m^2/ha., 20 m^2/ha.or uncut). Refer to Figure 7 for locations of individual treatment units. A total of 10 treatment units were assigned to each target stocking level.

2) *Quality of Growing Stock*

For future timber production, high quality of young residual diameter-classes will be maintained and improved by:

i) minimizing logging damage to healthy residuals;

ii) favoring retention of young undamaged spruce and all Douglas-fir, over retention of subalpine fir;

ii) removal all pre-existing defective merchantable trees;

iii) sanitation cutting and/or removal of logging-damaged advance regeneration and residual trees after harvest.

3) *Retention of Douglas-fir*

Protection of Douglas-fir of ALL sizes in the stand, where present. These trees would be retained over and above those retained for 'B-level' stocking purposes.

4.2 Implementation of Selection Prescription

4.21 Pre-harvest Tree-marking

4.211 Rationale for Tree-marking

Pre-harvest tree-marking is an essential component of this silviculture prescription, if silvicultural and research objectives are to be met. Through careful marking-to-cut and harvest planning, the silviculturist can have more direct control over almost all cutting decisions. This approach will avoid the pitfalls of historical 'faller-selection' and 'diameter-limit' partial-cutting methods, which often had inadequate harvest supervision.

As discussed in Section 2.0, this stand contains a relatively open overstory of dominant spruce and some Douglas-fir, over a very well-developed intermediate layer of younger balsam and spruce. Most of the large, dominant spruce appear to be windfirm, but generally not very vigorous or capable of much further diameter increment. It is not necessary to retain a large number of these trees as seed sources, due to an abundance of subalpine fir advance regeneration and some thrifty intermediate spruce. Therefore, the majority of the larger trees (with the exception of isolated Douglas-fir seed-trees) will be harvested. The younger and more vigorous intermediate balsam-spruce layer is well-stocked and of generally good quality. Much of this intermediate layer will be protected and retained as potential crop trees for the next stand entry.

The main objectives of the tree-marking phase are to remove selected overstory trees and intermediate trees and any defective or damaged trees in the stand, while ensuring that a residual basal area stocking of at least 20 m^2/ha. is protected and maintained. This 20 m^2/ha. must:

- be as *evenly-distributed* over the area as possible, and;
- include only *vigorous, undamaged, sound* trees. These are most likely to release well and form good quality crop trees (primarily sawlogs) for future stand entries.

4.212 Development of Marking Criteria

In Section 4.11, careful definition of long-term stand management objectives for selection-cutting in this stand were developed; Section 4.12 detailed the short-term prescription goals, which indicated the desired post-harvest stand structure and composition. The final step in this process is the development of detailed criteria for controlling the tree-marking activities, which will help ensure that the stated silvicultural objectives are achieved.

Simplified pre-harvest tree-marking guidelines for the selection cut were developed through analysis of the available cruise data (supplemented by additional sampling of the stand, which included non-merchantable diameter-classes of (5.0 to 17.5 cm). Preliminary guidelines were refined through discussions with District Small Business and Silviculture staff and the tree-marking contractor (SBS Forestry Ltd.). A detailed knowledge of the present stand structure, stocking, and composition allowed the tree-marking criteria to be customized to the existing stand condition and management objectives.

Specific, operational tree-marking criteria for the Summit Lake block were developed as follows:

Stand table data from the cruise compilation were used to estimate the basal area in each diameter-class and construct a graph of cumulative basal area by 5-cm diameter classes in the stand (Figures 5a and 5b). It can be seen from this graph that, theoretically, there is sufficient basal area in all trees about 30.0 cm or less to meet the B-level stocking objective of 20 m^2/ha. Therefore, 30 cm was the lowest possible *maximum residual diameter* that could be considered if minimum residual basal area objectives were be met (although application of this diameter as a rigid harvest cut-off would amount to a likely genetic high-grade of the stand). Figure 5b also indicates that about 50% of the target target stocking (about 10 m^2/ha) is contained within each of the non-merchantable (0-17.5 cm) and merchantable (17.6 - 45.0 cm) diameter-classes. This even distribution of basal area over a wide range of diameter-classes suggests that it is possible to maintain a relatively balanced residual diameter distribution in this stand.

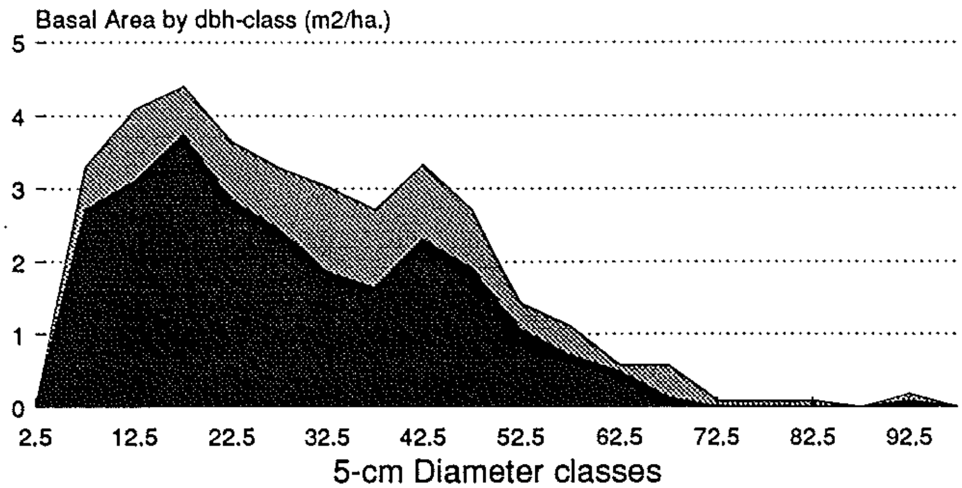
The maximum residual diameter was increased to 40 and 45 cm respectively for tree-marking of *experimental* treatment units to basal areas of 10 and 20 m2/ha. These higher maximum diameters provide more flexibility in tree-marking decisions. Flexibility is needed in tree-marking to allow marking-to-cut of inferior phenotypes and of defective trees which do not meet stand management objectives. The higher maximum residual diameter also allows the retention of larger thrifty trees still capable of vigorous growth. Therefore, a range of merchantable tree sizes from the lower marking limit (25 cm) up to the maximum residual diameter (40 - 45 cm) were included within a '*marking-decision zone*'. All trees above the specified maximum residual diameter were automatically marked-to-cut. Trees within the marking-decision zone were individually evaluated by the tree-marker in the field to determine whether to mark (to cut) or retain each tree, with the objective of retaining at least 50 % of the volume of trees within this zone across the range of available diameters.

For each tree within the marking decision-zone, the decision whether to mark-to-cut or leave was based on the following broad criteria:

i) species

ii) quality criteria (damage / defects)

Figure 5a : Distribution of Sound and Defective Stand Basal Area by Diameter Class

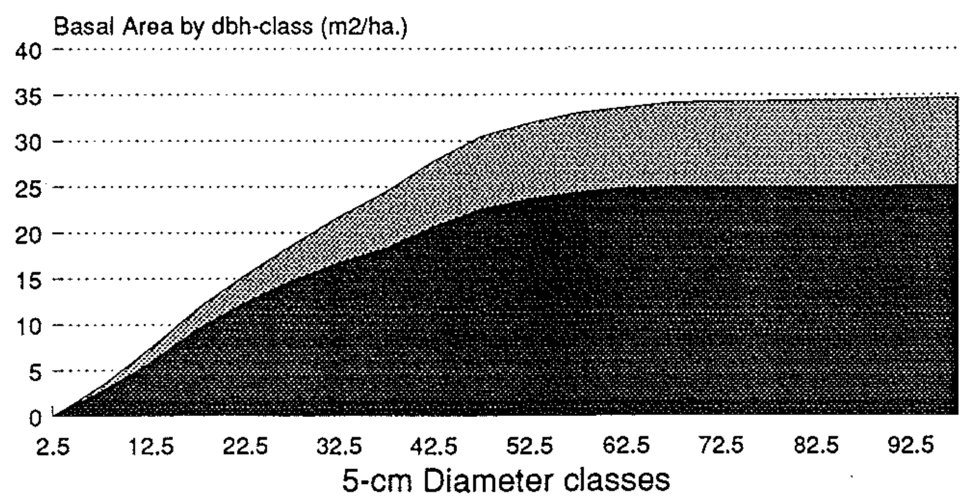


Stand Component

Sound Trees Defective Trees

(Possess path. indicators, poor form, unacceptable species)

Figure 5b: Cumulative Sound and Defective Basal Area by 5-cm Dbh-classes



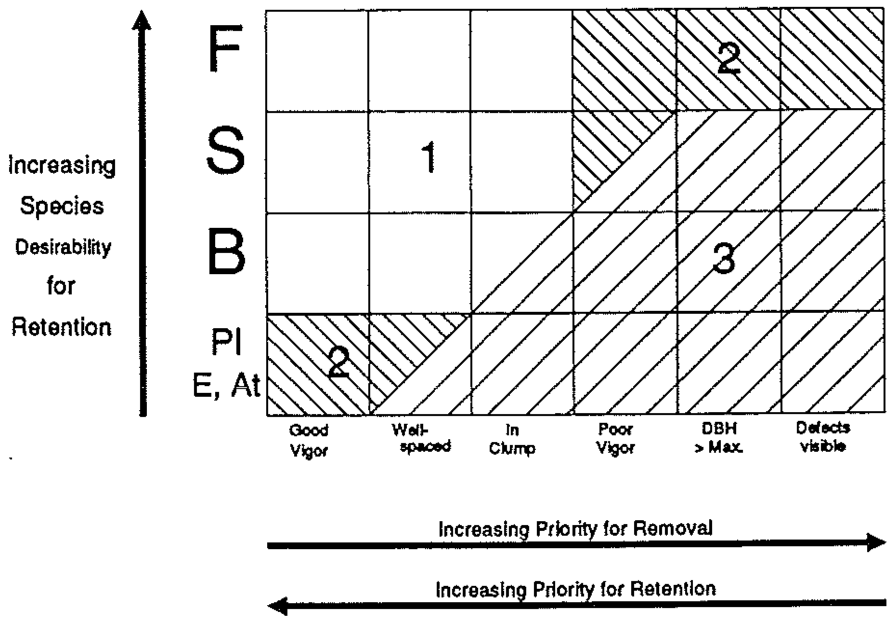
Stand Component

Sound Trees Defective Trees

(Possesses path. indicator, poor form, or unacceptable species)

Figure 6 : Identification of Stand Components for Planning of Selection Tree-marking

SBSmk1 subzone : Summit Lake Selection Trial



Stand Component	Description	Silvicultural Objective(s)
1	Quality Timber Residual	- Quality sawtimber production - Crop tree seed source - Aesthetics, non-timber values - Regulated by residual basal area, diameter distribution.
2	Non-timber Residual	- Maintenance of non-timber values are primary focus. - Integrated resource management and biodiversity are key goals. - Can be crop tree seed source. - Density and characteristics of residual trees are customized to stand and landscape objectives.
3	Sanitation Harvest	- Stand improvement for timber values. - Removal of defective residuals and high-risk trees is highest priority.

Table 1 : Summary of Anticipated Per-hectare Residual and Mark-to-cut Stand Components in Experimental Treatment Units (based on cruise data).

	Volume (m^3/ha)	**Basal Area** (m^2/ha)	**Stems /ha.**
RESIDUALS < 25.cm	41.7	16.1	1679
RESIDUALS 25. - 40.cm (50% assumed)	30.7	4.3	128
TOTAL RESIDUAL	71.4	20.4	1807
MARK-TO-CUT > 40. cm	119.1	11.2	81
MARK-TO-CUT 25.- 40.cm (50% assumed)	30.7	4.3	128
TOTAL MARK-TO-CUT	149.8	15.5	203
ORIGINAL STAND TOTALS	221.9	35.9	2010

iii) vigor (as indicated by live-crown percentage, crown thickness, and general appearance of tree, and;

iv) density and proximity of suitable adjacent leave-trees.

The marking decisions will be guided by overall stand management objectives. Species and characteristics of each tree will be considered together to identify suitable residual or harvest stand components, as illustrated schematically in Figure 6. For example, the most preferred residual leave-trees from a timber management perspective will be well-spaced, thrifty spruce and Douglas-fir with no defects. In contrast, all spruce and subalpine fir with pathological defects (e.g. - conks, large scars, catfaces, large forks or broken tops) will have a high priority for removal from the stand and will be marked-to-cut. Section 4.212 will discuss this process in more detail.

Certain trees, such as large Douglas-fir veterans will be retained as 'non-timber residuals', which will act as seed sources, and also provide structural and species diversity within the stand.

Table 2 provides a brief summary of anticipated harvest removals and residual stand components, based on existing stand data and operational tree-marking criteria.

All non-merchantable (less than 17.5 cm) and pole-sized (17.6 - 25 cm) trees are not marked, and will be treated with a post-harvest sanitation thinning. Post-treatment basal area of non-merchantable and pole-sized trees will be no greater than half (50%) of the target residual basal area of the stand as a whole.

4.213 Field Procedures and Guidelines

PLEASE NOTE that the specific tree-marking guidelines used by the field crews are detailed in Appendix 1.

For the tree-marking phase of this selection method (in conjunction with research objectives), the following general steps were followed :

1) Compassed, flagged lines (candystripe flagging) running N45E at 100 m spacing, were run to divide the block into 10 'marking strips' of uniform width but various lengths (see Figure 1);

2) Each marking strip was marked by crews of 2 persons moving back and forth across the strip in zigzag fashion;

Table 2 : Target Residual Stand Characteristics for Experimental Selection Treatment Units

Target Residual Basal Area (m^2/ha.)	**Maximum Residual Diameter** (cm)	**Mean q-value**	**% Basal Area Removal**
10	40	2.04	71 %
20	45	1.75	42 %
Uncut (35)	50-95	1.77	0 %

3) Only the non-experimental portions of the stand were marked by the operational marking crew. The 30 pre-located 50mX50m research plots (as shown in Figure 1) were marked to residual basal area targets by Forest Science personnel;

4) Operational, non-experimental mark-to-cut tree marking in the marking strips (as described in Appendix 1) involved two simultaneous functions, including marking of :

   i) a) all trees greater than maximum residual dbh (40 - 45 cm in experimental units and 35 cm in non-experimental areas), and;

      b) all unacceptable leave-trees in the 25 cm and greater dbh-classes (as defined in Table 1), and;

   ii) spacing out of some of the remaining, acceptable merchantable leave-trees in the 25 cm and greater dbh-classes, if necessary;

5) Each tree marked for cutting was marked with red tree-marking paint by:

   i) a line running around the tree on all sides at about 2.5 meters in height, and;

   ii) two large dots on opposing sides of the tree base below stump height (30 cm).

4.22 Harvesting Systems

As indicated in Figure 1, the northern three-quarters of the cutblock will be harvested in the winter months, using hand-falling and machine-skidding techniques. Logs will be skidded with small machines such as D4 or D5's, hi-drives, or FMC's, on predesignated skid trails.

The southern quarter of the block will be harvested in early winter, but with hand-falling and *horse-logging* techniques.

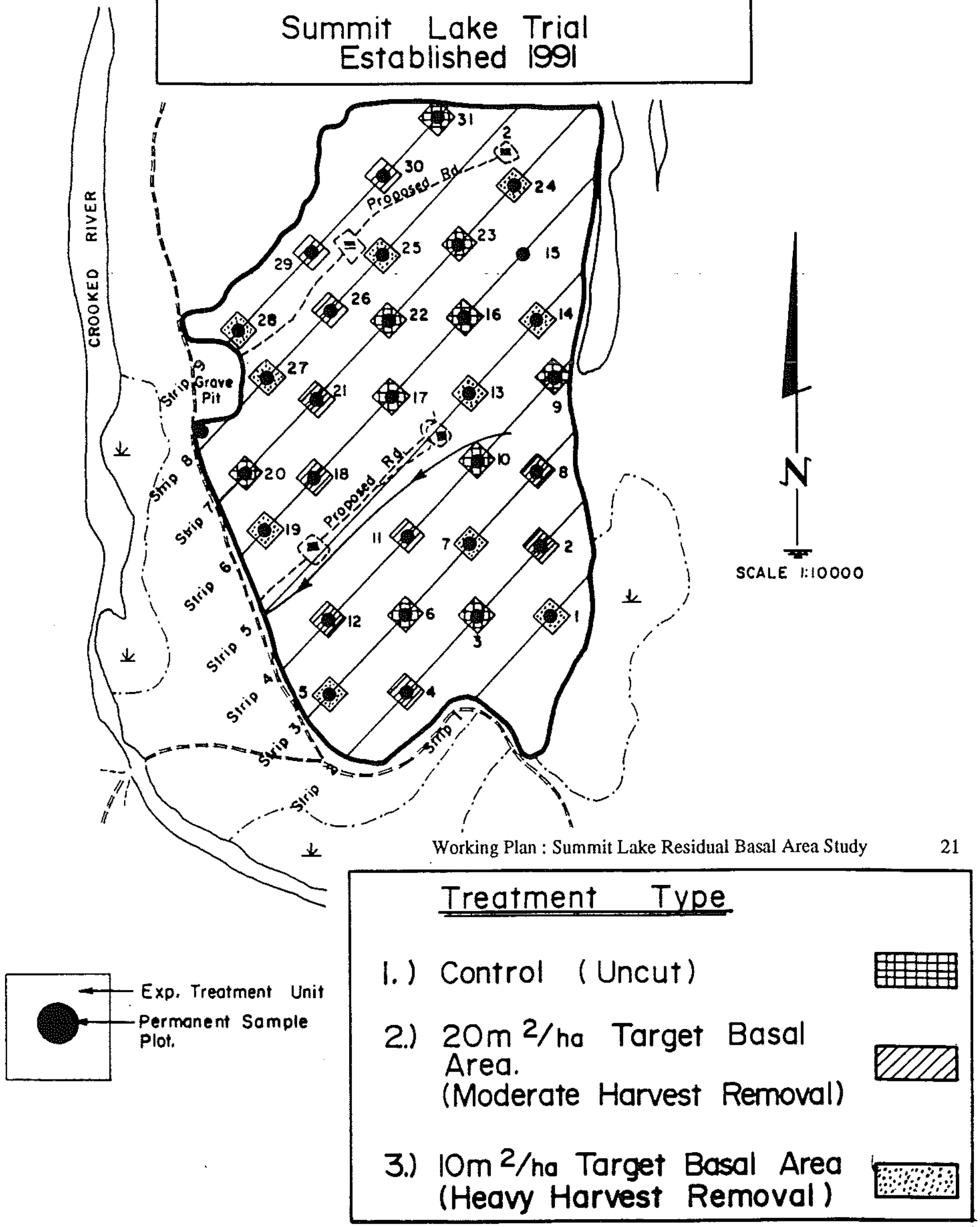
4.3 Research Methods

4.31 Experimental Design

Within the 69.9-hectare study site, thirty 50m X 50m (0.25 ha.) experimental treatment units were systematically located at approximately 200 m spacing on compassed strips spaced 100 m apart (Figure 7). The locations of the blocks on a given strip were staggered relative to those on adjacent strips. In a few cases, where necessary, locations of a

Figure 7: Layout of Experimental Selection Treatment Units and Sample Plots

Summit Lake Trial
Established 1991



few units were shifted along the strips to avoid any unmapped swamps, or prelocated road and landing locations encountered in the field.

Target basal area treatments (10 m^2/ha. residual basal area, 20 m^2/ha., or uncut) were allocated randomly among the 30 available treatment units on the grid, with 10 units per each of the 3 selection treatment types. Target residual stand characteristics for each experimental treatment are provided in Table 2. The experiment follows a completely randomized design. Within each of the 50m X 50m experimental treatment units, the stand was intensively inventoried by means of 3 variable-radius (BAF 4) prism plots. In the units to be partially cut, customized marking-to-cut was carried out based on this intensive inventory data. Of the 30 plots, 5 are in the horse-logging block, while 25 are in the machine-logging block. Due to winter logging conditions, harvest method was not be considered in the experimental layout or supplementary sampling.

Despite a similar experimental layout, Analysis of Variance (ANOVA) is NOT an appropriate statistical techique for analyzing results of this trial (as will be discussed in Section 5.0). Rather, linear regression analysis will be used.

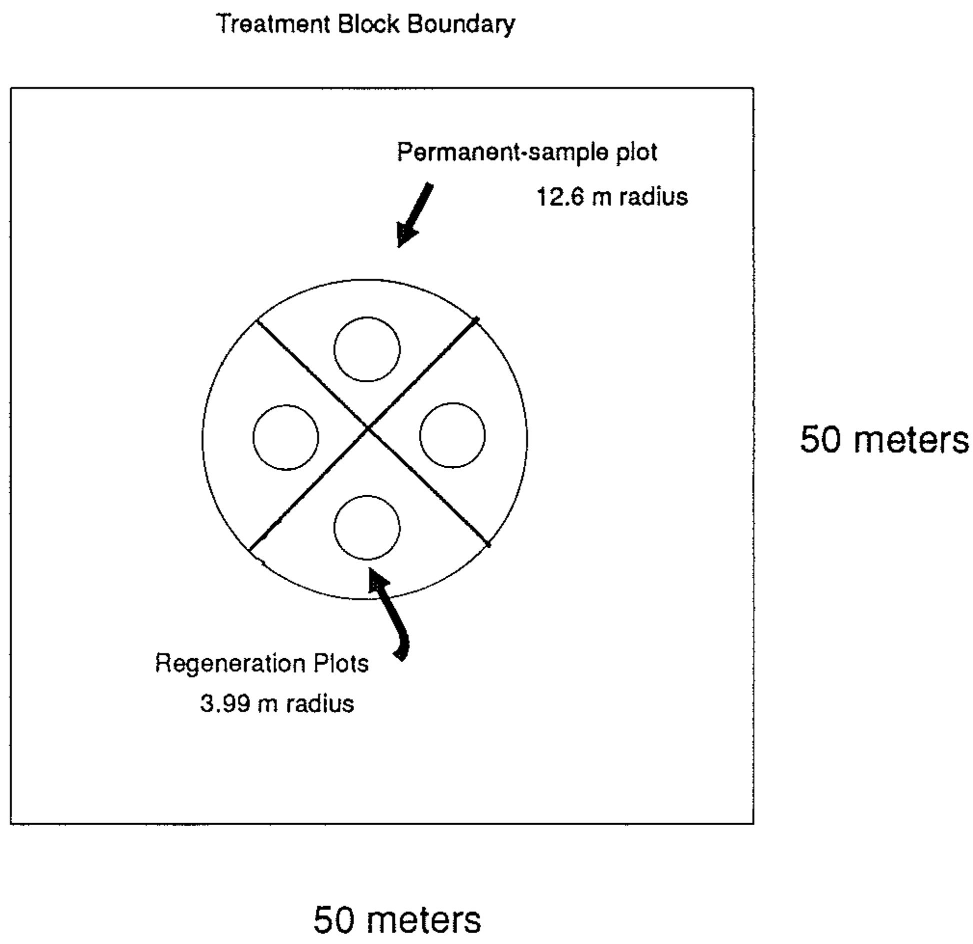
4.32 Permanent Sample Plot Layout

At the center of each 0.25-hectare treatment unit, a 0.05-hectare (12.6 m-radius) circular growth-and-yield permanent sample plot (PSP) is to be established, measured, and monitored according to established standards (B.C. Forest Productivity Council, 1990). Within the plot, all live trees 4.0 cm d.b.h. and above will be tagged and measured to monitor changes in post-harvest stand development. The plot will be divided into 4 sectors along cardinal directions (North, South, East, West), and individual trees will be numbered and assigned to individual sectors. To monitor and measure advance regeneration release, new regeneration establishment and growth, and regeneration mortality, 4 regeneration plots of 3.99 m radius (0.005 ha.) will be established at a standard distance of 6.0 m from the plot center in the approximate center of each sector (at bearings from plot centre of NE, SE, SW, and NW. The overall plot layout in each treatment block is illustrated in Figure 8.

Corners of the square 50 m X 50 m treatment units will be permanently marked with 4-foot long X 1.5 inch steel angle-iron stakes painted with yellow rust-resistant paint. The permanent plot centers will be marked with the same size of angle-iron stake painted with red rust-resistant paint. The permanent regeneration plots will be marked with 2-foot X 1-inch aluminum red angle-iron stakes.

Figure 8 :

Layout of growth-and-yield permanent sample plot (PSP) and 4 regeneration plots within treatment block.



Note: drawing is not exactly to scale.

4.33 Initial Measurements and Data Collection

At the permanent sample plot inside each treatment unit, all residual leave-trees greater than 4.0 cm diameter will be tagged at breast height (1.3 m) with a numbered aluminum tag and aluminum nail.

Initial collection of stand data for the permanent sample plots will include:

- Treatment number, block number, tree number, and species;
- Diameter at breast height, and;
- Pathological indicators for all trees;

For each plot, at least 6 spruce and 6 subalpine fir subsamples will be systematically selected, with subsamples distributed as evenly as possible across the available diameter classes. For each of the subsamples, the following additional information will be collected:

- Estimated % Live Crown on all trees;
- Total height (as measured with suunto clinometer);
- Age (at 1.3 m) of subsampled trees;
- Periodic 5-year radial increment for the last two 5-year periods for subsampled trees, and;
- Bark thickness to nearest millimeter.

Collection of site information for each treatment unit will include:

- Description of soil texture and effective rooting depth, and;
- Description of biogeoclimatic site unit classification.

Post-harvest initial data collection for each regeneration sub-plot will include tagging and sampling of all trees greater than 30 cm height and less than 4.0 cm dbh. Regeneration less than 30 cm height will be tallied by species and germination substrate. For trees greater than 30 cm height, the following information will be collected:

  - total height;

- diameter at seedling base;
- estimated age (number of whorls);
- length of live crown;
- width of live crown (North/South, East/West orientations), and;
- damage assessment and recording of damage indicators, including:

    a) broken terminal leaders;
    b) broken stems;
    c) snapped or broken lateral branches;
    d) stems pushed to ground;
    e) stems pinned to ground by debris, and;
    f) scars exposing cambial tissue.

- germination / rooting substrate (i.e. - mineral soil, forest floor, decomposing wood).

5.0 PROPOSED ANALYSES

5.1 Analytical Approach and Limitations

The main benefit of the long-term data collection from the Summit Lake selection trial is the development of statistical relationships which will aid in more reliable prediction of stand behavior after selection-cutting. Residual basal area is a fundamental concept in the regulation of selection and shelterwood cuttings. It is useful to describe and quantify post-harvest trends in other stand parameters (e.g. - amount of regeneration, rate of stand growth, etc.) as a function of residual basal area. In this way, optimum basal area levels for achieving a given set of stand management objectives can be better identified.

This study will analyse the relationship of residual stand basal area levels to the post-harvest response of basal area increment, diameter and height growth of residual trees, new regeneration establishment and composition, and the incidence and severity of logging damage to individual stems in the residual stand. Analytical methods must be tailored to the variable, less-than-fully-controlled conditions of an operational selection-cut stand. This situation will almost always occur to some degree, not withstanding careful pre-harvest planning and harvest supervision. An Analysis of Variance was initially considered for this experimental design; however, after much consideration of its advantages and disadvantages, this approach was rejected for the following reasons:

1) *Non-homogeneous Study Area*

It was not possible to reliably identify and isolate relatively homogeneous treatment replicates within a specified treatment type. Like most natural stands, the study site has inherent natural, non-systematic variation in stand composition, structure, soils, and site quality throughout the block. The experiment was not stratified (e.g. - into ecological site types or landscape units) because it is felt that this process is quite subjective at the experimental scale used, and would introduce uncontrolled bias into the analysis. At present, there is insufficient preliminary evidence upon which to base stratification criteria relevant to uneven-aged stand development.

2) *Lack of rigid control of treatment intensities*

Although the initial experimental units are marked to one of three 'target' basal areas (10 m^2/ha. and 20 m^2, with an uncut control), the actual post-harvest basal area attained on any given experimental treatment unit will often be somewhat higher or lower than these target stockings. This variation may be due to pre-existing variation in stand structure, incidence of defect, and stocking; also to be considered are the unpredictable effects of logging damage and possible post-logging mortality, blowdown, windsnap, exposure mortality, etc. Even in the unharvested plots, where there will be only very limited basal area removal, there is substantial existing variation in basal stocking (22 to 54 m^2/ha), levels of defect, and species composition.

3) *Continuous Treatment Response Data is Desirable for Silvicultural Management*

A limited number (3) of discrete residual basal area treatment levels provides information about treatment reponse only at those levels. Interpolation is necessary to infer treatment response at intermediate levels. It is desirable for the purposes of future stand modelling and silvicultural management to have information on stand response over a wide range of possible residual stand densities.

For these three reasons, general linear regression is proposed as the primary method of statistical analysis of the post-harvest stand response data. Residual basal area will be used as the independent variable in this analysis. Basal area removal (in total m^2/ha. or %) will also be used where appropriate. Graphical analysis and logistic regression analysis will be used to visually illustrate observed trends.

Regression analysis will allow the use of statistically significant regression equations as tools for the preliminary prediction of stand response after partial-cutting.

5.2 Detailed Analyses

For the purposes of the following analyses, all stand parameters and response variables discussed (basal area, volume, regeneration, height growth) are defined explicitly as the measured values and measured changes occuring within the permanent sample plots (P.S.P.'s) located within each of the 31 treatment units. The circular, 0.05-hectare PSP located within the center of the 0.25-hectare treatment unit is assumed to be representative of this surrounding treatment unit. Regression analyses will treat measured values from each single PSP as individual observations.

5.21 Stand-level Basal Area Increment

The relationship of post-harvest periodic basal area increment (b.a.i.) to initial residual basal area will be determined using general linear regression techniques. Basal area increment as a function of residual basal area will be presented graphically to compare and illustrate broad trends in response over a range of stockings. Percentage response due to different stand components (e.g. - by species, height classes, or age classes) will also be examined.

5.22 Post-harvest Tree Height Growth Response

Post-harvest periodic height growth of representative sample trees selected over a range of diameter classes within each plot will be determined by initial measurements after harvest and remeasurements at 3, 6, 10, 15, and 20 years after harvest. Tree height release data will be stratified by initial post-harvest canopy class (1.3 -3.0, 3.0 - 10.0, 10.0 + m) to examine possible differences in response as a function of residual basal, species, or initial size at harvest. Graphical analysis and logistic regression techniques will be used to display broad trends, while linear regression will be used to develop predictive relationships.

5.23 Gross and Merchantable Volume Increment

Rates of periodic gross volume increment will be calculated for each plot at each remeasurement period. Gross volumes and net merchantable volumes by 5-cm diameter classes, species, and the whole stand (plot) will be calculated using standard B.C. Ministry of Forests cruise compilation methodology and generalized taper functions (B.C. Ministry of Forests, 1983). The presence or absence of pathological indicators will be noted on individual trees to determine merchantable volume from the initial gross volume estimates.

General linear regression will be used to examine the relationship between gross (and merchantable) volume increment (the response variables) as functions of both residual basal area and residual volume (independent variables).

Components of volume increment (i.e. - by diameter-class or species) will be analysed graphically to determine general trends over time, and differences between broad treatment types (i.e. - uncut control plots versus partial-cut treatment units).

5.24 Regeneration Dynamics

For the purposes of the analysis of regeneration response within each treatment unit, treatment response (i.e. - height growth, rates establishment, survival) wil be quantified as a cluster mean of the 4 regeneration subplots within each treatment unit. In regression analysis of the data, the cluster mean (expressed, for example, as stems-per-hectare (s.p.h.) per year, or mean height growth per size strata) will be the observation from each treatment unit.

5.241 New Regeneration Recruitment

General linear regression will be used to examine the relationship between residual basal area and:

i) periodic rates of establishment of all regeneration (defined as s.p.h. /yr.), and;

ii) cumulative establishment of regeneration by species (s.p.h.) at a given point in time.

Regeneration data will be stratified by establishment substrate (mineral soil, undisturbed forest floor, or rotting log).

Graphical analysis and logistic regression will be used to present and compare broad trends *over time* since harvest in:

i) cumulative regeneration establishment (in terms of s.p.h.), and;

ii) rates of periodic regeneration establishment (s.p.h./year) by species.

5.242 Advance Regeneration Release

Relationships between the rate of advance regeneration periodic height increment or diameter increment and the residual basal area of the overstory will be examined through regression techniques also. Advance regeneration release data will be stratified both by initial height class and by tree species.

Graphical analysis, and logistic regression, if necessary, will be used to illustrate and compare possible differences in the response of different height classes and tree species.

5.25 Logging Damage and Post-harvest Mortality

Graphical analysis, and logistic regression, if necessary, will be used to examine possible trends in the incidence of logging damage or destruction of residual stems as a function of either % or total basal area removal. The % incidence of damage by residual diameter class and/or species will be graphically examined also.

Finally, graphical analysis will also be used to examined long-term trends in post-harvest mortality over time, and over a range of residual basal area densities. The mortality data will be stratified into components (i.e. - type and apparent cause of death; blowdown, standing dead, windsnap, root rot, etc.).

6.0 PHOTOGRAPHIC RECORDS

Color photographs of 2 representative treatment units in each of 3 target residual basal area treatments (6 in total) will be taken to document the following stand conditions:

1) Pre-harvest stand conditions;

2) Post-harvest stand conditions before sanitation cutting (Spring of 1993);

3) Post-harvest stand conditions after sanitation cutting (Fall of 1993)

3) 6 Years post-harvest (Spring of 1996);

4) 10 Years post-harvest (Spring of 2001);

5) 20 Years post-harvest (Spring of 2011);

At each treatment units selected, steel corner stakes will be used and noted as photo-references to record the exact spots from which photos were taken.

Other photographs will also be taken on the same schedule:

Several middle-distance photographs of the broad-scale stand profile will be taken from locations on the gravel pit and roadsides to changes in stand structure, if any.

Several long-distance, broad-scale photographs of the stand and its surrounding landscape will be taken from the eastern viewpoint on the adjacent Teapot Mountain.

Also, general photos of falling, logging, and skidding operations will be take to provide historical detail for future reference.

7.0 MAINTENANCE SCHEDULES

The objectives of this study are to collect and analyze long-term information on the post-harvest stand response after this type of partial cutting. Therefore, frequent data collection and research plot maintenance will be carried out according to the following 20-year remeasurement schedule:

Year	Years from cutting	Mortality/ Damage	Regeneration	Growth and Yield
Winter 1991/2	0	X		X
May 1993	1	X	X	
Fall 1993	2	X		
Fall 1994	3	X	X	X
Fall 1997	6	X	X	X
Fall 2001	10	X	X	X
Fall 2006	15	X	X	X
Fall 2011	20	X	X	X

At the end of the 20-year remeasurement period, the timing of the next stand entry should be evaluated, and a new remeasurement schedule prepared, if necessary. Otherwise, measurements should continue on a 5-year interval.

8.0 EXTENSION AND DEMONSTRATION

Planned extension and demonstration activities relating to this project include:

1) Field tours for both foresters, students, and the public;

2) Submission of journal articles;

3) Preparation of silvicultural recommendations and decision-tools for similar forest and site types;

4) Newspaper features.

The close proximity and easy access of this site from Prince George should facilitate the use of the site for demonstration field tours.

9.0 RESEARCH ROLES AND RESPONSIBILITIES

The administration and remeasurement of this research project will be the responsibility of the Forest Science Section of the Prince George Forest Region. Michael Jull (Research Silviculturist) and Craig Delong (Research Ecologist) will supervise research activities.

10.0 WORK SCHEDULE (Proposed 3-Year Plan)

June 1991	Completion of Draft Working Plan
June 1991	Field Location and Layout of 30 50m X 50m experimental treatment units.
July 1991	Operational mark-to-cut tree-marking on all non-experimental portions of cutblock.
September 1991	Intensive inventory, assessment of experimental treatment units.
	Analysis of treatment-unit inventory data for tree-marking to specified basal area.
	Pre-harvest tree-marking to specified basal areas on experimental treatment units.
October, 1991	Completion of Final Working Plan
Winter, 1991/2	Partial-cut Harvest of cutblock.
	Supervision of partial-cutting activities.
Feb./ March 1991	Establishment and measurement of 30 growth-and yield permanent sample plots (1 per experimental treatment unit).
May, 1993	Initial Post-harvest Permanent-sample Plot (PSP) visits: • Plot marker maintenance; • Logging damage/mortality to residuals, and; • Logging damage/mortality to advance regeneration. • Establishment and measurement of 3.99m-radius permanent regeneration plots(4 per unit).
September, 1993	Second-year PSP data collection:
	Monitoring of post-harvest mortality and damage.

(continued)

September, 1994 Third-year PSP data collection:

1) Mortality of residuals/regeneration;
2) Advance regeneration growth;
3) New regeneration establishment;
4) Growth and yield plot remeasurements.

11.0 PROJECT COSTS

Proposed Budget for 1991 :

Completion of Working Plan	1,750.
Location and Layout of Experimental Units	1,250.
Mark-to-cut Tree-marking of non-experimental portions of cutblock	10,000.
Inventory and analysis of experimental units	1,600.
Assessment and Critique of tree-marking procedures	500.
Pre-harvest initial establishment and measurement of growth-and-yield and regeneration plots	4,850.
Materials (Flagging, paint, stakes, nails, tags)	500.
TOTAL COSTS FOR 1991:	$ 20,450.

Proposed Costs for 1992 :

Initial post-harvest plot maintenance and damage/mortality recording.	1,500.
First year site visit: regeneration and mortality data.	2,500.
TOTAL COSTS FOR 1992:	$ 4,000.
PROJECTED TOTAL COSTS 1993	$ 4,000.
PROJECTED TOTAL COSTS 1994	$ 10,000.

12.0 REFERENCES

Aho, P.E. 1981. Decay problems in true fir stands. Pp. 203-208. In: Oliver, C.D., and R.M. Kenady (eds.) Proceedings of the Biology and management of True Fir in the Pacific Northwest Symposium. Seattle, Washington, Feb. 24-26, 1981. University of Washington, College of Forest Resources and U.S. Forest Service, Pacific Northwest Forest and Range Experiment Sta.

Alexander, R.R. 1987. Ecology, silviculture, and management of the Engelmann spruce-subalpine fir type in the central and southern Rocky Mountains. USDA Forest Service. Agriculture Handbook # 659. Washington, D.C. 144 PP.

Anderson, H.W., B.D. Batchelor, C.M. Corbett, A.S. Corlett, D.T. Deugo, C.F. Husk, and W.R. Wilson. 1990. A silvicultural guide to the tolerant hardwoods working group in Ontario. Forest Resources Working Group, Ontario Ministry of Natural Resources. Publications Ontario, Toronto, Ontario. 178 pp.

Barnes, G.H. 1937. The development of uneven-aged stands of Engelmann spruce and the probable development of residual stands after logging. For. Chron. 13:417-457.

B.C. Forest Productivity Council. 1990. Minimum standards for the establishment and remeasurement of permanent sample plots in British Columbia. Inventory Branch. B.C. Ministry of Forests. Victoria, B.C.

B.C. Ministry of Forests. 1983. Manual of cruising procedures and compilation. B.C. Forest Service. Province of British Columbia, Victoria, B.C.

Bergstrom, B.W. 1983. Growth response and stand management of the advance subalpine fir on diameter-limit cut stands in the Adams Lake area of the Kamloops Forest Region. B.S.F. Thesis. Faculty of Forestry. University of British Columbia. 93 pp.

Bier, J.E., P.J. Salisbury, and R.A. Waldie. 1948. Studies in forest pathology V : Decay in fir, *Abies amablis* and *lasiocarpa*, in the upper Fraser area of British Columbia. Can. Dept. of Agr. Tech. Bull. 66. 28 pp.

Bloomberg, W.J. 1950. Fire and spruce. Forestry Chronicle 26:157-161.

Coopersmith D. and H. Coates. 1987. Subalpine Fir and White Spruce Sanitation-spacing Trial at Wansa Lake. Progress Report: SX 80405. Research Report. Prince George Forest Region. Ministry of Forests and Lands. Province of B.C. 16 pp.

David, C.A. 1987. Post-harvest forest-floor changes and nitrogen mobilization in and Engelmann spruce-subalpine fir forest. PhD Thesis. Faculty of Forestry, University of British Columbia, Vancouver, B.C. 325 pp.

DeLong, C. G. Hope, and A. McLeod. 1987. A field guide for the identification and interpretation of ecosystems of the SBSe2 in the Prince George Forest Region. Second Approximation. Ecology Section. Prince George Region. B.C. Ministry of Forests and Lands.

Filip, G.M., and C.L. Schmidt. 1990. Rx for *Abies:* Silvicultural options for diseased firs in Oregon and Washington. U.S.D.A. Forest Service. Pacific Northwest Research Station. Gen. Tech. Rep. PNW-GTR-252. November, 1990. 34 pp.

Freese, F. 1962. Elementary forest sampling. U.S.D.A. Forest Service . Agr. Handbook # 232. 91 pp.

Graham, R.T. and R.A. Smith. 1983. Techniques for implementing the individual tree selection method in the Grand Fir-Cedar-Hemlock ecosystems of northern Idaho. U.S.D.A. Forest Service Forest and Range Experiment Station. Res. Note INT-332.

Griffith, B.G. 1931. The natural regeneration of spruce in Central British Columbia. For. Chron. 7:204-219.

Guldin, J.M. 1991. Uneven-aged BDq regulation of Sierra Nevada mixed conifers. Journal of Forestry 6(2):27-32.

Herring, L.J. 1977. Studies of advance subalpine fir regeneration in the Kamloops forest district. B.C. Ministry of Forests. Research Note # 80. 23 pp.

Hornibrook, E.M. 1950. Estimating defect in mature and overmature stands of three Rocky Mountain conifers. Journal of Forestry 48: 408-417.

Johnston, W.F. 1986. Manager's handbook for Balsam fir in the North Central states. USDA Forest Service, North Central Experiment Station. Gen. Tech. Rep. NC-111. 27 pp.

Jull, M.J. 1990a. Historical partial-cutting methods and opportunities for silvicultural system development in the Prince George and Robson Valley Forest Districts. Contract Report. Forest Sciences Section, Prince George Forest Region, B.c. Ministry of Forest. Prince George, British Columbia.79 pp.

Jull, M.J. 1990b. Long-term stand dynamics in high-elevation Engelmann spruce-subalpine fir forests. M.Sc.F. Thesis. University of British Columbia. Vancouver, B.C. 145 pp.

Klinka, K., and R.E. Carter. 1991. A stand-level guide to the selection of reproduction methods for regenerating forest stands in the Vancouver Forest Region. Contract Report. B.C. Ministry of Forests. Vancouver Forest Region. Burnaby, B.C.

Kneeshaw, D. 1991. An investigation of stand dynamics in the SBSmc subzone. Research update. Unpublished memo. 2 pp.

Laing, K.C., and L.D. McCulloch. 1988. Assessment of the performance of *Abies lasiocarpa* in the Interior biogeoclimatic zones of the Prince Rupert Forest Region. Contract Report. B.C. Ministry of Forests, Smithers, B.C. 28 pp.

McCaughey, W.W., C.E. Fieldler, and W.C. Schmidt. 1991. Twenty -year natural regeneration following five silvicultural prescriptions in spruce-fir forest of the Intermountain West. U.S.D.A. Forest Service. Intermountain Res. Station. Res. Paper INT-439. 12 pp.

Monchak, D.K. 1982. Factors affecting the growth performance of subalpine fir advance regeneration in the Kamlops Forest Region. Unpublished Project Report. Silviculture Section. Kamloops Region, B.C. Ministry of Forest.

Oliver, C.D. and B.C. Larson. Forest stand dynamics. Biological Resource Management Series. McGraw-Hill Inc. Toronto, Ont. 467 pp.

Parker, A.K., and A.L. Johnson. 1960. Decay associated with logging injury to spruce and balsam in the Prince George Region of British Columbia. For. Chron. 36(1): 30-45.

Pogue, H.M. 1946. Regeneration and growth of white spruce after logging. B.C. For. Serv. Victoria, B.C. Tech. Publ. 29.

Roe, A.L. and G.M. DeJarnette. 1965. Results of a regeneration cutting in a spruce-subalpine fir stand. U.S.D.A. Forest Service Res. Paper INT-17. Intermountain Forest and Range Exp. Station. Ogden, Utah. 14 pp.

Smith, H.G. 1955. Some factors affecting reproduction of Engelmann spruce and alpine fir.B.C. Forest Service. Dept. of Lands and Forests. Tech. Publ. T-43. 43 pp.

Smith, H.G., and M.B. Clark. 1974. Results of mthods of cutting and related studies in Engelmann spruce-subalpine fir forests near Bolean Lake in 1950. Progress Report on E.P. 371 of the B.C. Forest Service. Unpubl. Mimeo. 61 pp.

Smith, D.M. 1986. Principles of silviculture. 8th edition. John Wiley and Sons, New York. 500 pp.

Smith, R.B. and H.R. Craig. 1968. Decay in advanced alpine fir regeneration in the Kamloops District of British Columbia. Forestry Chronicle 46: 217-220.

Stettler, R. F. 1958. Development of a residual stand of Interior spruce-alpine fir during the first twenty-eight years following cutting to a 12-inch diameter limit. B.C. Dept. of Lands and Forests. Victoria, B.C., Canada. Res. Note 34. 12 pp.

Vankka, J.M. 1983.The Barkerville cutovers and cemetary: a lesson in spruce-fir silviculture. B.S.F. Thesis. Faculty of Forestry, University of British Columbia, Vancouver, B.C. 94 pp.

Weetman, G.F., E. Panozzo, M. Jull, and K. Marek. 1990. An assessment of opportunities for alternative silviculture systems in the SBS, ICH, and ESSF biogeoclimatic zones of the Prince Rupert Forest Region. Contract Report. B.C. Ministry of Forests, Prince Rupert Forest Region, Smithers, B.C. March 1990. 151 pp.

--------------, and A. Vyse. 1990. Natural regeneration. Pp. 118-130. In: Lavender, D.P. *et al.* Regenerating British Columbia's Forests. University of British Columbia Press.

Zasada, J. 1990. Developing silvicultural alternatives for the boreal forest: an Alaskan perspective on the regeneration of white spruce. Forest Industry lecture series. Forestry Program, Faculty of Agriculture and Forestry. University of Alberta. 44 pp.

APPENDICES

APPENDIX 1:

OPERATIONAL GUIDELINES USED FOR PRE-HARVEST MARKING-TO-CUT OF A SINGLE-TREE SELECTION TRIAL

Summit Lake, B.C.
May, 1991

GENERAL REQUIREMENTS:

1) DO NOT MARK within experimental treatment units.

2) DO NOT MARK any trees less than 25 cm d.b.h.

3) DO NOT MARK any Douglas-fir

4) MARK ALL Lodgepole pine, Birch, Aspen, and Cottonwood.

5) Trees to be marked shall be painted with a band on all sides at 2 to 3 meters in height, two spots at the base of the tree on opposing sides. Red fluorescent spray paint shall be used.

INITIAL PASS

6) Mark all trees greater than the maximum residual d.b.h. except Douglas-fir.

7) Mark all trees between 25 and maximum d.b.h. that:

   i) have one or more visible pathological indicators:

      - conk or blind conk
      - broken top
      - fork in lower two-thirds of tree
      - scar (exposed bare wood or deep bleeding bark indent), and/or;
      - frost crack

   ii) have a live crown percentage of less than 30% of height.

8) Mark additional sound trees between 25 cm and the chosen maximum residual d.b.h. on a discretionary basis (up to 50% of diameter-class *including* defectives), according to the following guidelines:

   i) DO NOT mark Douglas-fir

   ii) DO NOT mark sound trees at the edge of roads or natural openings.

   iii) DO mark subalpine fir if adjacent to an equally vigorous white spruce.

   iv) DO mark (and thereby thin) clumped trees before equally vigorous lone or well-spaced trees.

   v) DO mark trees whose crown is entangled with that of a large marked tree.

   vi) DO mark trees with declining, thin crowns before those with vigorous, healthy crowns.

SECOND PASS

10) Double check ALL unmarked merchantable trees and mark as required using the above guidelines.

APPENDIX II :

SUMMARY OF PRE-HARVEST STAND BASAL AREA AND PROJECTED HARVEST REMOVAL FOR INDIVIDUAL EXPERIMENTAL TREATMENT UNITS

			Harvest Removals			
Trmt. Basal Area Target	Plot #	Pre-harvest Basal Area	Defective Basal Area	Excess sound B.A. Removed	Total Removed	Projected Residual
10 m^2/ha.	1	24.0	2.7	10.0	12.7	11.3
	5	41.3	6.7	23.0	30.6	10.7
	7	32.0	6.7	13.3	20.0	12.0
	13	26.7	10.7	7.6	18.3	8.4
	14	24.0	5.3	5.3	10.6	13.4
	19	36.0	10.7	14.3	25.0	11.0
	24	28.0	12.0	4.1	16.1	11.9
	25	45.3	8.0	23.7	31.7	13.6
	27	32.0	10.7	10.0	20.7	11.3
	28	24.0	6.7	7.6	14.3	9.7
20 m^2/ha.	2	33.3	8.0	2.7	10.7	22.6
	4	30.6	7.9	2.7	10.6	20.0
	8	26.7	6.7	4.3	11.0	15.7
	11	32.0	10.7	2.7	13.4	18.6
	12	50.7	17.4	14.7	32.1	18.6
	18	45.3	15.6	11.7	27.3	18.0
	21	41.3	13.3	10.7	24.0	17.3
	26	29.3	5.3	0.0	5.3	24.0
	29	42.7	6.7	12.1	18.8	23.9
	30	22.7	1.4	4.1	5.4	17.3
Uncut	3	37.3	-	-	0.0	37.3
(control)	6	28.0	-	-	0.0	28.0
	9	29.3	-	-	0.0	29.3
	10	22.7	-	-	0.0	22.7
	16	38.7	-	-	0.0	38.7
	17	38.7	-	-	0.0	38.7
	20	30.6	-	-	0.0	30.6
	22	42.7	-	-	0.0	42.7
	23	54.7	-	-	0.0	54.7
	31	40.0	-	-	0.0	32.0

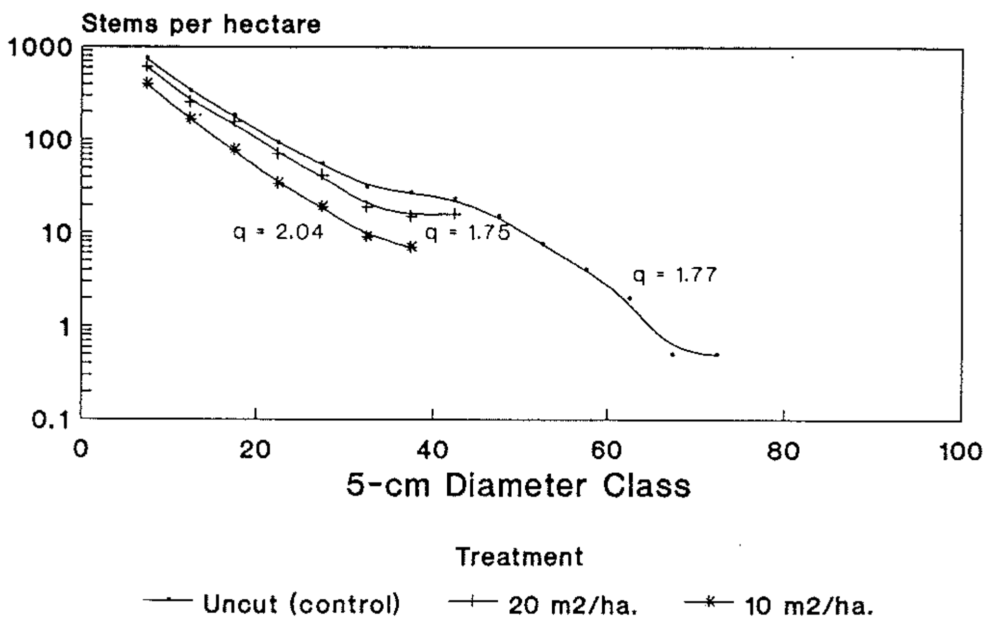
APPENDIX III :

RESIDUAL STAND DIAMETER-DISTRIBUTIONS FOR THE 3 EXPERIMENTAL SELECTION OBJECTIVES

Table 3 : Stems-per-hectare by Diameter Class in 3 Target Basal Area Treatment Groups.

Diameter-Class	Target Basal Area Treatment		
	Uncut	20 m^2/ha.	10 m^2/ha.
5.1 - 10.0	745	614	399
10.1 - 15.0	333	254	165
15.1 - 20.0	183	155	77
20.1 - 25.0	92	71	34
25.1 - 30.0	55	41	19
30.1 - 35.0	31	19	9
35.1 - 40.0	27	15	7
40.1 - 45.0	23	16	-
45.1 - 50.0	15	-	-
50.1 - 55.0	7		
55.1 - 60.0	4		
60.1 - 65.0	2		
65.1 - 70.0	0.5		
70.1 +	0.5		

Figure 9 : Comparison of Residual Diameter Distributions in 3 Treatment Types



Y-axis is Log 10 Scale