



TIMBER SUPPLY REVIEW

Revelstoke TSA Timber Supply Analysis



Revelstoke TSA

Timber Supply Analysis

Integrated Resources Branch
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Preface

This analysis is part of the provincial Timber Supply Review being carried out by the British Columbia Forest Service. The review is examining the short- and long-term effect of current forest management practices on the availability of timber for harvesting in timber supply areas (TSAs) throughout British Columbia. In many areas of the province, timber supply analyses performed in the early 1980s have not been updated to reflect new inventory information and knowledge, or changes in management practices.

To determine allowable timber harvesting levels accurately and rationally, the Chief Forester must have an up-to-date assessment of timber supply based on best available information and reflecting current management direction.

Unlike past analyses, which normally assessed the implications of several forest management scenarios, this report focuses on a single scenario - current management practices. This approach will expedite the analysis process, and allow analysis of all timber supply areas in the province to be completed by the end of 1994. An important part of these analyses, however, is an assessment of how results might be affected by uncertainties - a process called "sensitivity analysis." Together, the sensitivity analyses and the assessment of the effects of current forest management on timber supply will form a solid basis for discussions among stakeholders about alternative timber harvesting levels.

Executive Summary

As part of the provincial Timber Supply Review, the B.C. Forest Service has examined the availability of timber in the Revelstoke Timber Supply Area (TSA). The analysis assesses how current forest management practices affect the supply of wood available for harvesting over the next 200 years. It also examines the potential changes in timber supply stemming from uncertainties about forest growth and management actions. It is important to note that the various harvest forecasts included in the report only indicate the timber-supply implications of current practices and uncertainty. As such, the forecasts should be used for discussion purposes only; they are not intended to imply any particular AAC recommendations.

The Revelstoke TSA covers a total area of 504 000 hectares, of which about 63 000 hectares are considered available for timber harvesting under current management practices. The area is dominated by balsam and spruce mixtures, hemlock and cedar stands. The current allowable annual cut (AAC) for the TSA is 269 000 cubic metres per year.

Given current management assumptions, the analysis shows the current AAC cannot be maintained without causing a sharp drop in future harvest levels below the long-term level. The maximum harvest over the first decade is 254 000 cubic metres per year, 5.6 % below the current AAC. Then, beginning in the second decade, harvests must decrease 12 % per decade until the long-term harvest level of 98 000 cubic metres per year is reached 80 years from now.

Initial harvest levels greater than 254 000 cubic metres per year or rates of decline less than 12 % per decade result in harvests falling significantly below the long term level, usually around 100 years from now. Conversely, if slower rates of decline are desired the initial

harvest must drop below 254 000 cubic metres per year. Given current management assumptions, future decreases in harvest levels can only be avoided by decreasing the initial harvest rate by over 60 % to the long-term harvest level of 98 000 cubic metres per year. Sustained harvesting at this rate maintains significantly higher growing stock volumes and higher harvest ages than for the forecast that starts with a harvest of 254 000 cubic metres per year.

Many of the data and assumptions used in the analysis are subject to varying degrees of uncertainty. Revelstoke forest district staff feel in particular that the volumes for existing stands used in the analysis may be optimistic and the forest cover requirements for the timber zone may not be tight enough. They also believe that the regenerated yields used in this analysis may be too low and as a result the long-term harvest level under-estimated. Sensitivity analysis was used to examine how uncertainty about these and other data and assumptions impact the results of the timber supply analysis.

In the short term, harvest levels are very sensitive to decreased yield estimates for existing stands and to tightening of forest cover requirements, which account for non-timber values such as visual quality, wildlife and old-growth.

Short-term harvest levels are moderately sensitive to increases in yield estimates for existing stands, relaxation of forest cover requirements, changes in green-up periods, and minimum harvest ages. Uncertainty about yields for regenerated stands has very little impact on short-term harvest levels.

The long-term harvest level is highly sensitive to uncertainty about regenerated yields but in general the long-term harvest level is not very sensitive to uncertainty about other data and assumptions.

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Introduction

Timber supply is the quantity of timber available for harvest over time. Timber supply is dynamic, not only because trees naturally grow and die, but also because conditions that affect tree growth, and the social and economic factors that affect the availability of trees for harvest change through time.

Assessing the timber supply involves considering physical, biological, social and economic factors for all forest resource values, not just for timber. Physical factors include the land features of the area under study as well as the physical characteristics of living organisms, especially trees. Biological factors include the growth and development of living organisms. Economic factors include the financial profitability of conducting forest operations, and the broader community and social aspects of managing the forest resource.

All of these factors are linked: the financial profitability of harvest operations depends upon the terrain as well as the physical characteristics of the trees to be harvested. Determining the physical characteristics of trees in the future requires knowledge of their growth. The judgment of whether or not a stand is available for harvest might depend on how its harvest may affect the growth and development of another part of the forest resource, such as wildlife or a recreation area.

These factors are also subject to both uncertainty and different points of view. Financial profitability may depend upon changes in world timber markets. Unforeseen losses due to fire or pest infestations will alter the amount and value of timber. The appropriate balance of timber and non-timber values in a forest is an ongoing subject of debate, and is complicated by changes in social objectives over time.

Because of these uncertainties, timber supply is dictated by a particular set of physical, biological, social, and economic conditions. When these conditions change, the timber supply changes. Thus, before interpreting an estimate of timber supply, it is important to understand the set of conditions upon which it is based.

Timber supply analysis is the process of assessing and predicting the current and future timber supply for a management unit (a geographic area). For a timber supply area

(TSA)*, the timber supply analysis forms part of the information used by the chief forester of British Columbia in determining an allowable annual cut (AAC) -- the permissible harvest level for the area.

Timber supply projections made for TSAs look far into the future - 200 years or more. However, because of the uncertainty surrounding the information and because forest management objectives change through time, these projections should not be viewed as static prescriptions that remain in place for that length of time. They remain relevant only as long as the information upon which they are based remains relevant. Thus, it is important that re-analysis occurs regularly using new information and knowledge to update the timber supply picture. Indeed, the *Forest Act* now requires that the timber supply for management units throughout British Columbia be reviewed at least every 5 years. This allows close monitoring of the timber supply and the implications for AAC of changes in management practices and objectives.

Timber supply analysis involves three main steps. The first is the collection and preparation of information and data. The B.C. Forest Service forest inventory* plays a major role in this. The second step is using this data along with a timber supply computer model or models to make projections or estimates of possible harvest levels over time (called harvest flows). These projections are made using different sets of assumed values or conditions for the factors discussed above. The third step is interpreting and reporting results.

** Throughout this document, an asterisk after a word or phrase indicates that it is defined in a box at the foot of the page.*

Timber Supply Area (TSA)

An integrated resource management unit established in accordance with Section 6 of the Forest Act.

Forest inventory

Assessment of British Columbia's timber resources. It includes computerized maps and a database describing the location and nature of forest cover, including size, age, timber volume, and species composition, as well as a description of some non-timber values such as recreation and visual quality.

Introduction

The following sections outline the timber supply analysis for the Revelstoke TSA. Following a brief description of the TSA in section 1, data preparation and formulation of assumptions are discussed in section 2. Then analysis methodology and results are presented in sections 3 and 4. Section 5 examines the sensitivity of the results to uncertainties in the data

and assumptions used. The report ends with a summary and conclusions.

For the more technically oriented reader, the appendices contain more details about the data and assumptions used in this analysis. They are included here for completeness, but their review is not necessary to obtaining a basic understanding of the timber supply for the Revelstoke TSA.

1 Description of the Revelstoke TSA

The Revelstoke TSA is located in the northern part of the Nelson Forest Region (Figure 1). It is administered from the Revelstoke Forest District office. The TSA covers approximately 504 000 hectares. However, the topography is rugged and mountainous and a relatively small proportion of the area is productive forest land. The TSA consists of three major biogeoclimatic zones: Alpine Tundra (29% of the total area), Interior Cedar - Hemlock (32%) and Engelmann Spruce - Subalpine Fir (38%). The dominant tree species

groups are mixtures of spruce and balsam (49% of the total forested area), hemlock (30%), western redcedar (16%) and fir (11%).

The forest industry is a major employer in the TSA. There are three sawmills, two cedar shake and shingle mills and a pole yard in the City of Revelstoke. Tourism and recreation are also important in the area, in part because the Trans Canada highway bisects the TSA and because there are two national parks adjacent to the TSA.

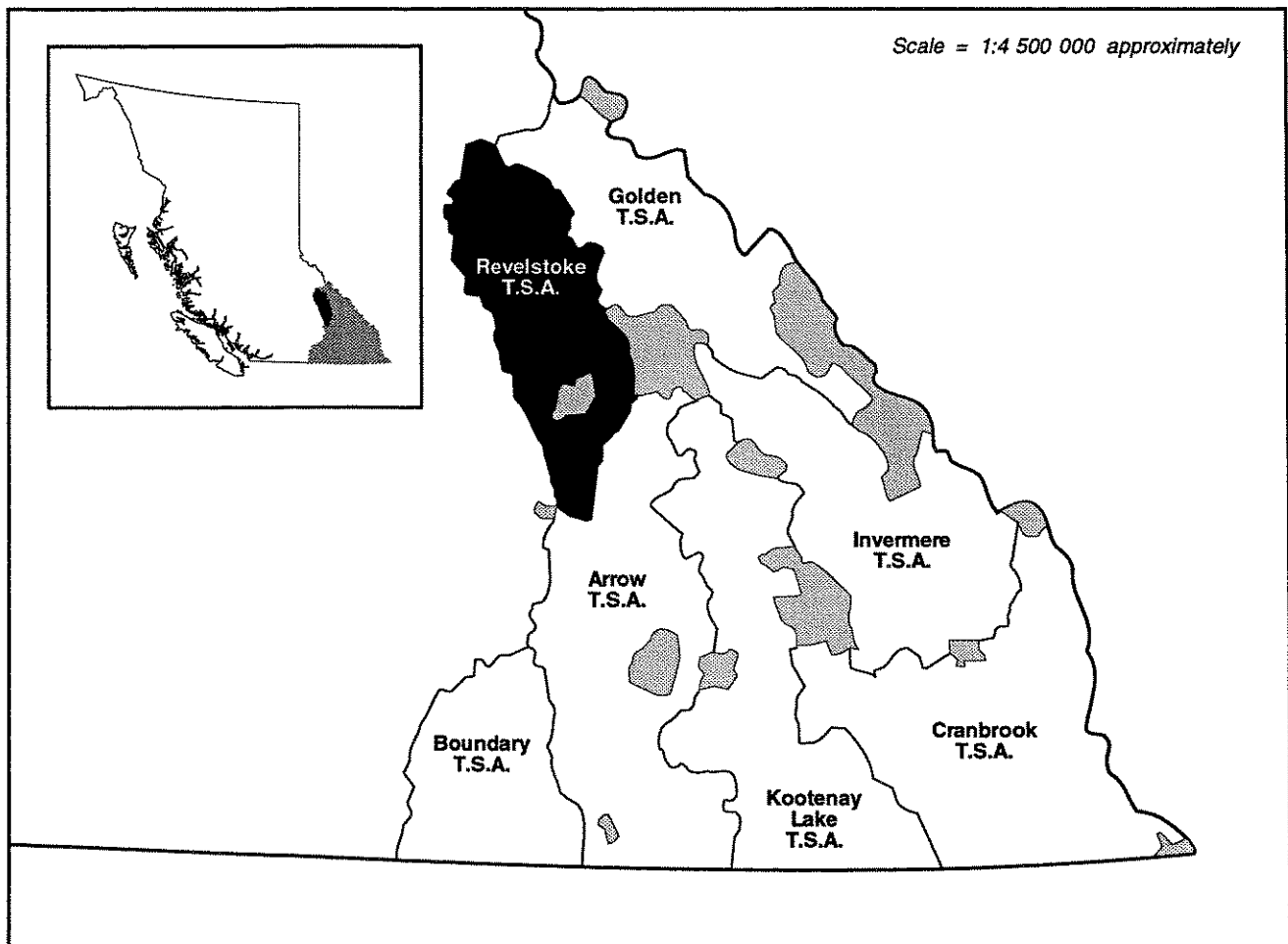


Figure 1. Map of the Revelstoke TSA

2 Information preparation

Many pieces of information are required for timber supply analysis. This information falls into one of three categories: land base inventory, timber growth and yield, and management practices.

2.1 Land Base Inventory

Land base information comes in the form of a computer file compiled by the B.C. Forest Service Inventory Branch. This file contains a wealth of data about the thousands of pieces of forest land that make up a TSA, including the geographic location, area, and nature of forest cover (such as presence or absence of trees, number of trees, species, age, and timber volume).

Initially, this file is a representation of the land base for the entire TSA. It includes data for areas upon which timber harvesting operations are not expected to take place, and therefore do not contribute to the timber supply of the area. Examples are land that has been set aside for a park, areas necessary for maintaining a certain type of wildlife habitat, or the areas occupied by power lines, highways or town sites. (Specific areas applicable to the Revelstoke TSA are described below). Before this land base file is used to make timber supply projections, it is important that data for these non-contributing areas be removed, to arrive at a file that represents the timber harvesting land base*.

This reduced data file is derived through a computer process that identifies data for non-contributing areas and removes it from the file. When making these reductions, care is taken to make only a single reduction where there are overlaps in categories (for example, where a park area is also suitable for wildlife habitat).

It is important to remember that removal of data for areas not contributing to the timber supply does not imply withdrawal of areas from the TSA. The B.C. Forest Service still manages the entire area of the TSA (except for certain designated lands) as a forest unit that contributes a mix of timber and non-timber values. The timber supply is managed within this integrated resource context and the timber supply analysis contained herein is consistent with this philosophy.

This section describes the types of areas not contributing to the timber harvesting land base. Use of the term timber harvesting land base in this report does not mean that an area is open to

unrestricted logging activities. Rather, it implies that forests in the area contain timber of sufficient economic value - and sites with adequate environmental resilience - to accommodate timber harvesting with due care for other resources.

For Revelstoke, the following areas were not part of the timber harvesting land base:

- non-Crown areas - areas not managed directly by the B.C. Forest Service;
- non-forest areas - areas not occupied by productive forest cover (e.g., rock, swamp and alpine areas);
- non-commercial cover areas - areas occupied by non-commercial tree or brush species;
- inoperable areas - areas defined as unavailable for harvest for terrain-related or economic reasons. Characteristics used in defining inoperability include slope, elevation, topography (e.g., the presence of gullies or exposed rock), difficulty of road access, soil stability, and timber quality;
- Environmentally sensitive areas* - A proportion of the areas considered to be sensitive were deducted from the timber harvesting land base.
- non-merchantable forest types* - areas occupied by timber stands containing non-merchantable species, stands of low volume or value, and areas with low timber-growing potential (low site index*.) A portion of the total area in each category was removed.

Timber harvesting land base

The portion of the total land area of a management unit considered to contribute to, and be available for, long-term timber supply. The harvesting land base is defined by reducing the total land base according to specified management assumptions.

Environmentally sensitive areas

An area with significant non-timber values, fragile or unstable soils, problems in establishing a new tree crop or where timber harvesting may cause avalanches.

Non-merchantable forest types

Stands that are accessible and otherwise available for harvesting but are assumed to be non-merchantable due to stand characteristics such as small piece size, incidence of decay and low stocking.

Site index

A measure of site productivity. Site indices are based on tree height as a function of stand age and are usually expressed graphically as site index curves. A number of site index curves have been developed for British Columbia's major commercial tree species.

2 Information preparation

- riparian zones* and avalanche chutes - for the Revelstoke TSA, a 2% area reduction was applied to account for this category
- specific area exclusions:
 - Greeley Creek watershed - this area was considered inoperable because of low value, high cost timber combined with high sensitivity to site degradation and concern for water quality;
 - Mount MacKenzie ski hill development area;
 - road, skid trail and landing areas - to account for the loss of productive forest land that has occurred during past timber harvesting

and development. A deduction of 11% was applied to all areas currently younger than 80 years old. It should be noted that future losses related to access are deducted as harvesting occurs in the B.C. Forest Service timber supply model.

Table 1 summarizes the areas represented by these categories. A more detailed description of these categories and the rationale for their removal is located in Appendix A: Description of Data Inputs and Assumptions.

Riparian Zone

Areas of land adjacent to wetlands or bodies of water such as swamps, streams, rivers or lakes.

Table 1. Timber harvesting land base for the Revelstoke TSA

Classification	Area (ha)	Area (ha)	% of total area	% of productive forest area
Total land base		503 984	100.0	
Non-Crown land		19 309	3.8	
Non-forest land		282 577	56.1	
Total productive forest		202 098	40.1	100.0
Reductions:				
Non-commercial cover	106		0.0	0.1
Inoperable	108 993		21.6	53.9
Environmentally sensitive	21 086		4.2	10.4
Greeley Creek	708		0.1	0.4
Mt. MacKenzie	1 552		0.3	0.8
Non-merchantable types:				
Deciduous types	1 724		0.3	0.9
Low site	1 521		0.3	0.8
Problem forest types	5 020		1.0	2.5
Not satisfactorily restocked	4 629		0.9	2.3
Riparian/Avalanche	1 135		0.2	0.6
Existing Roads	1 745		0.3	0.9
Total current reductions	148 221	-148 221	29.4	73.3
Current timber harvesting land base (less additions)		53 877	10.7	26.7
Additions				
Operable NSR & restocked	4 208			
Timber licence reversions	4 641			
Total additions	8 849	8 849	1.8	4.4
Total current timber harvesting land base		62 725	12.4	31.0
Future reductions				
Roads	4 383	-4 383	0.9	2.2
Long term timber harvesting land base		58 342	11.6	28.9

Note: Some sub-totals may not add up exactly because areas shown have been rounded.

2 Information preparation

Table 1 shows that not satisfactorily restocked* (NSR) areas are also initially deducted. However, the portion of the total NSR area considered available for timber production is then added back into the timber harvesting land base.

Other additions to the final timber harvesting area are Timber Licence reversions. Harvested volumes from these old tenure arrangements do not contribute to the AAC for the TSA. However, once they are harvested, these areas revert to the Crown and future harvests from them will contribute to the AAC. In the Revelstoke TSA, these reversions occur in decades one and four. Only operable areas are included in Table 1.

The bar charts in Figures 2 and 3 summarize the land base categories for the Revelstoke TSA. Figure 2 shows that less than one half of the TSA is Crown forest land and Figure 3 shows that only about one quarter of the Crown forest land is available for timber harvesting. Overall, the timber harvesting land base comprises only about 12% of the total TSA area (see Table 1).

Not satisfactorily restocked (NSR)

An area not covered by a sufficient number of tree stems of desirable species. Stocking standards are set by the Forest Service, Silviculture Branch. If the expected regeneration delay has not elapsed, the land is defined as current NSR. If the expected delay has elapsed, the land is classified as backlog NSR.

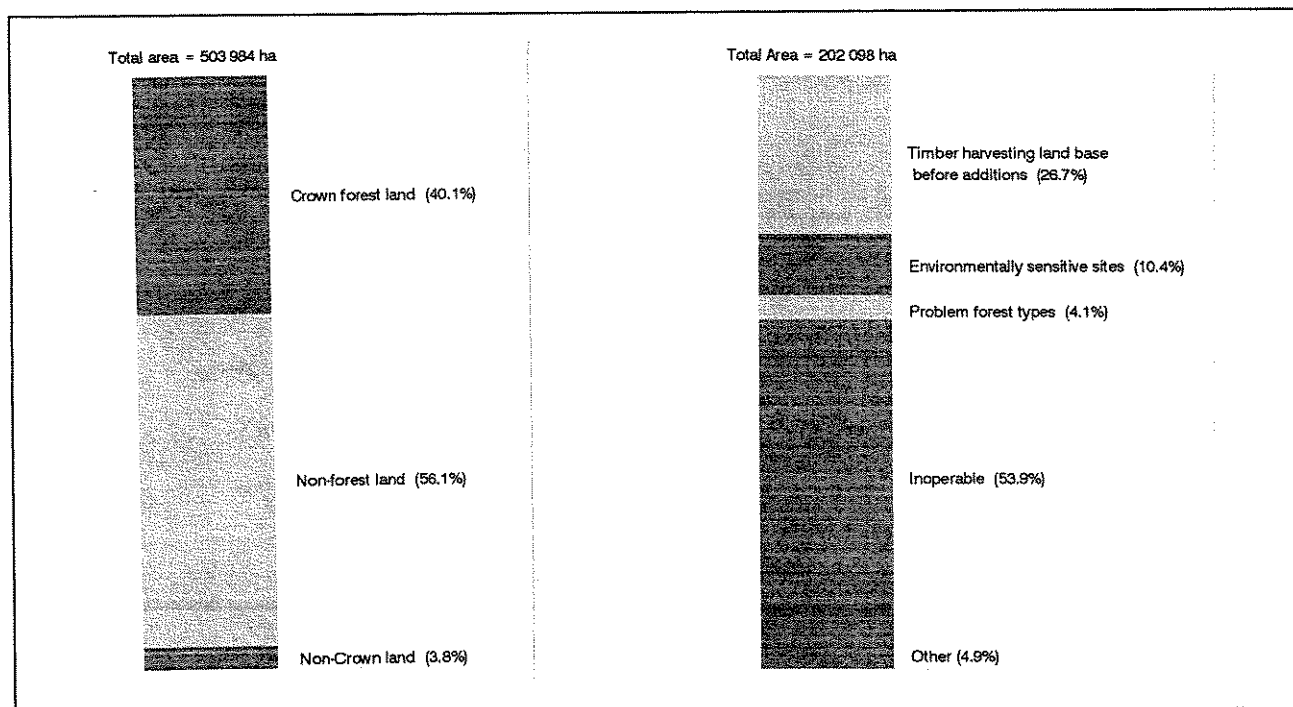


Figure 2. Classification of the gross land base for the Revelstoke TSA.

Figure 3. Crown forest land classification for the Revelstoke TSA

2 Information preparation

Figure 4 shows the distribution of current ages for the timber harvesting land base. For convenience, actual stand ages have been grouped into 20 year age classes. (For example, the 40 year age class represents the area of all stands currently 21 - 40 years old.) Although 50% of the total area is over 200 years old, a significant proportion of the total is also quite young (26% is less than 21 years old). This concentration of younger stands can cause problems in achieving forest cover requirements*. This is demonstrated later in the report (in Section 5, Timber Supply Sensitivity Analyses).

Figures 5 and 6 summarize the tree species composition by area and volume for the timber

harvesting land base. Hemlock, spruce and balsam mixtures and cedar stands are most prevalent but fir stands are also common. It is interesting to note that spruce or balsam dominated stands account for approximately 50% of the total forested area of the TSA (see Section 1, Description of the Revelstoke TSA), but these stands only account for about one quarter of the timber harvesting land base. This is because spruce or balsam stands are the major stands impacted by many of the larger reductions summarized in Table 1. Figures 5 and 6 also show that a much higher proportion of fir, larch and pine stands are immature compared to the other species groups.

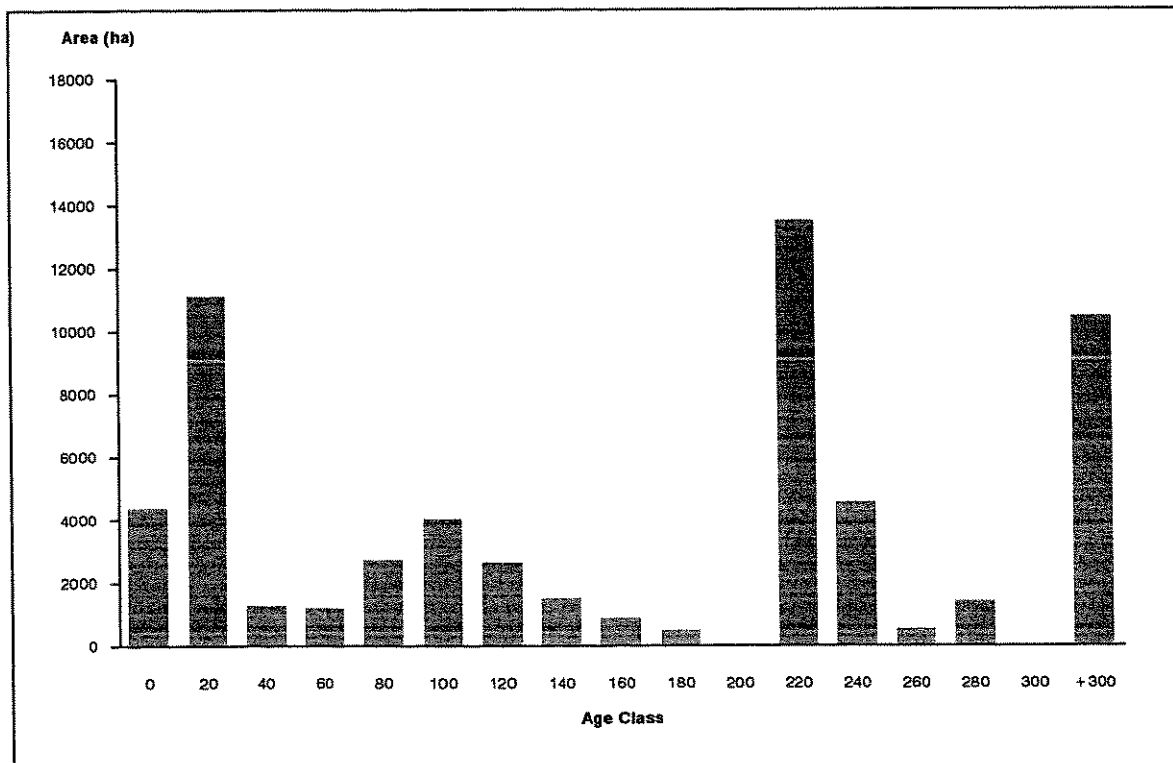


Figure 4. Current age class distribution - timber harvesting land base

Forest cover requirements

Specify desired distributions of areas by age or size class groupings. These objectives can be used to reflect desired conditions for wildlife, watershed protection, visual quality and other integrated resource management objectives. General adjacency and green-up guidelines (see definition boxes for cutblock adjacency and green-up period) are also specified using forest cover objectives.

2 Information preparation

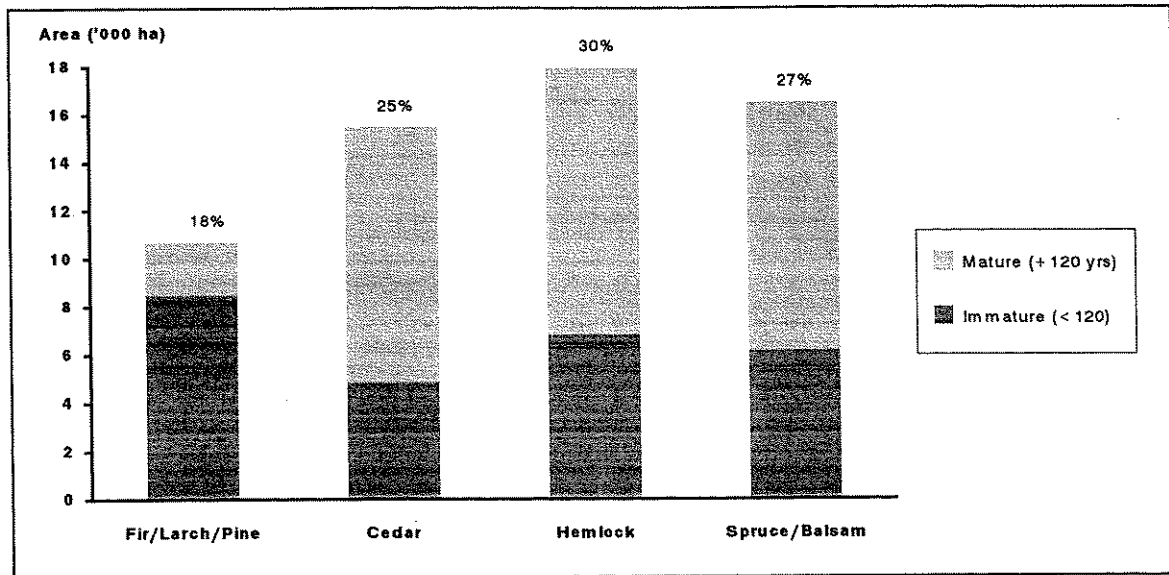


Figure 5. Area by dominant tree species -- timber harvesting land base

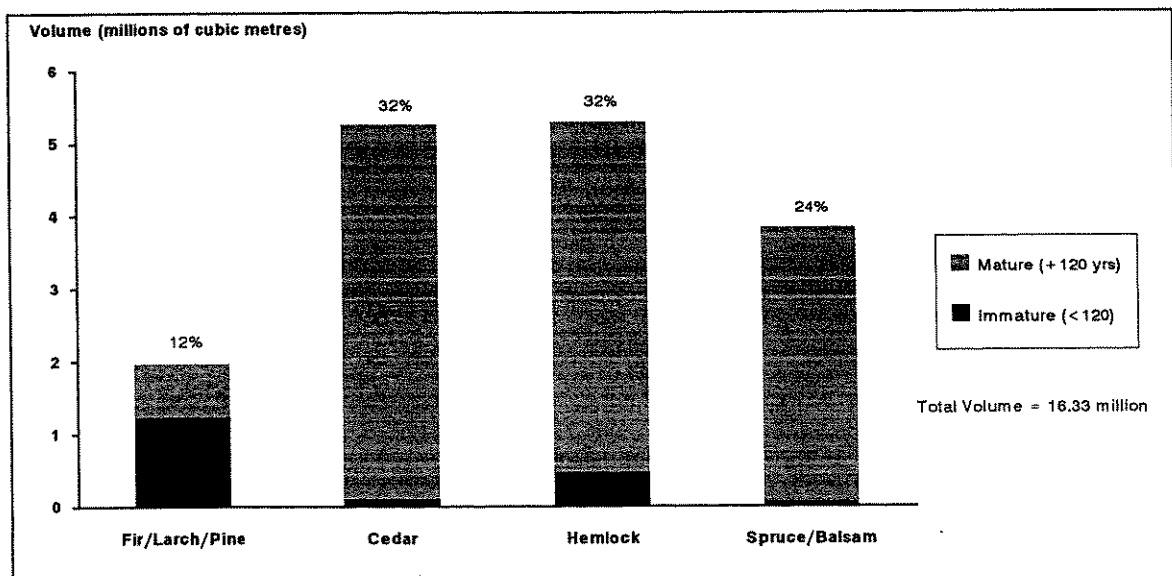


Figure 6. Volume by dominant tree species -- timber harvesting land base

2 Information preparation

2.2 Timber Growth and Yield

Timber growth and yield refers to the prediction of the growth and development of individual forest stands over time. The most common measure of the amount of standing timber is volume per area (in British Columbia, cubic metres per hectare). This measure assumes a utilization level or set of dimensions that establish minimum size limits for trees and logs that can be harvested and must be removed from a site. Utilization levels specify a maximum stump height and minimum diameters at the tree base and top.

Timber volumes for the Revelstoke TSA analysis are based on the variable density yield projection (VDYP) model developed by the B.C. Forest Service Inventory Branch. This model provides estimates of volumes for existing and regenerated (or future) stands according to their age. Sensitivity analysis will address the possibility that actual stand volumes may be different from those predicted.

2.3 Management Practices

The focus of the Timber Supply Review is to describe the timber supply based on current management practices, as implemented in plans for the area. Staff in the Revelstoke Forest District provided descriptions for the following management assumptions*:

- Basic Silviculture - defines reforestation activities required to establish free-growing* stands of acceptable species after harvesting as well as the basic silvicultural systems used in the TSA. In the Revelstoke TSA most areas are managed using a clearcutting system but a small proportion of the TSA is managed using selection management*.
- Unsalvaged Losses - expected timber losses due to fire, pest (insects, disease, animals) and wind damage. For the Revelstoke TSA, unsalvaged losses are estimated to be 30 000 cubic metres per year. These losses are deducted from gross harvest volumes to produce the net volumes shown in Sections 4 and 5.
- Utilization Levels - tree and log size limits assumed.
- Minimum Harvest Ages - the time it takes for stands to grow to harvestable size. The minimum harvest age defines the lower limit for harvesting. Actual harvest age depends on many factors including the ages of other stands, limits on overall harvest level, and forest cover requirements. In the Revelstoke TSA the minimum age for existing stands is 120 years; for regenerated stands the minimum age varies from 100 to 140 years depending on species and site productivity.
- Cutblock Adjacency* and Green-up* - guidelines that specify the spatial pattern of

Management assumptions

Approximations of management objectives, priorities, constraints and other conditions needed to represent forest management actions in a forest planning model. These include, for example, the criteria for determining the timber harvesting land base, the specification of minimum cutting ages, utilization levels and standards, integrated resource guidelines and silviculture and pest management programs.

Free-growing

An established seedling of an acceptable commercial species that is free from growth-inhibiting brush, weed and excessive tree competition.

Selection management

A silvicultural system used to maintain or create areas containing a wide range of tree ages or sizes. The time interval between harvests in such areas is fairly short (usually less than 30 years) and during these harvests either single scattered trees or small groups of trees are removed from across the entire area.

Cutblock adjacency guidelines

Integrated management guidelines that specify the desired spatial relationship among cutblocks.

Green-up period

The time needed for a stand of trees to reach a desired condition (e.g., height) to ensure maintenance of water quality, wildlife habitat, soil stability or aesthetics.

2 Information preparation

cutblocks and amount of time (green-up period) required for regenerated stands to reach some desired condition before adjacent mature timber may be harvested. A related concept, forest cover objectives, is described next.

- Forest Cover Objectives - specify the desired distribution of areas by age or size class groupings (e.g. at least 70% of the forest area should be over 40 years old). These objectives are used to specify general adjacency and green-up guidelines as well as desired conditions for wildlife, watershed protection and visual quality.

A more detailed discussion of these management assumptions can be found in Appendix A: Description of Data Inputs and Assumptions. Current practices do not specifically address old-growth objectives in the Revelstoke TSA. However, impacts of a possible old-growth objective are examined in section 5 using sensitivity analysis.

2 Information preparation

2.4 Management Zones

In the Revelstoke TSA, the basic forest cover objective for the timber harvesting land base was defined by considering cutblock adjacency and green-up period. However, some areas were identified as being particularly important for wildlife and for other areas, visual quality considerations were paramount. Additional forest cover requirements were needed to account for these kinds of areas. It was also necessary to distinguish areas where selection management is to be applied because the harvesting methods used in these areas changes how forest cover objectives are specified.

In recognition of the variety of concerns and objectives the TSA was divided into four major zones for the analysis. These zones are:

- Timber Zone - this zone covers all areas within the timber harvesting land base not specifically assigned to another zone. Current management for this zone is to allow no more than 33% of the zone area to be below green-up height of 3 metres at any time. It was estimated to take 18 years for regenerated stands to reach 3 metres in this zone. It is important to note that the Timber label applied to this zone does not imply that non-timber resource values are ignored. For example, wildlife summer range requirements must be considered in this zone. The use of this label only means that harvesting can occur subject to the normal guidelines for the TSA.
- Zone with Visual Quality* as Objective (VQO Zone) - this zone includes most of the approved partial retention and retention areas in the TSA. Basic forest cover requirements are that no more than 18% of the zone can be less than 5 metres tall (or 25 years old) at any time.
- Wildlife Zone - this zone, located at lower elevations in the northwestern part of the TSA, provides important winter habitat for caribou in the TSA. Forest cover which intercepts snow is crucial, therefore regenerated stands must be fairly tall, with reasonably close-together tree canopies, before adjacent stands can be harvested. Green-up age is estimated to be 40 years (the time required to reach 10 metres) and at least 75% of the area must be past green-up age at all times.
- Selection Management Zone - this zone includes the Dolan Creek watershed and the Begbie Falls area. Normal forest cover requirements do not apply as only small cleared patches are created during harvest.

Figure 7 summarizes the area breakdown by zone for the timber harvesting land base.

Visual quality objective (VQO)
Defines a level of acceptable landscape alteration resulting from timber harvesting.

2 Information preparation

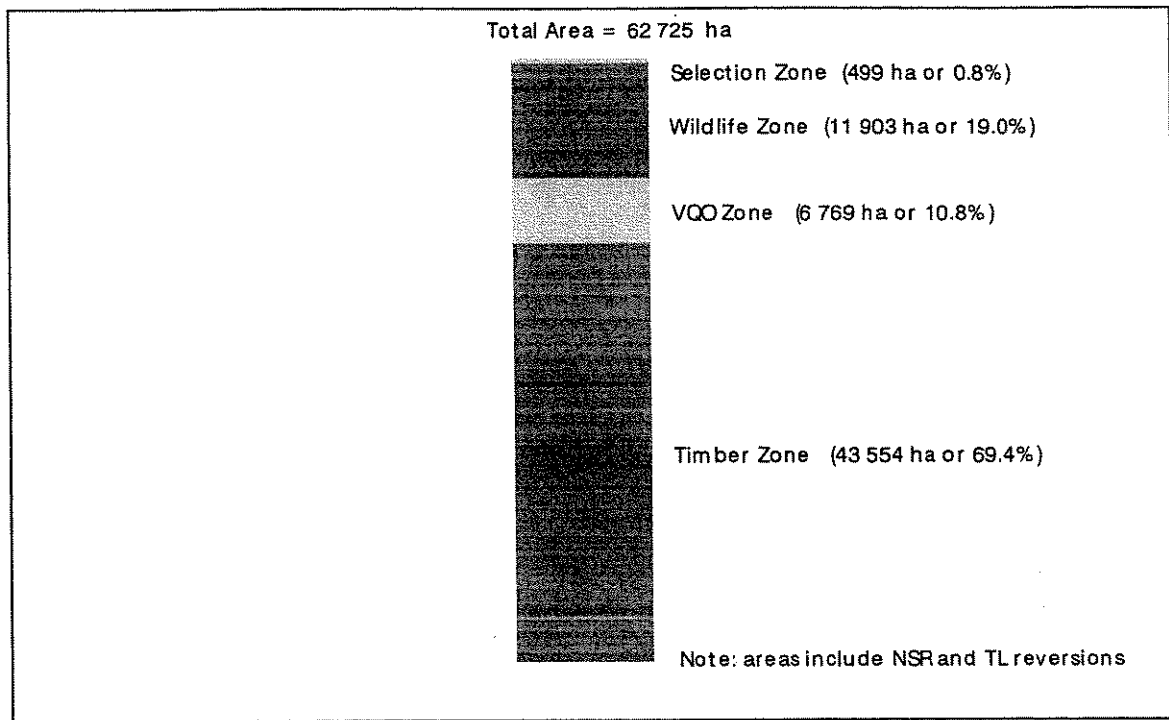


Figure 7. Management zones defined for the Revelstoke TSA timber harvesting land base.

3 Analysis methods

The purpose of this analysis was to examine both the short- and long-term timber harvesting opportunities in light of current forest management practices. A timber supply computer simulation model developed by the B.C. Forest Service was used to aid in the assessment. A timber supply model, as distinguished from a growth and yield model, assists in determining how a whole forest, or collection of stands, should be managed in order to obtain a harvest flow, or supply of timber over time. The simulation model uses information about the timber harvesting land base, timber volumes and the management regime to represent how trees grow and are harvested over a period of 0 to 200 years.

Similar to other models, the B.C. Forest Service model assumes that trees grow according to provided volume projections, and are harvested according to either a volume target or a specified objective set by the analyst, such as harvest volume maximization. However, it differs from other models in that it allows the use of forest cover guidelines that specify the desired age composition of the forest. These cover guidelines can be used to examine the effects of cutblock adjacency and green-up prescriptions. For example, guidelines might specify that no more

than some maximum per cent of the area can be younger than a specified green-up age; or that some minimum per cent of the area must be in older age classes to provide wildlife habitat. The B.C. Forest Service simulation model tests such guidelines to examine their effects on timber supply.

This type of analysis is used to determine the timber-supply implications of a particular timber harvesting regime. The results of the analysis are especially important when determining allowable cuts that will not restrict options of future resource managers, and will allow local B.C. Forest Service staff to administer their programs according to relevant guidelines and principles. However, the results of the analysis should not be viewed as implying any particular AAC recommendation.

The main results of the analysis are forecasts of potential timber harvests and timber inventory changes (ages and volumes) over time. This information gives field staff only very limited guidance in the design of operational activities such as harvesting block location and silviculture planning. It does, however, help ensure that the timber harvest level supports rather than hinders sound sustainable forest management in the field.

4 Results

This section presents the results of the timber supply analysis based on the timber harvesting land base and management practices already described.

4.1 Harvest Forecast

The base harvest forecast* for the Revelstoke TSA is shown in Figure 8. The harvest level is initially 254 000 cubic metres per year or 5.6% less than the current AAC. After the first decade the harvest level declines at 12% per decade until a long-term harvest level of 98 000 cubic metres is reached in decade 8. The harvest from that period on can be maintained indefinitely except for the tenth decade when the harvest is slightly below the long-term level.

This short fall occurs primarily because much of the initial inventory, particularly in the Timber Zone, has been harvested but there is not enough regenerated or second-growth timber old enough yet to harvest. This is magnified by forest cover requirements - in two zones it was not possible to harvest all of the mature timber available because forest cover constraints limited the total area that could be harvested in decade 10. Beginning in decade 11, more second-growth stands become mature and maintaining the long-term harvest level to the end of the planning horizon is possible.

It is important to note that the long-term harvest level of 98 000 cubic metres per year should not be interpreted as being the same as a maximum sustainable harvest level based on the mean annual increment*. The maximum long-term harvest which is about 134 000 cubic metres per year is not achievable because of a number of factors. First, losses from fire and other causes must be deducted from the theoretical maximum. This reduces the maximum to about 104 000 cubic metres. Second, stands are frequently harvested at ages other than those that maximize stand volume production. This can occur because of specified minimum harvest ages, the required harvest flow pattern over time and because of forest cover requirements.

A constant volume of growing stock* serves as one indicator that a particular harvest level can be sustained over the long-term. Figure 9 shows that the harvest forecast does produce a fairly constant growing stock level over the long-term once most of the initial forest is replaced by a second-growth forest and the harvest decreases to a constant 98 000 cubic meters per year. If the long-term harvest level exceeded the productive capability of the land, the growing stock would continue to decline, resulting in a shortage of available timber. Figure 9 also shows available growing stock which is the growing stock volume counting only stands above the minimum harvest age. The low level in decade 10 illustrates the difficulty in achieving the long-term harvest level in that period.

Note that the harvest forecast shown here, as well as those in Section 5, provides an upper limit on timber supply given the land base and management practices discussed above. This forecast is for discussion purposes only and is not meant to suggest a particular AAC.

Harvest forecast

The flow of potential timber harvests over time. A harvest forecast is usually a measure of the maximum timber supply that can be realized, over time, for a specified land base and set of management assumptions. It is a result of forest planning models and is affected by the size and productivity of the land base, the current growing stock, and management objectives, constraints and assumptions

Mean annual increment

Stand volume divided by stand age. The stand age at which the MAI assumes its maximum value is called the culmination age. Harvesting all stands at this age results in a maximum average harvest over the long-term.

Growing stock

The volume estimate for all standing timber, of all ages, at a particular time.

4 Results

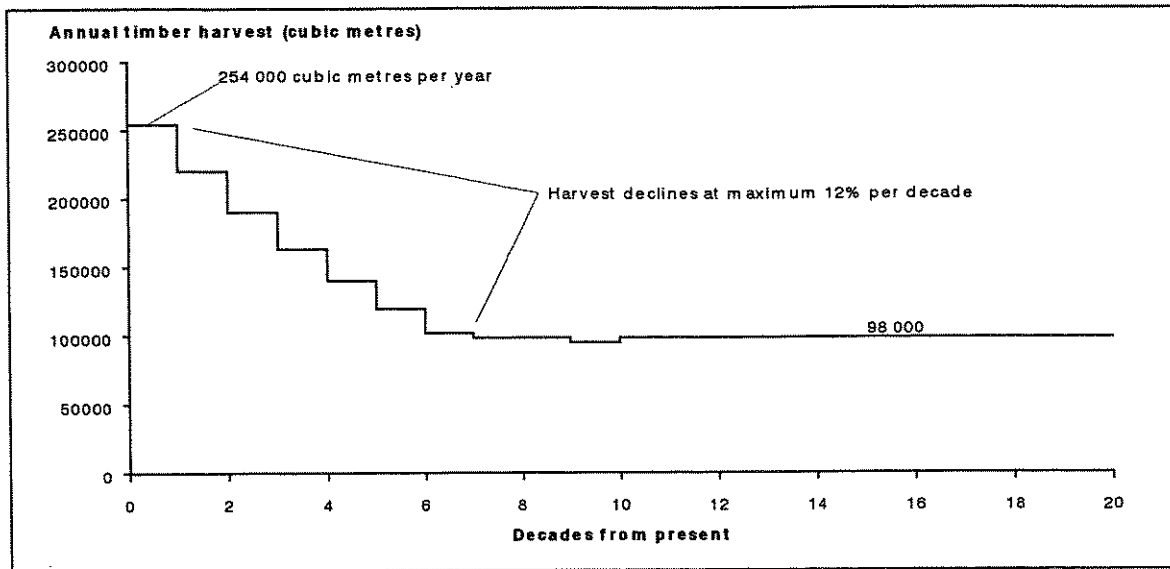


Figure 8. Harvest forecast for the Revelstoke TSA

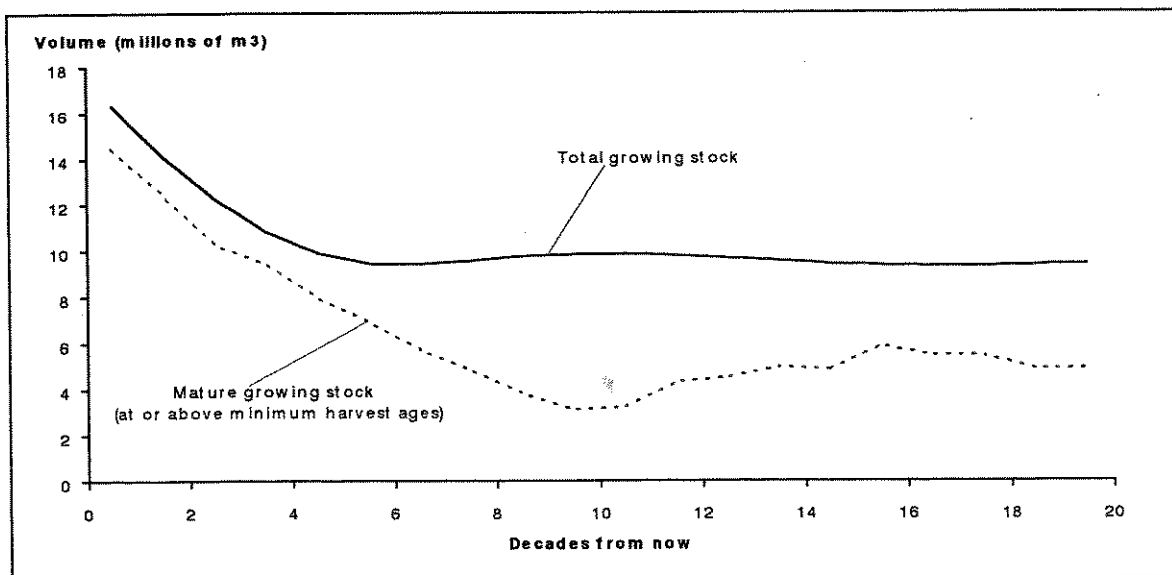


Figure 9. Growing stock over time for the Revelstoke TSA

4 Results

4.2 Age Class Distribution over Time

Figure 10 shows the changes that occur in the forest age class distribution over the 20 decade planning horizon. Initially most of the forest is over 200 years old but over the planning horizon it is gradually converted to a much more balanced age class distribution. The projected age class distribution 10 decades from now helps illustrate why there is a problem in achieving the long-term harvest level in that decade. Initially 55% of the area is over 120 years old but in decade 10 the area over 120 years drops to only 12%. In addition, the area of timber available for harvest in decade 10 is actually less than the total shown because forest cover constraints make some of the mature timber unavailable for harvest. After decade 10 the proportion of area above 120 years increases and by decade 20, the proportion of the area above 120 years is 24%.

4.3 Average Area Harvested, Harvest Age and Volume per Hectare

Average area harvested, shown in Figure 11, starts at over 550 hectares per year then declines generally to a low of about 300 hectares per year in decades seven to nine before stabilizing at an average of slightly less than 400 hectares per year from decade 10 onwards. The initial decline is due primarily to the decreasing total harvested volume in each period from decade one to decade eight. However average area increases again as regenerated stands begin to get harvested. Since these second-growth stands are harvested at lower ages, volumes per hectare are less and more area must be harvested to achieve the same total harvest as earlier (see Figures 12 and 13).

Average harvest ages initially decline slowly from over 300 years in decade one to about 225 years in decade eight (Figure 12). Then there is a rapid decrease to less than 150 years in decade ten. Average harvested volume per hectare (Figure 13) follows a similar trend.

4 Results

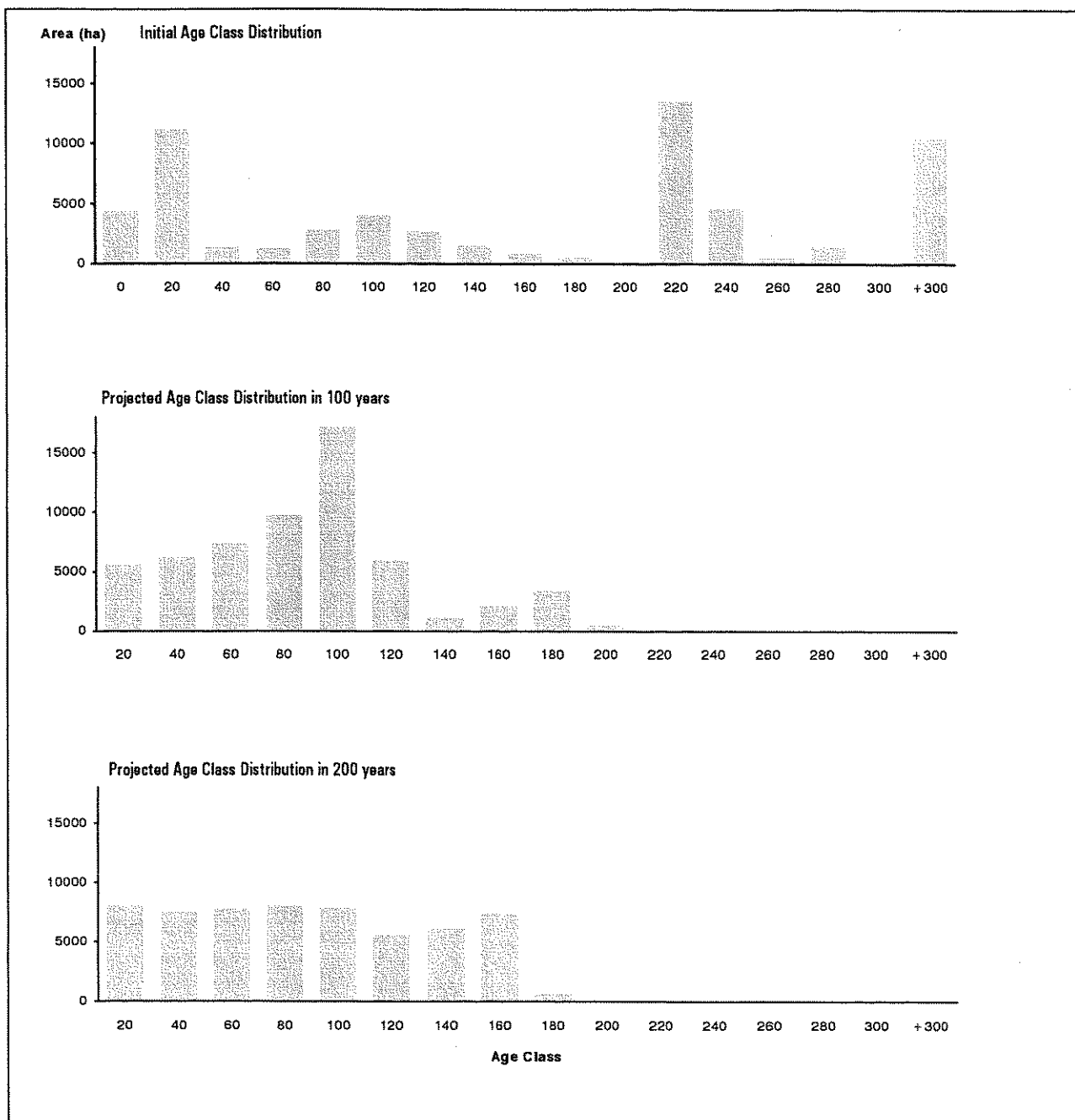


Figure 10. Changes in the age class distribution for the TSA over time.

4 Results

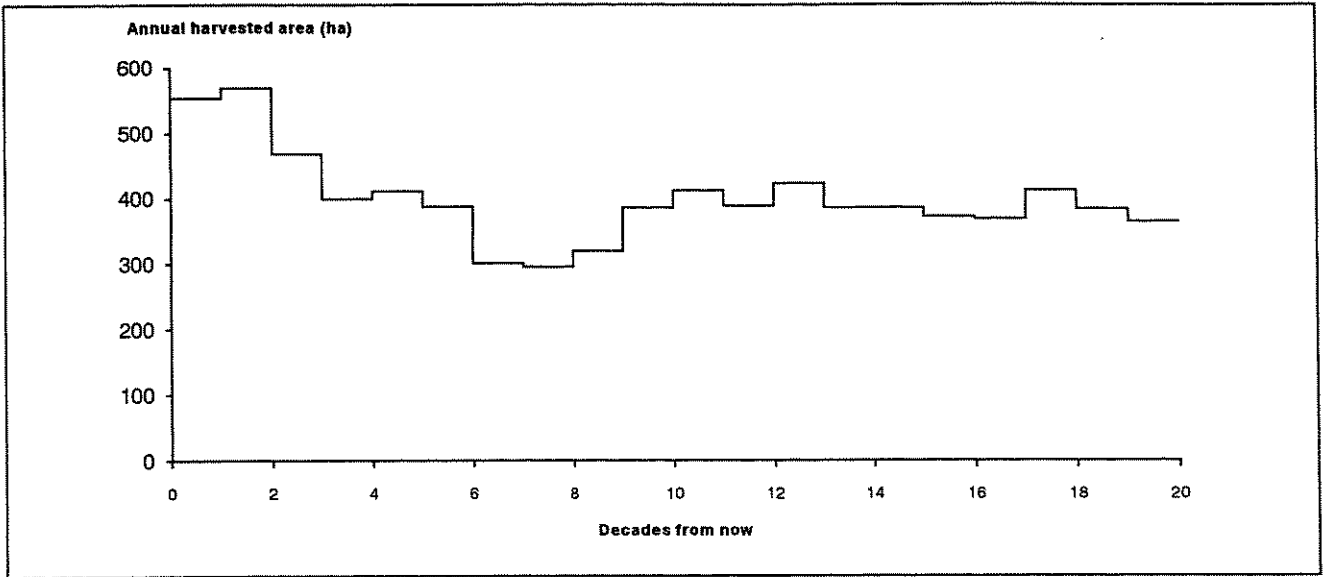


Figure 11. Change in area harvested per year over time

4 Results

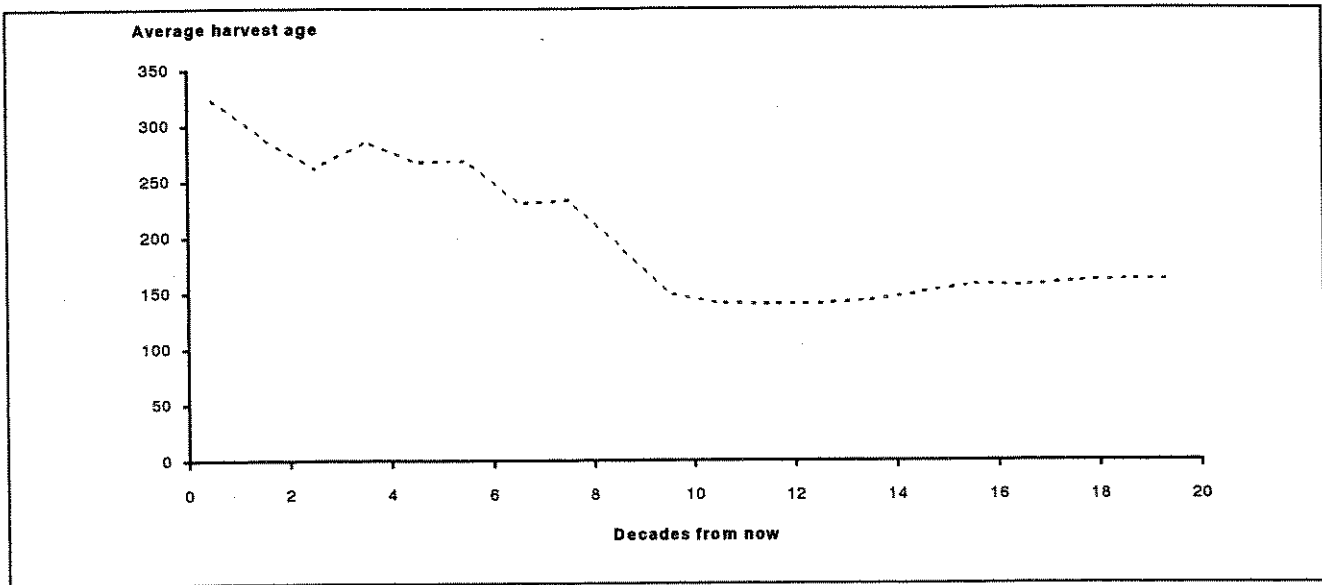


Figure 12. Change in harvest age by decade over time

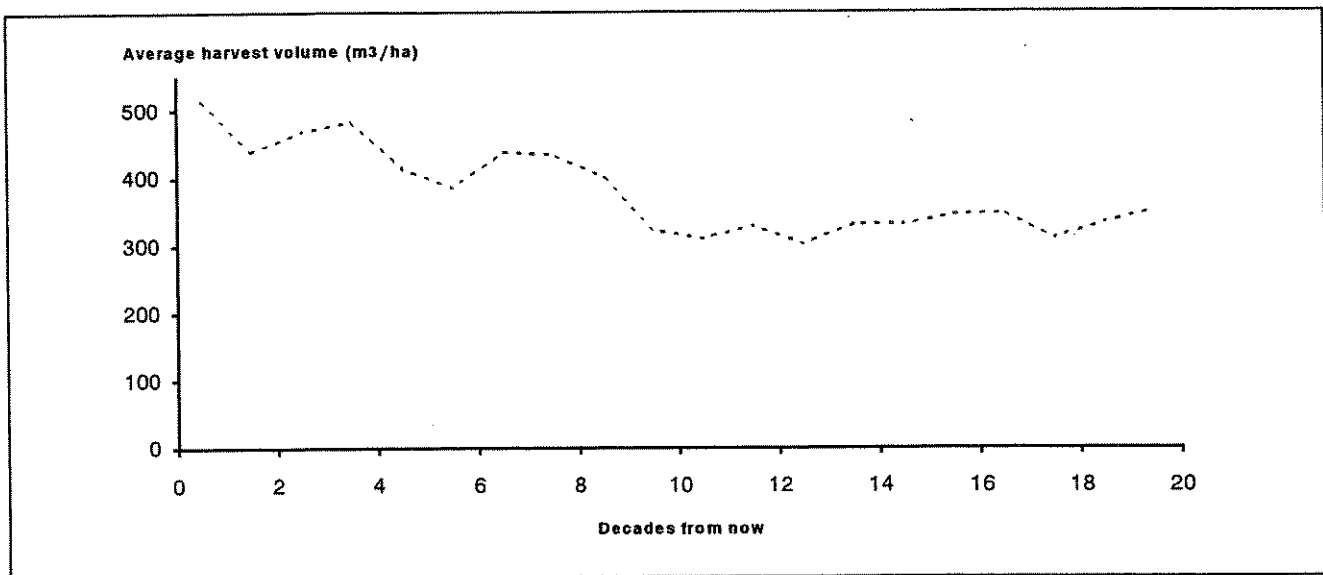


Figure 13. Average harvested volume per hectare over time

4 Results

4.4 Species Mix for the first two Decades

Figure 14 summarizes the tree species composition for the first decade harvest based on two separate runs of the Forest Service timber supply model. The runs were identical except that the ordering of stands for harvest was varied slightly. In both runs, oldest stands were always harvested first but the order of harvest changed within similar age

groups. The results indicate that it may be difficult to achieve the desired species mix in the first decade. The results for the second decade (not shown) are much closer to the desired mix of species in both runs although the volume obtained from stands dominated by fir remains at less than 1 % of the total and approximately 5 % more volume from cedar dominated stands is harvested than desired.

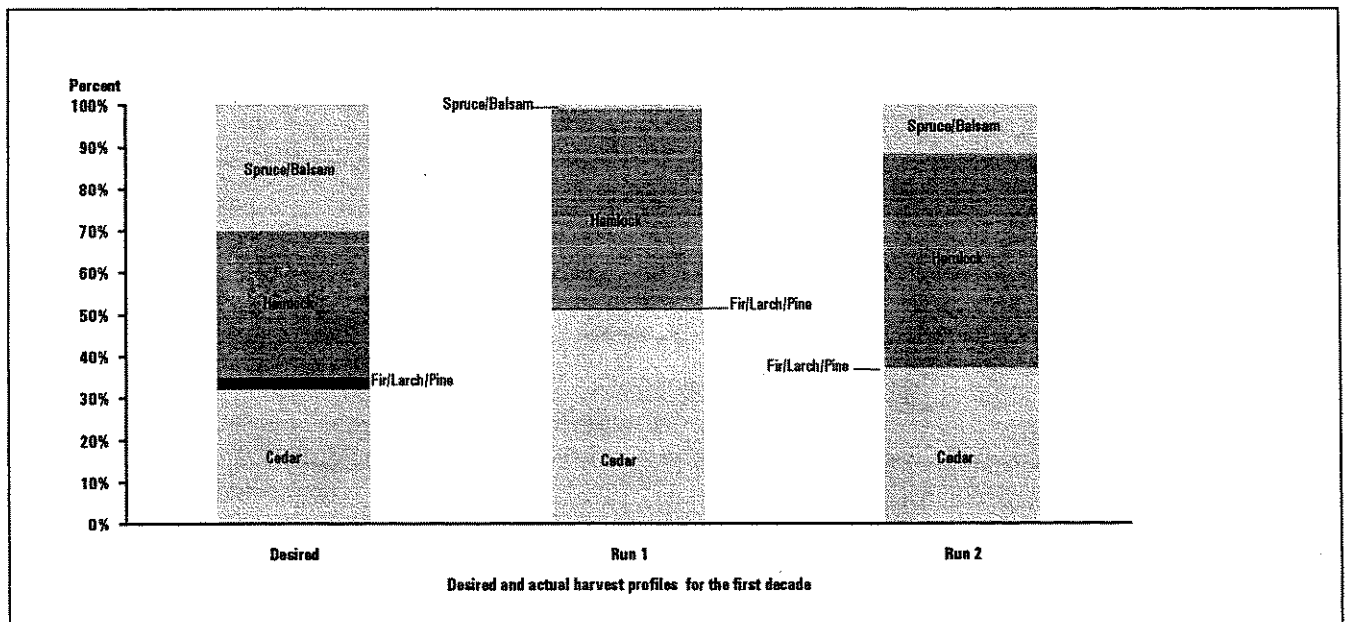


Figure 14. Volume harvested by dominant species in the first decade

5 Timber supply sensitivity analyses

Sensitivity analysis is the exercise of examining how uncertainty in data and assumptions affect the outcome of analysis. The main purpose of timber supply sensitivity analysis is to highlight which variables most affect results. It is an important aid to decision making, since uncertainty surrounds estimates of many variables used in timber supply analysis. The best available information on forest inventories and management practices is used to analyze the implications for timber supply of current performance. However, it is possible that small inaccuracies in some variables could have large effects on results. On the other hand, fairly large inaccuracies for other variables may have negligible effects. Sensitivity analysis can therefore highlight priorities for collecting information for future analyses. As well, it can clarify for decision makers whether current best estimates are safe bases for decisions, or whether high uncertainty around important variables necessitates more conservative decisions.

In this section, results of several sensitivity analyses are outlined. The results that are based on current forest management assumptions (shown in Figure 8) is referred to as the base case.

5.1 Changes in Harvest Flow over Time

The base case harvest forecast in this analysis started at 254 000 cubic metres then declined by a constant 12% per decade until the long-term harvest level was achieved in decade eight. Many other harvest patterns are possible. This section examines several alternatives.

It is often useful to evaluate the impacts of setting the initial harvest volume to the current AAC. Figure 15 shows the results of starting with a harvest level equal to the current AAC, 269 000 cubic metres, and then declining by 10% per decade. If management assumptions remain constant, significant shortfalls will occur in decades eight to ten with volumes falling below 36 000 cubic metres in decade ten. The reason for this is that the existing growing stock has been depleted before sufficient regenerated stands are old enough to harvest. Increasing the rate of decline from 10% per decade to 12% per decade prevented the harvest shortfalls in decades eight and nine but the harvest in decade 10 still fell 60% below the long-term harvest level (this alternative is not shown). It is clear that the current AAC is not achievable without allowing faster rates of decline each period, by accepting major shortages in later periods or by changing management practices.

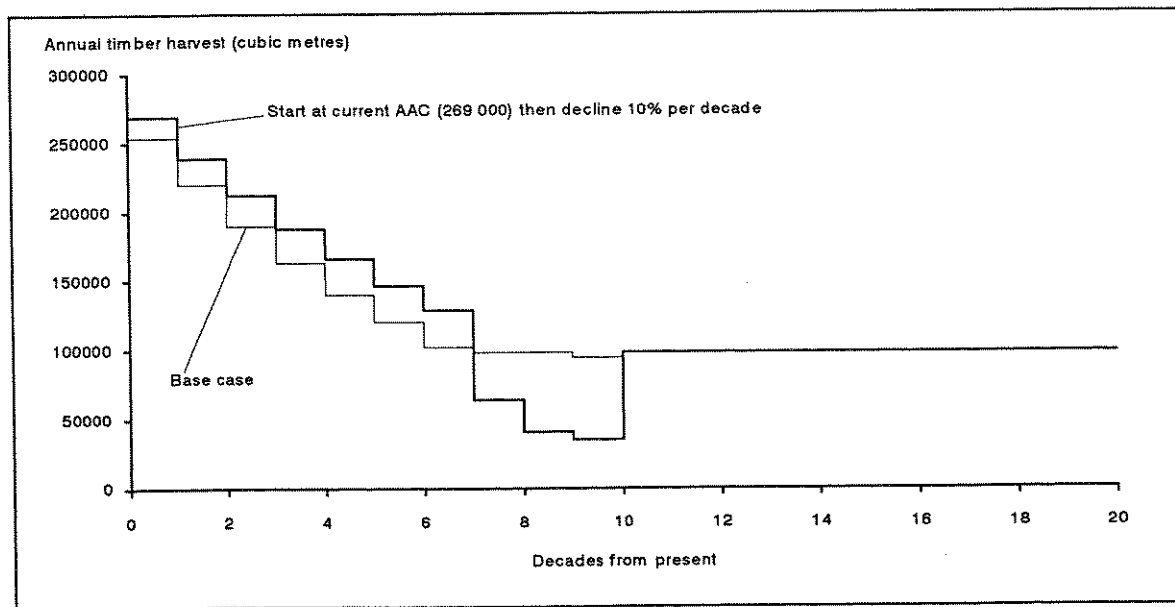


Figure 15. Harvest forecast if start at current AAC and decline at 10% per decade.

5 Timber supply sensitivity analyses

If a rate of decline slower than 12% per period is desired the initial harvest level must be lowered. This is illustrated in Figure 16. If the maximum rate of decline permitted is 10% per decade the initial harvest level must drop to 237 000 cubic metres (7% less than the base case) to avoid future supply problems. A slight shortfall (4% below the long-term level) in decade ten still occurs with this alternative.

Another possible flow pattern is to maintain the same harvest for two decades before declining at some specified rate in later periods. Initially, an attempt was made to hold the base case initial harvest, 269 000 cubic metres, for two decades before declining 12% each decade. This alternative is not shown here because the volumes in decades nine and ten are identical to those shown in Figure 15 and the volume for decade eight is only slightly larger than shown in that figure. The next alternative was to find an initial harvest level that would not cause future harvests to decline significantly below the long-term level.

Figure 17 shows that the initial harvest must be decreased 11% relative to the base case if the

initial harvest is to be maintained for 20 years followed by a 12% decline each period.

The last flow pattern evaluated was to lower the initial harvest to the long-term level of 98 000 cubic metres per year and then remain at the long-term level for the entire planning horizon. With this alternative, the initial harvest is 61% less than the base case initial harvest and the total volume harvested over 200 years is 20% less than for the base case.

If harvests are decreased immediately to the long-term level growing stock declines at a much slower rate than for the base case (Figure 18). At the end of 200 years total growing stock is still over 12 million cubic metres, almost 30% greater than for the base case. Figure 19 shows that average harvest ages remain above 275 years for the first 11 decades before declining below 200 years. Maintenance of older timber and higher levels of growing stock over longer periods of time may increase risks to forest health and raise protection concerns. It is interesting to note that both growing stock and average harvest age were still decreasing at 400 years when the planning horizon was extended past 20 decades.

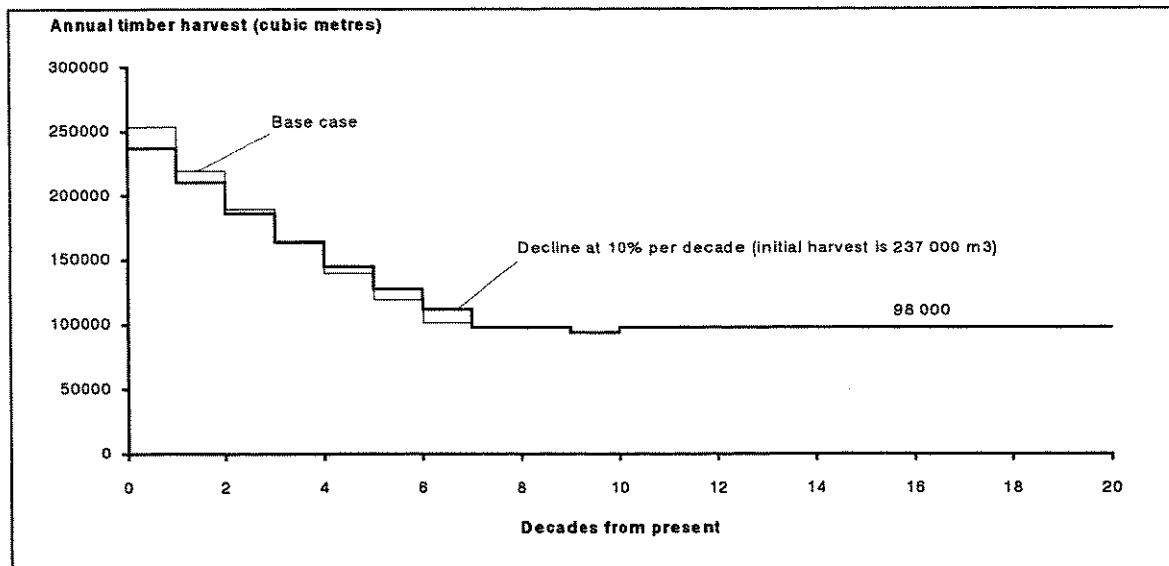


Figure 16. Harvest forecast if maximum rate of decline is 10% per decade

5 Timber supply sensitivity analyses

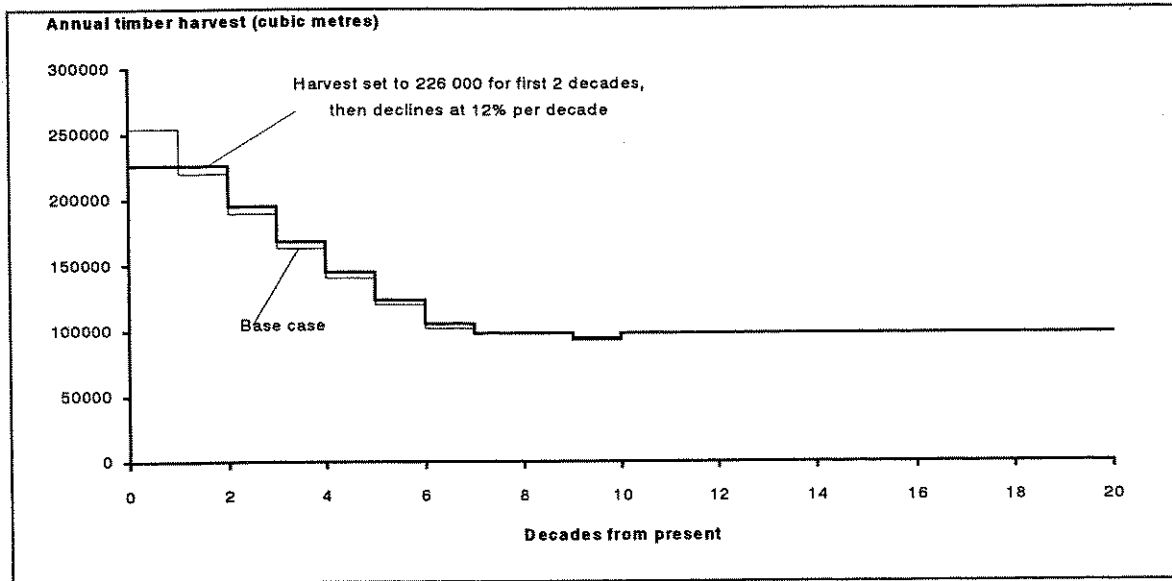


Figure 17. Harvest forecasts if decline in harvest begins after the second decade

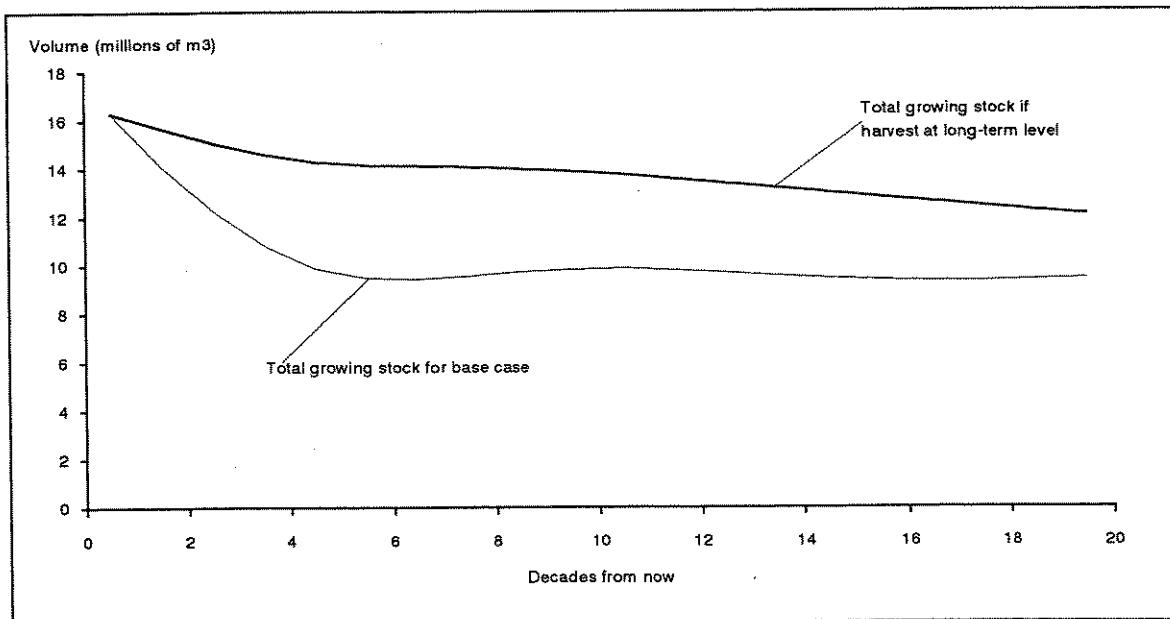


Figure 18. Growing stock over time if harvest level is constant at the long-term level

5 Timber supply sensitivity analyses

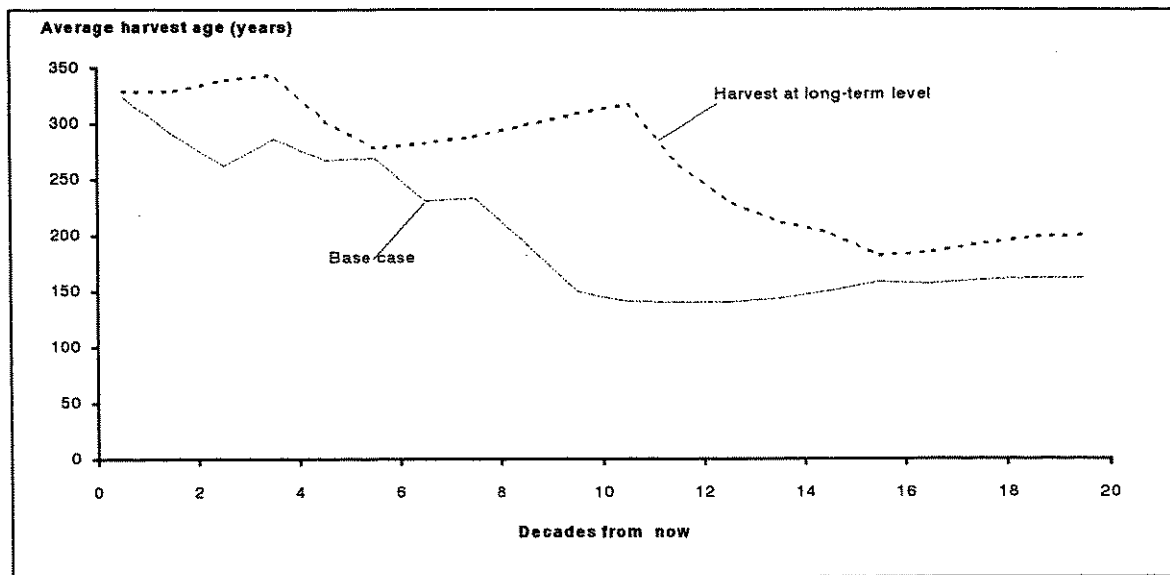


Figure 19. Harvest age by decade if harvest level is constant at the long-term level

In summary initial harvest rates are highly sensitive to changes in the harvest flow pattern specified. Initial harvest levels above the base case of 254 000 cubic metres would require rates of decline of more than 12% per decade if future harvests cannot fall significantly below the long-term level. In contrast, lower initial harvest levels would permit slower rates of decline to the long-term level.

5.2 Uncertainty about Minimum Harvest Ages for Existing Stands

In the base case the minimum harvest age for existing stands was set to 120 years. In the simulation results, actual harvest ages remained above 150 years until the tenth decade when some stands less than 120 years old were harvested.

Figure 20 shows the results of changing the minimum harvest age by 20 years (to 100 and 140 years). Although decreasing minimum harvest ages makes more timber available in all periods, this increased availability is particularly important in the critical period around decade ten. The additional volume available then allows the harvest in the first decade to increase 6%, to the current

AAC, although a 12% rate of decline is still required in subsequent decades to prevent future harvests from declining below the long-term level.

Increasing the minimum age in contrast makes less timber available in all periods. As a result the initial harvest must be lowered so that the available inventory lasts longer. The initial harvest in Figure 20, 242 000 cubic metres, is 5% less than for the base case harvest.

Initial harvest levels are moderately sensitive to changes in minimum ages for existing stands. Moreover, increasing minimum ages has about the same impact, but in an opposite direction, as does decreasing minimum ages an equal amount.

5.3 Uncertainty about Minimum Harvest Ages for Regenerated Stands

For the base case, the youngest ages at which second-growth stands will be available for timber harvest vary from 100 to 140 years with the average being 114 years. These ages are subject to a moderate degree of uncertainty given changes in harvesting and processing technology, silvicultural practices and because of lack of information on regenerated yields.

5 Timber supply sensitivity analyses

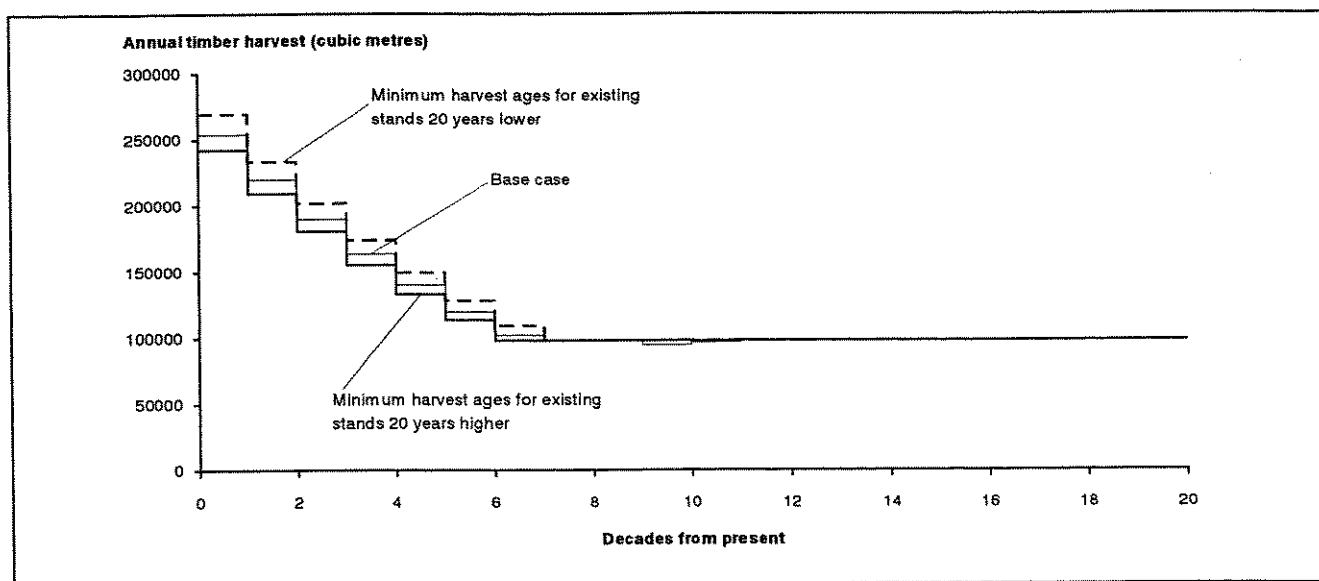


Figure 20. Harvest forecasts if minimum harvest ages for existing stands are 20 years shorter or longer than assumed for the base case.

Analysis results in this section are intended to show how uncertainty about minimum harvest ages for second-growth stands can affect timber supply.

Figure 21 shows the harvest forecasts that result if the minimum harvest ages used in the base case were actually 20 years younger or older than assumed for the base case. Lower ages make regenerated timber available earlier. This makes more timber available in the transition period between harvest of existing natural stands and second-growth stands. As a result the initial harvest can be raised 6% to the current AAC. The long-term harvest level also increases slightly but not enough to be evident in Figure 21.

Higher minimum harvest ages have the opposite effect. There are fewer regenerated stands available in the transition period to offset the declining availability of natural stands. The initial harvest must decrease by 3% to 247 000 cubic metres to avoid supply problems in later periods. The long-term harvest level decreases

slightly to 96 000 cubic meters because most stands are harvested at ages that reduce average volume production.

Minimum harvest ages for the base case were based on a number of factors, only one of which was maximum average volume production. Setting minimum ages on the basis of maximum average volume growth (or maximum mean annual increment) increases the range of minimum harvest ages from 80 to 160 years but the average age decreases to 107 years. The impact of using these revised ages is presented in Figure 22. The initial harvest again increases to the current AAC (269 000 cubic metres) and the long-term harvest increases slightly to 99 000 cubic metres.

Overall, the short-term timber supply for the Revelstoke TSA is only moderately sensitive to assumptions about minimum harvest ages for regenerated stands. The positive impact of lower minimum ages is slightly larger than the negative impact of an equivalent increase in ages.

5 Timber supply sensitivity analyses

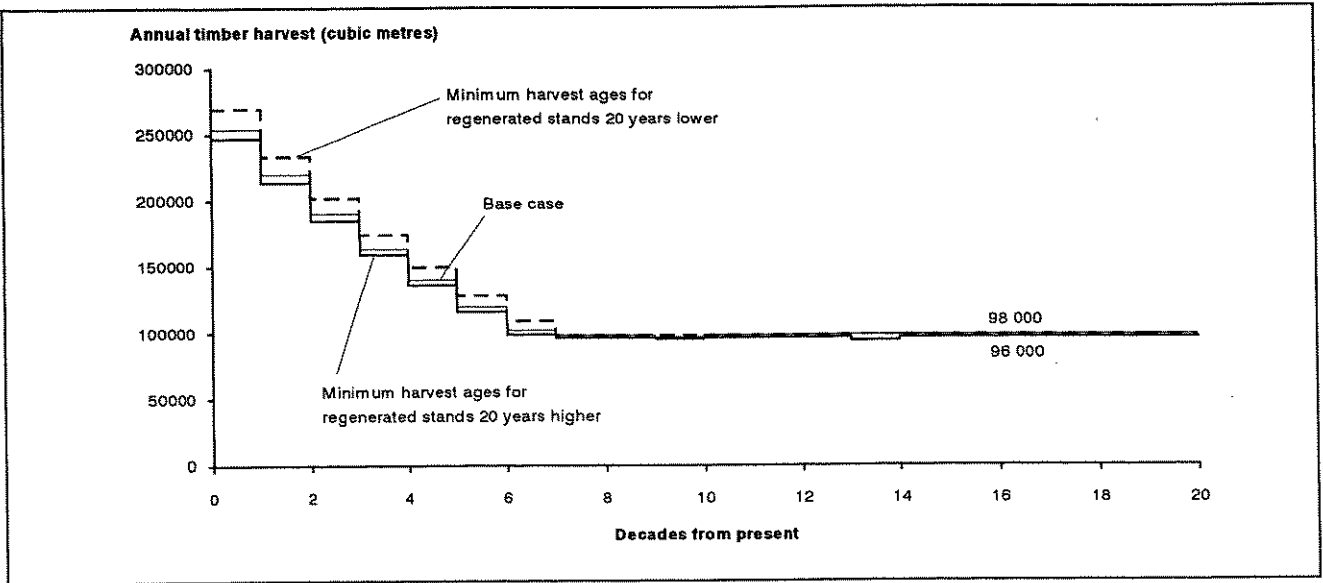


Figure 21. Harvest forecasts if minimum ages for regenerated stands are 20 years lower than assumed in base case.

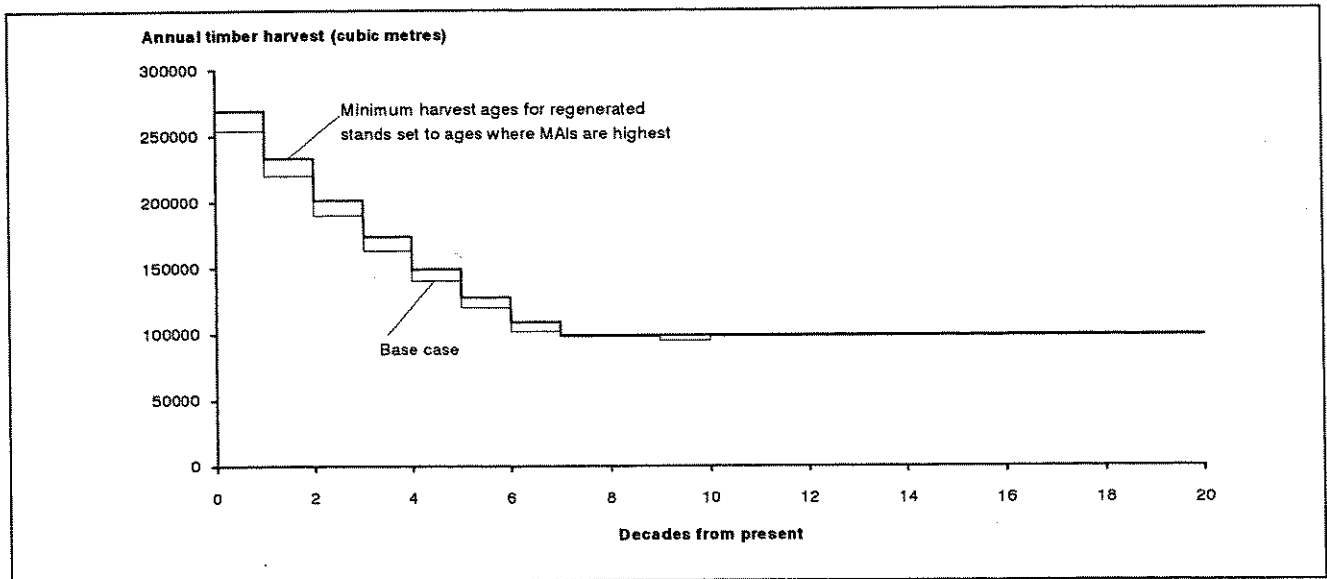


Figure 22. Forecast when minimum ages for regenerated timber are based on MAI culmination

5.4 Uncertainty about Existing Stand Volume Estimates

Volume estimates from the variable density yield projection (VDYP) system were used in the base case for existing stands. The purpose of this analysis is to estimate the impacts on timber supply if volume yields of existing stands are greater than or less than those assumed for the

base case. The analysis also approximates the impacts of aging errors in the inventory as under- or over-estimates of actual ages results in more or less actual volume being realized than is predicted by the yield projections system. The impacts of uncertainty in regenerated yields and of uncertainty about all yields concurrently are examined in the following 2 sections.

5 Timber supply sensitivity analyses

If current yields are 10% higher than was assumed for the base case the initial harvest can be raised by 6% to the current AAC (Figure 23). The additional inventory also permits a slower rate of decline (10%) to the long-term level than was possible for the base case. Lower current yields have a larger impact than higher yields. If current yields are 10% lower, the initial harvest must be decreased by 16% from the base case harvest to avoid timber supply shortages in decade 10.

The results indicate that initial harvest levels are moderately sensitive to increases in existing

stand volumes but highly sensitive to decreases in existing volumes. Long-term harvest levels are unaffected by changes in current yields. It should be noted that Revelstoke district staff believe that the volumes for mature timber used in this analysis are optimistic. Analysis of the Revelstoke inventory and yield data indicate that this could be true as it appears that site quality (measured as site index) may in some instances be lower for mature stands than for immature stands. The lower site quality would result in lower predicted volumes for mature stands.

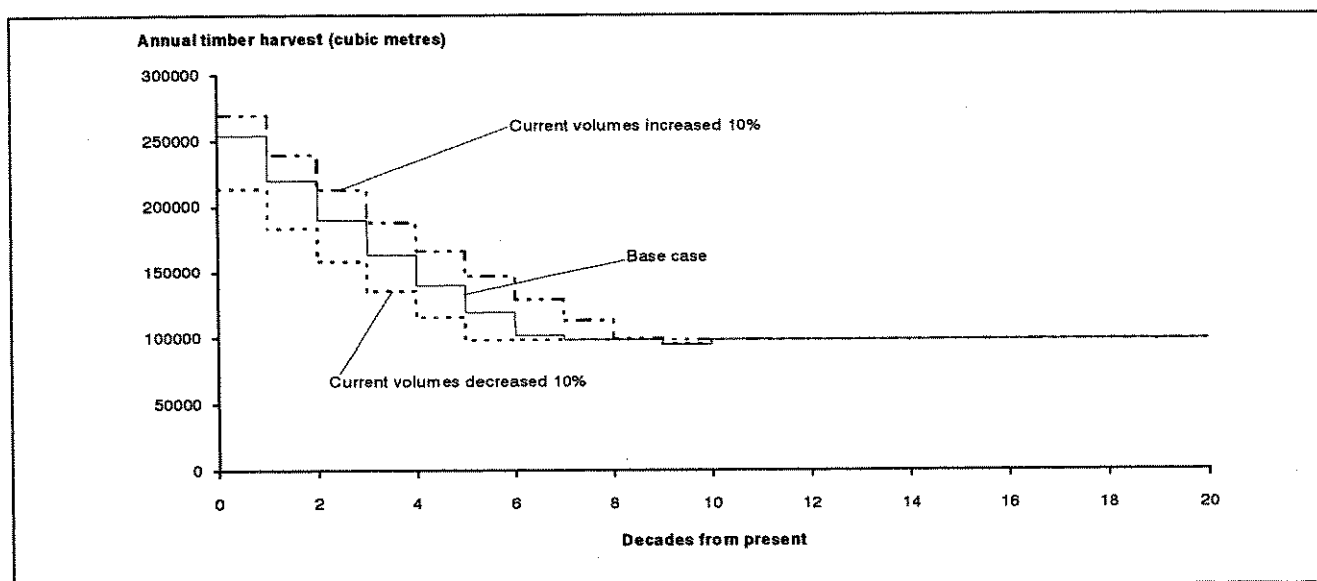


Figure 23. Harvest forecasts if current volume estimates are 10% higher or lower than assumed for the base case

5.5 Uncertainty about Regenerated Stand Volume Estimates

The VDYP system was also used to estimate volume yields for regenerated stands as it was not possible to use managed stand yield projection models (e.g. TASS) at the time of this analysis. In fact, regenerated volume yields were effectively the same as for existing stands. The purpose of

this analysis was to determine if there were any serious implications of using this procedure given that yields for regenerated stands might be quite different from those of the stands they replace.

Another reason for this particular analysis is that Revelstoke staff believe that the regenerated yields are too low and therefore the long-term harvest level is being under-estimated in the base case.

5 Timber supply sensitivity analyses

Figure 24 summarizes the results if regenerated yields are 20% higher than those used in the base case. If yields are 20% higher but minimum harvest ages are not changed from those used in the base case, it is not feasible to harvest above base case harvest levels until decade ten and there is no significant increase possible until the 11th decade. Any attempt to harvest at the new long-term level of 124 000 cubic metres per year in decades six to ten results in major shortfalls 90 to 110 years from now. This occurs because increased yields from regenerated stands are not yet available to offset the increased volumes requested for decades six to ten.

A second alternative was examined to see if lower minimum harvest ages would allow some increase in harvest levels in earlier decades. In this alternative, regenerated yields were increased 20% but in addition minimum ages were reduced to ages that produced the same volume per hectare as for the base case. From Figure 24 it is clear that the age adjustment is not sufficient to allow harvest rates to be increased in decades six to nine without creating a serious shortage of timber in decade ten.

These results indicate that while 20% higher volumes for regenerated stands would increase the

long-term sustainable harvest, they would not affect short-term timber supply. It is possible however that very large increases in regenerated yields, combined with substantially lower harvest ages, could produce some change in short-term timber supply.

Figure 25 summarizes the results if regenerated yields are 20% less than those assumed in the base case. In the first alternative, yields are decreased but minimum harvest ages are not changed. With this change, the initial harvest can increase by 5% over the base case to 267 000 cubic metres before declining at 12% per decade to a new long-term harvest of 71 000 cubic metres. This result is counter-intuitive because it seems that lower volumes in the future permit higher harvests now. The reason this happens is that the harvest levels in decades eight to ten can now be lower than they were in the base case while still satisfying the requirement that harvest levels not fall below the long-term level.

Since less timber needs to be held to avoid possible timber supply problems, particularly in decades nine and ten, the initial harvest can be raised without causing future harvests to fall below the new long-term level.

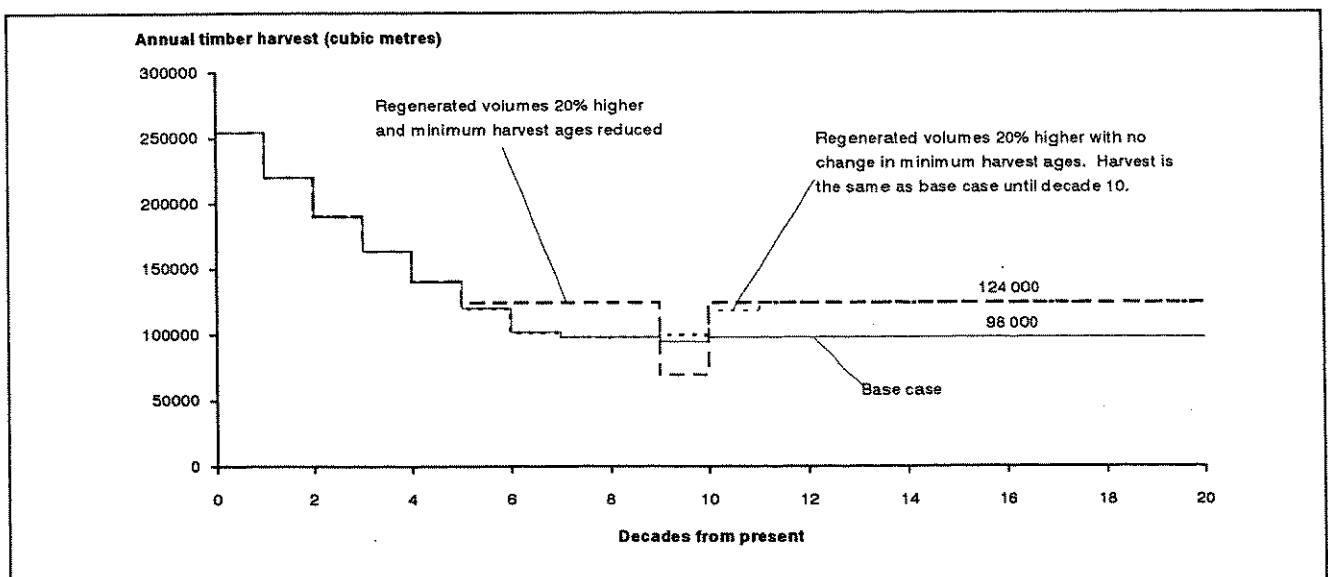


Figure 24. Harvest forecasts if regenerated yields are 20% higher than in base case yields.

5 Timber supply sensitivity analyses

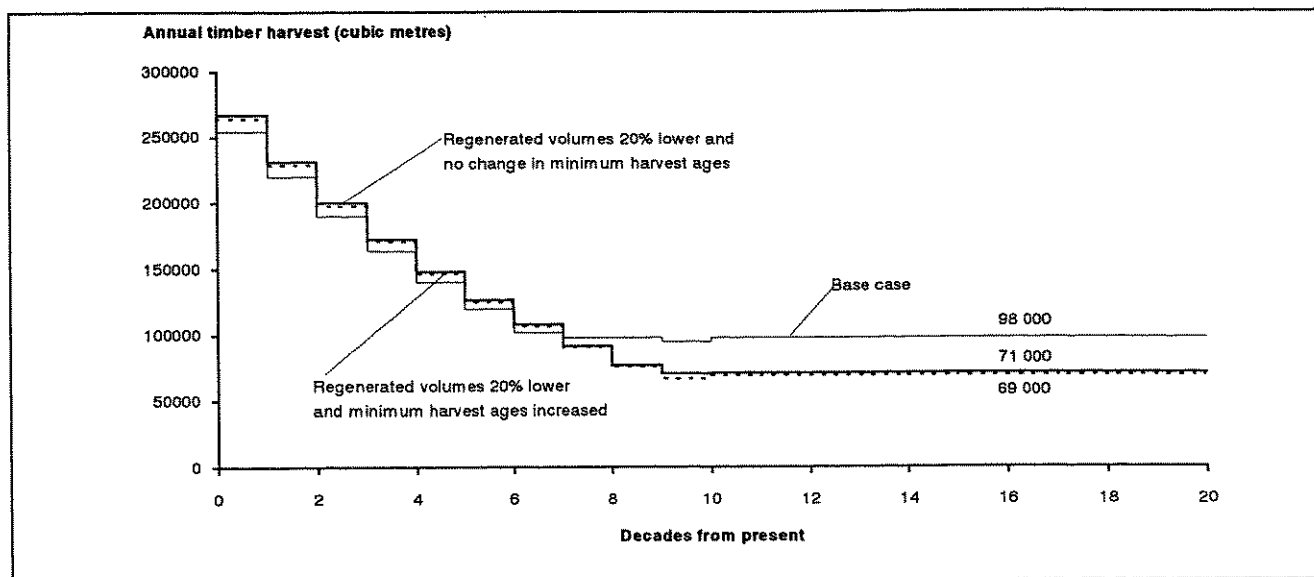


Figure 25. Harvest forecasts if regenerated yields are 20% lower than base case yields.

If minimum harvest ages are lengthened so that about the same volumes per hectare are produced at the new minimum harvest ages as for the base case, the initial harvest (264 000 cubic metres) and long-term harvest (69 000 cubic metres) are only slightly less than in the previous case.

In summary, moderate changes in regenerated yields would have little to no impact on initial harvest rates but do have a direct bearing on long-term timber supply. Larger changes in regenerated yields might produce some shorter term impacts if minimum harvest ages were also reduced. However, from a comparison of the results from this section with the results from Section 5.3 (Uncertainty about Minimum Harvest Ages for Regenerated Stands), it seems clear that most of the impact on short-term supply would derive from different minimum harvest ages not from different regenerated yields.

5.6 Uncertainty about Both Existing and Regenerated Stand Volumes

It is also possible that existing and regenerated yields could concurrently be higher or lower than was assumed for the base case. This situation might hold for the Revelstoke TSA as the same yields are assumed for both existing and regenerated stands. Mis-classification of site

quality might also have a similar type of impact as site quality is an input to most systems used to predict volumes. In this section, the impacts of all yields being 10% higher or lower are examined.

Figure 26 shows the results of this sensitivity analysis. Yields 10% higher, combined with reduced minimum harvest ages for regenerated timber, allows the initial harvest to be raised by 6% to 269 000 cubic metres per year. Higher yields also allow a slower rate of decline (11% per decade) to the new long-term harvest of 111 000 cubic metres per year.

There was little impact on the results of not assuming lower minimum harvest ages other than a slight shortfall of timber emerged in decade ten. For this reason that alternative is not shown in Figure 26. With 10% lower yields and increased minimum harvest ages, the initial harvest must be decreased by 13% compared to the base case (to 222 000 cubic metres per year) if harvest levels below the long-term level or rates of decline greater than 12% per decade are to be avoided. The new long-term level is 85 000 cubic meters per year. The harvest forecast if no adjustments are made to minimum harvest ages is not shown in Figure 26 because the initial harvest level, 226 000 cubic metres per year, is quite similar to the forecast when ages are adjusted.

5 Timber supply sensitivity analyses

As with uncertainty in existing volumes, initial harvest levels are moderately sensitive to possible increases in both existing and regenerated yields but highly sensitive to lower yields.

5.7 Uncertainty about Green-up Periods

For the base case, green-up periods were 18 years for the timber zone, 25 years for the VQO zone and 40 years for the wildlife zone. To test the sensitivity of green-up assumptions on timber supply, these periods were changed by 20% (± 4 , ± 5 , and ± 8 years for the 3 zones respectively).

As green-up ages are increased a higher proportion of the total inventory falls below the green-up ages and therefore less area can be harvested before maximum limits (on total area below green-up) are reached. The opposite situation occurs as green-up ages are shortened.

In the base case, harvesting in the first decade was not possible in the wildlife zone as too much area was initially below the specified green-up period. When green-up periods were increased 20% harvesting in the VQO zone was also prevented in the first decade (and less area was available for harvest in the timber zone). Reducing green-up periods made more area available for harvest in the first decade for the timber and VQO zones but it was still not possible to harvest in the wildlife zone.

The impacts of changing green-up period can be seen in Figure 27. That figure shows that timber supply is only moderately sensitive to changes in green-up ages. Reducing green-up period 20% allows the initial harvest to increase by 6% relative to the base case while increases in green-up period of 20% results in an initial harvest of 246 000 cubic metres (3% below the base case harvest).

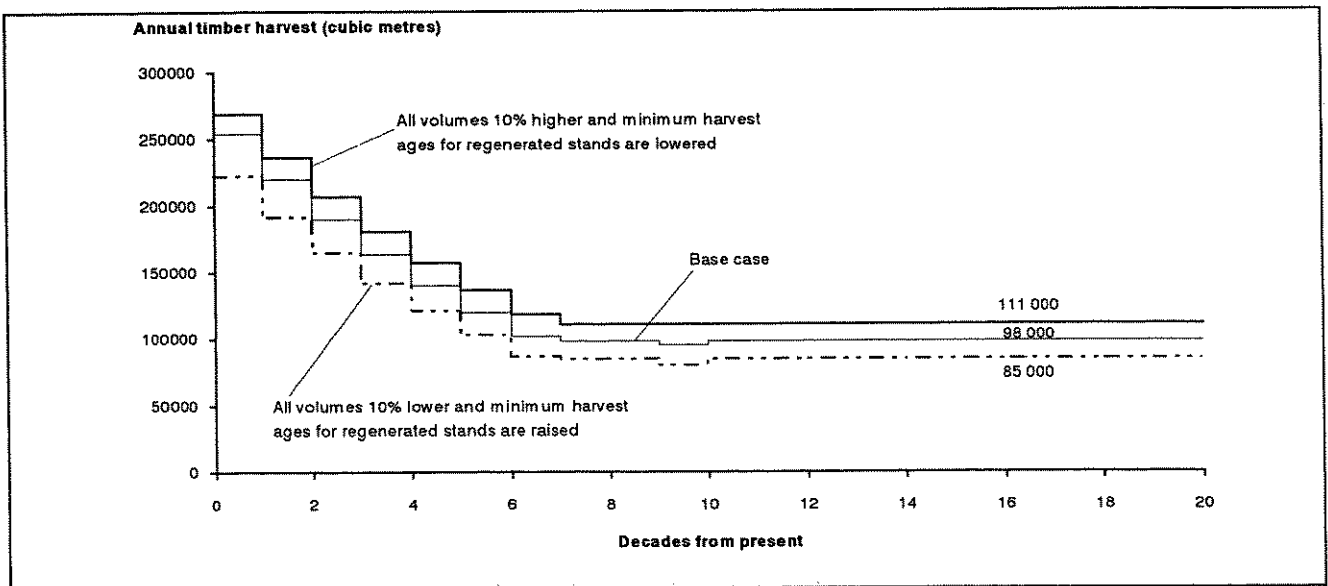


Figure 26. Harvest forecasts if all yields are 10% higher or lower than base case yields

5 Timber supply sensitivity analyses

5.8 Uncertainty about Forest Cover Constraints

The basic forest cover guidelines used for the base case require that no more than 33% of the timber zone, 18% of the VQO zone and 25% of the wildlife zone be younger than the green-up periods at any time. This section examines the sensitivity of timber supply to forest cover constraints.

Figure 28 is the harvest forecast when all constraints are set to the same levels as for the timber zone (i.e. a maximum of 33% of the area

can be less than 18 years old). The initial harvest can be set at the current AAC and the decline can be 11% each decade rather than 12% as in the base case. The long-term harvest level increases slightly to 100 000 cubic metres. This harvest forecast is not affected in any substantial way by the imposed cover constraints. This was confirmed by testing an alternative in which no cover constraints at all were applied. The results were identical to those shown in Figure 28 except for some minor differences in area harvested after decade eight.

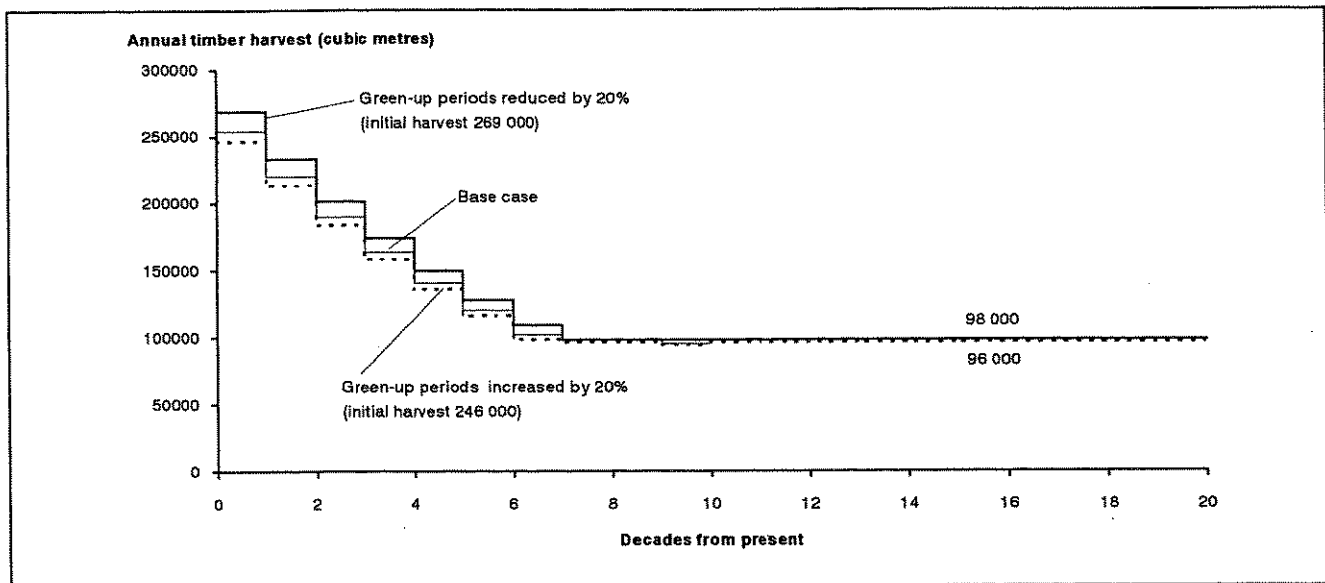


Figure 27. Harvest forecasts when green-up periods are 20% shorter or longer than assumed for the base case.

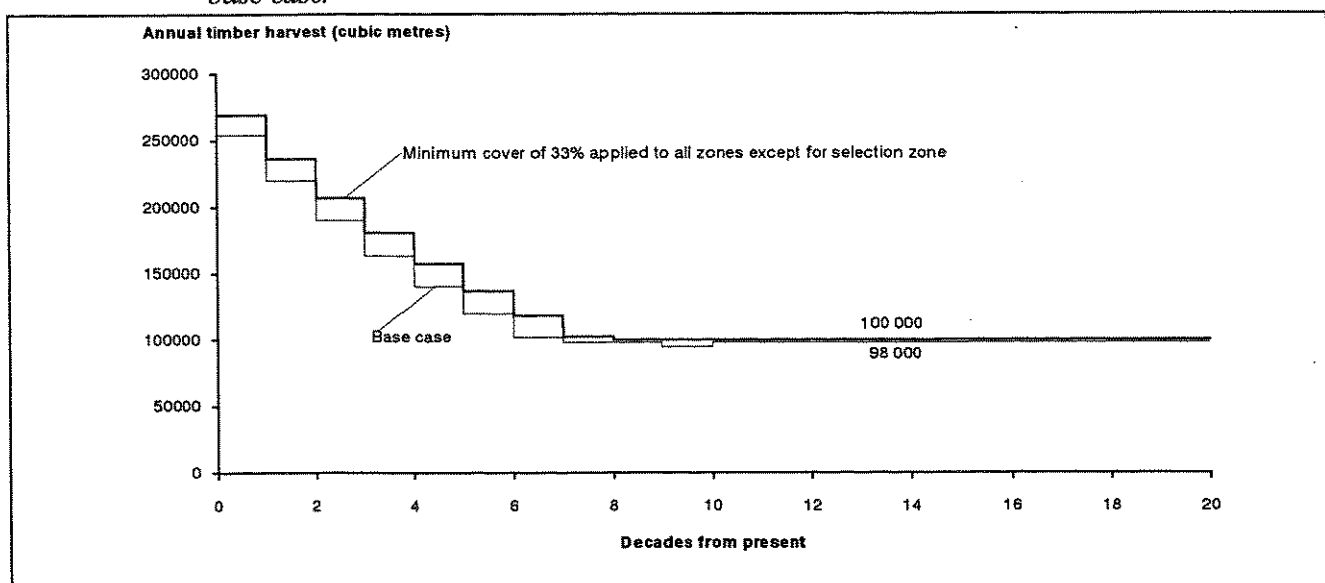


Figure 28. Harvest forecast if apply minimum cover requirements to all zones.

5 Timber supply sensitivity analyses

Figure 29 presents the results of adding and subtracting 5% to the percentages used in the base case. Relaxing the cover constraints (by increasing the percentage allowed) permits an initial harvest of 268 000 cubic metres and a long-term harvest level of 99 000 cubic metres. Tightening cover constraints, achieved by decreasing the percentages, forces the initial harvest to be reduced to 239 000 cubic metres (6% decrease from the base case) so that future

declines below the long-term level of 96 000 cubic metres can be avoided.

Figure 30 illustrates that timber supply can be very sensitive to forest cover. As expected from the results above, further relaxation of the constraints by adding 10% to the base case percentages has very little impact over that seen in Figure 29 -- both the initial harvest and the long-term harvest increase by only 1 000 cubic metres relative to the case in which 5% was added.

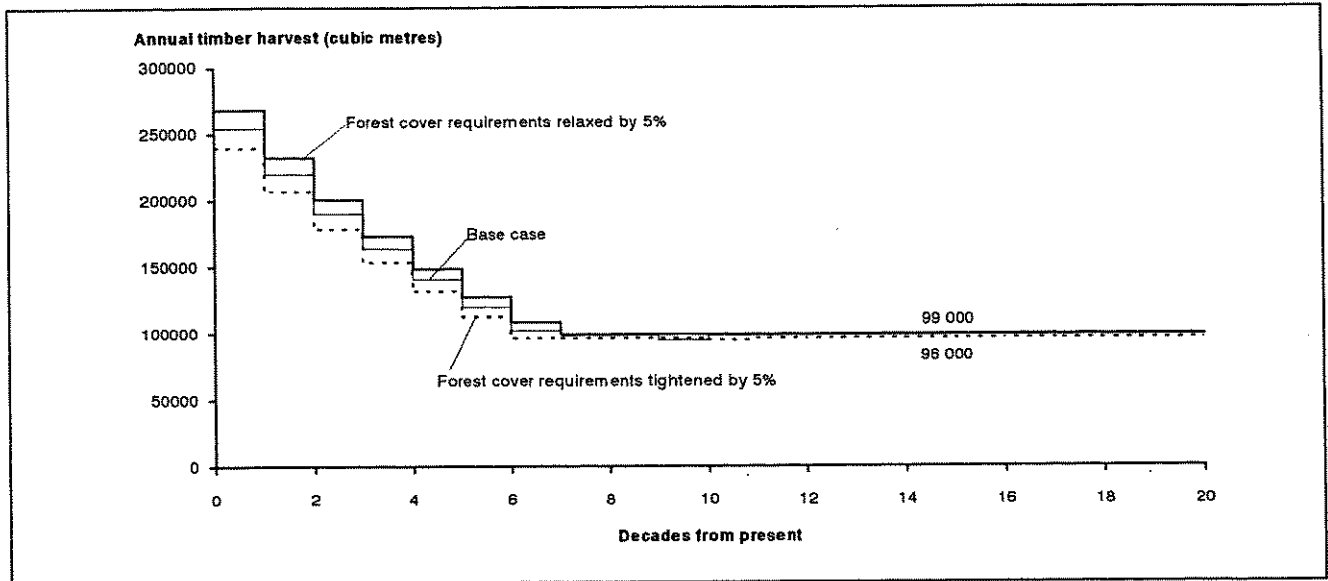


Figure 29. Harvest forecasts if forest cover requirements are changed by 5%.

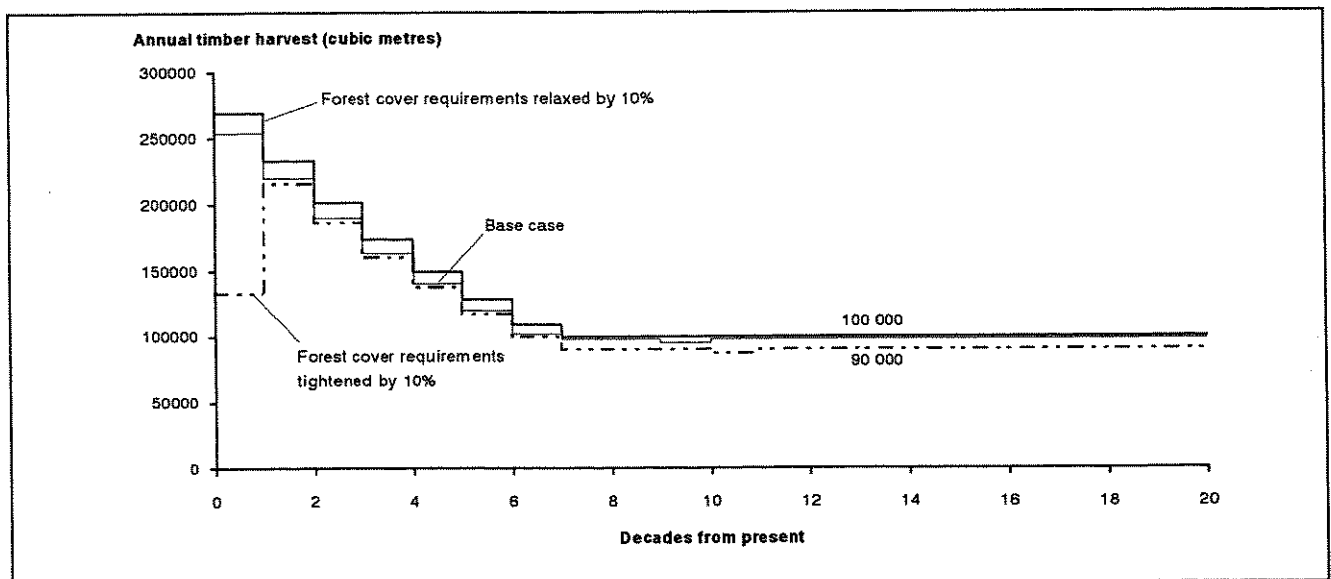


Figure 30. Harvest forecasts if cover requirements are changed by 10%.

5 Timber supply sensitivity analyses

However, tightening the constraints by 10% relative to the base case has a major impact on short-term availability and therefore on the volume that can be harvested in the first decade. The maximum annual harvest in decade one before all cover constraints are reached is 133 000 cubic meters which is 48% below the base case harvest for that same period. The harvest recovers to 215 000 cubic meters per year in decade two before declining by 12% per decade to a long-term level of 90 000 cubic metres per year.

In summary, the timber supply for the Revelstoke TSA is moderately sensitive to relaxation of forest cover constraints but is highly sensitive to tightening of those same constraints.

5.9 Uncertainty about the Adjacency Guideline for the Timber Zone

The major forest cover guideline applied to the timber zone was derived from adjacency considerations. Current criteria for development plans in the Revelstoke TSA require a 3-pass harvest system. On a zone-wide basis this means that no more than 33% of the zone can be younger than the green-up age. Revelstoke District staff are increasingly finding it difficult to achieve a 3-pass system in practice; they feel that a 4-pass system may be more reasonable. The purpose of this section is to examine the impact of assuming a 4-pass system for the timber zone.

Figure 31 shows the impact of requiring no more than 25% of the Timber Zone be below green-up. The maximum harvest in the first decade is 182 000 cubic metres - a decrease of 28% from the base case. Although the harvest could increase to 235 000 cubic meters in decade two, volumes would then begin declining at 12% per decade to the long-term level. The harvest forecast of Figure 31 is an alternative that allows only a slight increase in period 2 but then that harvest is maintained for three decades before volumes begin declining at 10% per decade in decade five.

In the Revelstoke TSA, the assumption of a 4-pass system in the Timber Zone has major impacts on short-term timber supply. The main reason for this large impact (and for the impact of decreasing forest cover in all zones by 10%, described in the previous section) is the current age class distribution for the TSA (Figure 4). Because of NSR areas and Timber Licence reversions a large proportion of the Revelstoke TSA is younger than 20 years. It is not possible to harvest in the wildlife zone in decade one because of the age class distribution in that zone and very little harvesting is possible in the VQO zone in that same period. Therefore any change that reduces the area that can be harvested from the Timber Zone in decade one can have a major impact on timber supply, particularly on short-term supply.

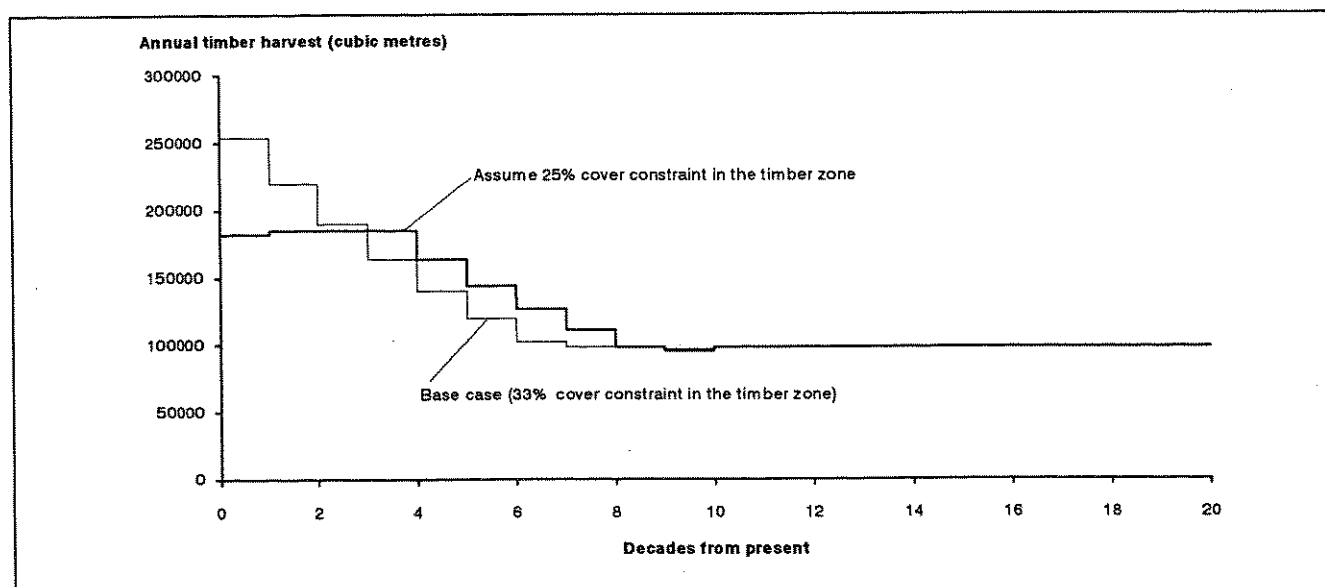


Figure 31. Harvest forecast if tighten forest cover requirement in the timber zone.

5 Timber supply sensitivity analyses

There is another reason why forest cover and adjacency constraints can impact short-term supply more than long-term harvest. As harvests are highest in the first few decades, the area harvested annually is also at a maximum early in the planning horizon (see Figure 13). The greater area harvested essentially creates more area below green-up and increases the likelihood that limits for forest cover will be encountered.

5.10 Impact of an Old Growth Requirement

Increased concerns for biodiversity* frequently result in, among other objectives, a desire to maintain a certain proportion of the land base in older age classes. For example, it may be decided that a minimum of 10-12% of all forested area be over 140 years old. Often, forest land outside the timber harvesting land base is also considered to contribute to this total. As a result, there may only need to be 5-7% of the timber harvesting

land base held in older stands. Revelstoke staff do not require old growth to be considered as part of development plans for the TSA. The purpose of this section is to demonstrate what the impacts might be if an old growth objective was to be incorporated into the analysis.

The old growth harvest forecast shown in Figure 32 assumed that at least 5% of the area in each zone would be at least 140 years old. The harvest for decade one, 238 000 cubic metres, is 6% lower than for the base case. Therefore, addition of an old growth objective has only moderate impact on short-term timber supply.

Biodiversity

Diversity of life in all its forms and levels or organization, including genes, species, ecosystems and the evolutionary and functional processes that link them.

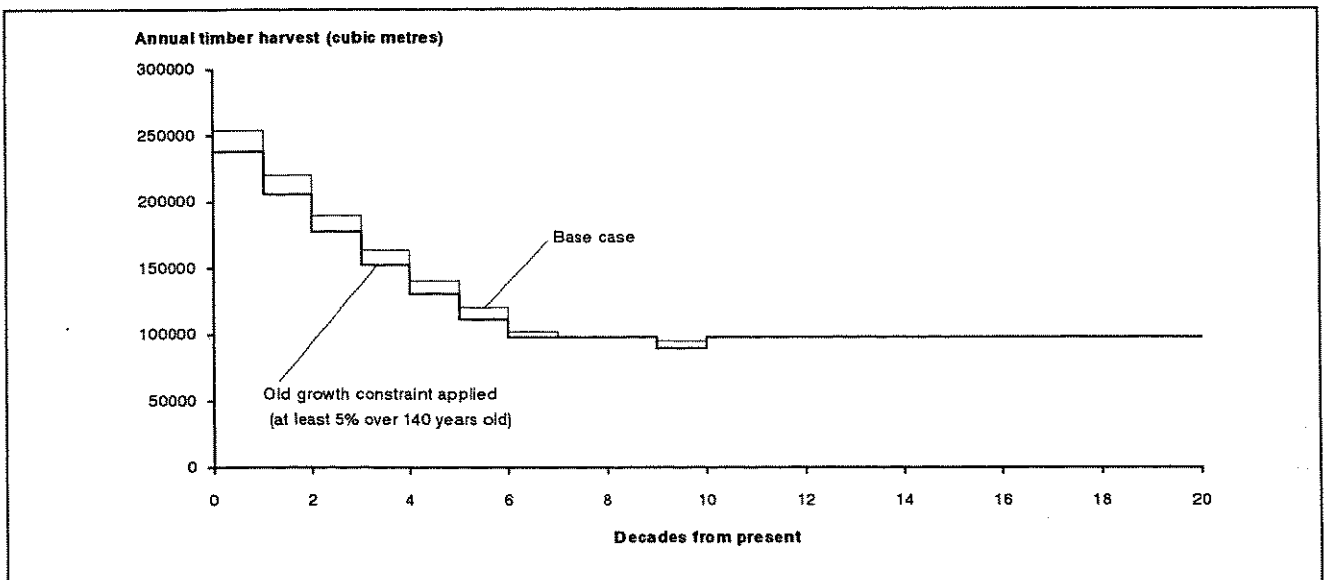


Figure 32. Harvest forecast if an old growth constraint is added.

6 Summary and Conclusions

The analysis for the Revelstoke TSA indicates that given current management assumptions an initial harvest of 254 000 cubic metres can be maintained for only one decade. Harvests must then begin to decline at 12% per decade until the long-term harvest level of 98 000 cubic metres per year is reached in decade eight.

The initial harvest rate can only be raised above 254 000 cubic metres by either allowing rates of decline greater than 12% or by accepting significant timber supply shortfalls in the future. For this reason, the current AAC of 269 000 cubic metres per year is not achievable. Conversely, any attempt to slow the rate of decline requires an immediate harvest reduction below the base case initial harvest.

This analysis employs the best current estimates for all variables used to describe forest

management in the Revelstoke TSA. However, varying degrees of uncertainty surround most of the estimates. Sensitivity analyses showed that short-term timber supply is particularly sensitive to lower yield estimates for existing stands and to tighter forest cover constraints. Even moderate changes in these assumptions can result in initial harvests more than 25% lower than for the base case.

Higher yield estimates for existing stands and relaxed forest cover requirements have more moderate impacts on short-term harvest levels. This is also true for uncertainty about minimum harvest ages and green-up requirements. Changes in regenerated yields have very little impact on short-term harvest rates although the long-term harvest level is significantly affected.

7 References

- B.C. Ministry of Forests. 1991. Ecosystems of British Columbia. Research Branch, Victoria. (Compiled and edited by D. Meidinger and J. Pojar). 330 pages.
- B.C. Ministry of Forests. 1990. Revelstoke Resource Management Plan Terms of Reference. Revelstoke Forest District and Nelson Forest Region. 25 pages.

8 Glossary

Allowable annual cut (AAC)	The allowable rate of timber harvest from a specified area of land. The Chief Forester sets AACs for Timber Supply Areas (TSAs) and Tree Farm Licences (TFLs) in accordance with Section 7 of the <i>Forest Act</i> , and for Certified Tree Farms in accordance with the <i>Assessment Act</i> .
Analysis unit	The basic building blocks around which inventory data and other information are assembled for use in forest planning models. Analysis units represent the general level of aggregation, or detail, at which a timber supply analysis is carried out. They are normally defined by tree species and site qualities, but may also be defined to incorporate specific geographic areas or areas under a similar set of management practices.
Available volumes	The portion of total inventory volumes that is available for harvesting after all management constraints on timber harvesting have been considered, including definition of the timber harvesting land base, age of tree merchantability, deferrals, and any other priorities or constraints on timber harvesting.
Biodiversity (biological diversity)	Diversity of life in all its forms and levels of organization, including genes, species, ecosystems and the evolutionary and functional processes that link them.
Cutblock adjacency guidelines	Integrated management guidelines that specify the desired spatial relationship among cutblocks. They can be approximated by specifying the maximum allowable proportion of a forested landscape that does not meet green-up requirements.
Environmentally sensitive area	An area with significant non-timber values, fragile or unstable soils, problems in establishing a new tree crop or where timber harvesting may cause avalanches.
Forest cover requirements	Specify desired distributions of areas by age or size class groupings. These objectives can be used to reflect desired conditions for wildlife, watershed protection, visual quality and other integrated resource management objectives. General adjacency and green-up guidelines are also specified using forest cover objectives (see Cutblock adjacency guidelines and Green-up period).
Forest inventory	Assessment of British Columbia's timber resources. It includes computerized maps and a database describing the location and nature of forest cover, including size, age, timber volume, and species composition, as well as a description of some non-timber values such as recreation and visual quality.

8 Glossary

Forest planning model	An analytical (usually computer-based) model that successively harvests and grows collections of forest stands over a period of several decades according to specific data and management assumptions. Forest planning models are of two basic forms: forest estate simulation models, which address "what-if" questions by determining the effects a specified policy or management alternative; and linear programming harvest scheduling models, which seek out the policy or management alternative that best attains a specified management objective (e.g., maximum volume harvested over time) subject to specified management constraints. This analysis employs a computer simulation model developed by the B.C. Forest Service.
Forest type	The classification or label given to a forest stand, usually based on its tree species composition. Pure spruce stands and spruce-balsam mixed stands are two examples of forest types.
Free growing	An established seedling of an acceptable commercial species that is free from growth-inhibiting brush, weed and excessive tree competition.
Green-up period	The time needed for a stand of trees to reach a desired condition (e.g., height) to ensure maintenance of water quality, wildlife habitat, soil stability or aesthetics.
Growing stock	The volume estimate for all standing timber, of all ages, at a particular time.
Harvest forecast	The flow of potential timber harvests over time. A harvest forecast is usually a measure of the maximum timber supply that can be realized, over time, for a specified land base and set of management assumptions. It is a result of forest planning models and is affected by the size and productivity of the land base, the current growing stock, and management objectives, constraints and assumptions.
Integrated resource guidelines	Guidelines requiring that forest management activities (such as harvesting, road building and silviculture treatments) be conducted in a special way to protect or enhance timber and non-timber forest resource values.
Management assumptions	Approximations of management objectives, priorities, constraints and other conditions needed to represent forest management actions in a forest planning model. These include, for example, the criteria for determining the timber harvesting land base, the specification of minimum cutting ages, utilization levels and standards, integrated resource guidelines and silviculture and pest management programs.
Maximum modification VQO	Alterations may dominate the landscape in this VQO class. Up to 40% of the area can be visibly altered by harvesting activity (see Visual quality objective).

8 Glossary

Mean annual increment (MAI)	Stand volume divided by stand age. The stand age at which the MAI assumes its maximum value is called the culmination age. Harvesting all stands at this age results in a maximum average harvest over the long-term.
Model	An abstraction and simplification of reality constructed to help understand an actual system or problem. Forest managers and planners have made extensive use of models, such as maps, classification systems and yield projections, to help direct management activities.
Modification VQO	Alterations can be seen but do not overwhelm in this VQO class. Up to 25% of the area can be visibly altered by harvesting activity (see Visual quality objective).
Non-merchantable forest types	Stands that are accessible and otherwise available for harvesting but are assumed to be non-merchantable due to stand characteristics such as small piece size, incidence of decay and low stocking.
Not satisfactorily restocked	An area not covered by a sufficient number of tree stems of desirable species. Stocking standards are set by the Forest Service, Silviculture Branch. If the expected regeneration delay has not elapsed, the land is defined as current NSR. If the expected delay has elapsed, the land is classified as backlog NSR.
Partial retention VQO	Alterations are visible but not conspicuous. Up to 15% of the area can be visibly altered by harvesting activity (see Visual quality objective).
Preservation VQO	No visible alterations to the landscape are permitted. (see Visual quality objective).
Regeneration delay	The period of time between harvesting and the date by which an area is occupied by a specified minimum number of acceptable well-spaced trees.
Rehabilitation of non-stocked land	Removing all non-commercial cover, preparing the site and stocking it with acceptable commercially valuable species.
Retention VQO	Alterations are not easy to see in this VQO class. Only 5% of the landscape can be altered by harvesting activity (see Visual quality objective).
Selection management	A silvicultural system used to maintain or create areas containing a wide range of tree ages or sizes. The time interval between harvests in such areas is fairly short (usually less than 30 years) and during these harvests either single scattered trees or small groups of trees are removed from across the entire area.
Silvicultural treatments	Activities that ensure the regeneration of young forests on harvested areas and enhance tree growth and improve wood quality in selected stands. Activities include: site rehabilitation and preparation, planting, spacing, fertilization and pruning.
Site index	A measure of site productivity. Site indices are based on tree height as a function of stand age and are usually expressed graphically as site index curves. A number of site index curves have been developed for British Columbia's major commercial tree species.

8 Glossary

Stocking	The proportion of an area occupied by trees, and measured by the degree to which the crowns of adjacent trees touch, and the number of trees per hectare.
Timber harvesting land base	The portion of the total land area of a management unit considered to contribute to, and be available for, long-term timber supply. The harvesting land base is defined by reducing the total land base according to specified management assumptions.
Timber Supply Area (TSA)	An integrated resource management unit established in accordance with Section 6 of the <i>Forest Act</i> .
Unsalvaged losses	The volume of timber killed or damaged annually by natural causes (e.g., fire, wind, insects and disease) and not harvested.
Visual quality objective (VQO)	Defines a level of acceptable landscape alteration resulting from timber harvesting and other activities. A number of visual quality classes have been defined on the basis of the maximum amount of alteration permitted. (See Preservation , Retention , Partial retention , Modification , and Maximum modification VQO definitions).
Watershed	An area drained by a stream or river. A large watershed may contain several smaller watersheds.
Yield projections (volume estimate)	Estimates of yields from forest stands over time. Yield projections can be developed for stand volume, stand diameter or specific products, and for empirical (average stocking), normal (optimal stocking) or managed stands. Yield projections can be based on a number of mensurational approaches and procedures, including the use of site index curves (see Site index) and generalized growth models (for example, Chapman-Richards and Ek-Payandeh).

APPENDIX A

Description of Data Inputs and Assumptions

Introduction

The following sections outline the methods and inputs used to derive the timber harvesting land base and to construct the timber supply model for the Timber Supply Review of the Revelstoke TSA. For purposes of the review, this information represents current forest management in the area. Current forest management is defined as the set of land use decisions and forest and stand management practices that are currently implemented and enforced. Future forest management objectives that may be intended, but not currently implemented and enforced, are not included here. Changes in forest management, when and if they occur, will be included in subsequent timber supply analyses after this Timber Supply Review has been completed.

A.1 Zone and analysis unit definitions

A.1.1 Definition of Zones

The timber harvesting land base was divided into zones on the basis of differences in forest cover requirements. These cover requirements simply reflect different forest management emphases within the TSA. Four zones were defined for this analysis:

- Zone 1 (Timber Zone). This is a general zone subject to normal guidelines. Many of these guidelines are outlined in the *Evaluation Criteria for (five year) Development Plans*. This document, prepared in October, 1991 by Revelstoke District staff, was a primary source of information in defining current management for the TSA. The Timber Zone includes all areas not specifically included in the other zones.
- Zone 2 (VQO Zone). This zone emphasizes visual quality objectives. It includes many of the approved retention and partial retention VQOs which are defined in the recreation layer of the 1991 version of the inventory file. All partial retention and retention classes on the file were recognized except for those located in the southern end of the TSA (In 1:20 000 scale map sheets 82K061, 82K071, 82K081 and 82L080). In addition, any areas contained within these VQO classes that overlapped Zone 4 were considered to be in Zone 4 not Zone 2.
- Zone 3 (Wildlife Zone). This zone is subject to revised management guidelines that emphasize provision of winter habitat for cariboo. It includes that part of the land base north of Highway 1 and west of the Columbia River that is below 914 metres (3000 feet). All forest cover polygons, or parts of polygons, that were below this elevation in the following map sheets were considered to be in the Wildlife Zone: 82M009, 82M019, 82M020, 82M029, 82M030, 82M038, 82M039, 82M048, 82M057, 82M058, 82M067, 82M077, 82M087, 82M098 and 83D008. District staff provided a listing of the polygons which was used to identify the zone on the inventory file.
- Zone 4 (Selection Management Zone). This zone includes both the Begbie Falls LRUP area and the Dolan Creek watershed. Both areas are located in mapsheet 82L099. The Dolan Creek watershed area was defined on the basis of the forest cover polygons contained within the watershed. A listing of these polygons was provided by the district. For Begbie Falls, district staff provided a list of forest cover polygons along with estimates of the proportion of each polygon available for harvesting.

A.1.2 Analysis Units

An analysis unit (AU) represents a group of similar stands. Generally an AU contains stands that possess similar tree species compositions and similar timber growing capabilities. In the inventory file the major combinations of species are called type groups and timber growing capability, or site quality, is indicated by a site index or site class. For the Revelstoke TSA analysis, site groups were assigned using new site class (NSITE) or where assigned, special site class (SSITE). Special site is a field corrected site class that can be assigned when the normal site class does not correctly reflect site quality.

The analysis units used for the Revelstoke TSA timber supply analysis, and the inventory file variables used to define them, are shown in Table A-1. It should be noted that there were actually no larch dominated stands in the timber harvesting land base and pine dominated stands formed only a small part of AUs 1 and 2 (390 ha of pine in AU 1 and 36 ha of pine in AU 2).

A.1 Zone and analysis unit definitions

Table A-1. Analysis Unit characteristics

Analysis Unit	Species Groups	Inventory Type Groups	Site Index Classes
1	fir/larch/pine	1-8, 27-34	good & medium
2	fir/larch/pine	1-8, 27-34	poor
3	cedar	9-11	good & medium
4	cedar	9-11	poor
5	pure hemlock	12	all sites
6	hemlock	13-17	good & medium
7	hemlock	13-17	poor
8	spruce/balsam	18-26	good & medium
9	spruce/balsam	18-26	poor
10	all (coniferous)	1-34	all

AUs 1 to 9 were used to group stands in zones 1, 2 and 3. Because of its' small area, only one analysis unit (AU 10) was defined for Zone 4. Table A-2 is a summary of the area in each zone and AU combination. Two points should be noted about the areas given in Table A-2. First, the areas shown are for the net land base from the inventory file. NSR and timber licence reversions are subsequently added to this net land base to give the final timber harvesting land base (a final summary is given in Section A.4.5). Second, the AU areas shown for Zone 4 are for information only. The areas indicated were actually combined into one aggregate (AU 10) for purposes of yield prediction and for input to the B.C. Forest Service timber supply model.

Table A-2. Area by zone and analysis unit

Analysis Unit	Zone 1	Zone 2	Zone 3	Zone 4	Total
1 (FLP - g,m)	4 349	2 941	1 603	319	9 213
2 (FLP - p)	456	240	143	28	865
3 (C - g,m)	7 593	502	2 735	20	10 851
4 (C - p)	1 468	265	942	0	2 675
5 (Pure H - all)	840	241	309	29	1 418
6 (H - g,m)	5 721	1 126	2 581	62	9 489
7 (H - p)	3 123	277	1 000	43	4 443
8 (SB - g,m)	9 246	410	493	<1	10 150
9 (SB - p)	4 434	46	292	0	4 772
Total Area	37 230	6 049	10 098	499	53 877

A.2 Utilization levels

The utilization level defines the maximum allowable stump height and minimum merchantable diameter by species and is used to calculate merchantable volume. A 10 cm diameter top and a 30 cm stump height is assumed for all species.

In Revelstoke, the utilization level currently practiced for all species is based on diameter at breast height of 17.5 cm.

A.3 Definition of the Timber Harvesting Land Base

The final timber harvesting land base was determined by first deducting from the total TSA area, all areas considered to be currently unavailable for timber harvesting. Then additions to the land base such as NSR areas and Timber Licence reversions was added back in to establish the current timber harvesting land base. Harvesting operations will subsequently result in the removal of some of that initial area because of long-term productivity losses. All these categories are summarized in Table 1 of the main report.

This section provides most of the information used to define the timber harvesting land base. However, the area adjustments for NSR additions and timber licence reversions are presented in later sections.

A.3 Definition of the timber harvesting land base

A.3.1 Non-Crown, Non-forest and Non-commercial Areas

All areas not designated as being ownership code 62C (Crown forest management unit available for long-term integrated resource management) or 69C (Miscellaneous reserves available for long-term integrated resource management) were excluded from the timber harvesting land base. In addition, any area with a type identity of 8 (no typing available) is included in this category. Only 2.4% of the TSA is excluded because of ownership (nearly 97% of the TSA is ownership 62C and about 1% is ownership 69C). Another 1.4% is excluded because of no typing being available.

Non-forested and non-productive areas, designated as type identity 6 on the inventory file, were also excluded from the timber harvesting land base. These areas account for the removal of about 283 000 ha or 56% of the total TSA area remaining after non-Crown lands are excluded.

Non-commercial or brush areas (type identity 5 on the inventory file) were also excluded.

A.3.2 Inoperable Areas

All areas defined as inoperable on the inventory file (operability code of "I") were excluded. Operability lines for supply blocks A, D, E and F were established in 1982 and according to district staff these are fairly accurate. The operability lines for the remaining supply blocks were modified in 1987. The criteria used in 1987 included physical features of the land base as well as logging, access and regeneration chance assessments. Types of areas excluded include the following:

- steep "V" shaped valleys with very difficult access;
- excessively steep, gullied and broken terrain;
- stands that contain low quality timber that are also remote or isolated;
- areas above 5 500 to 6 000 feet often contain a Mountain Hemlock leading types which are very difficult to reforest;
- areas underneath or adjacent to avalanche chutes; (and)
- areas previously burned by wildfire and not regenerating.

The total area of the TSA considered as inoperable is 373 000 hectares or 74% of total TSA area. However, much of this area is also non-forest. As a result about 109 000 hectares is actually excluded, for operability reasons, from the area remaining after non-forest and non-Crown areas are deleted.

A.3.3 Environmentally Sensitive Areas (ESAs)

Some forest areas are categorized as being environmentally sensitive areas (ESAs). Table A-3 summarizes the percent area reductions that were applied by ESA category for the Revelstoke TSA analysis.

A.3 Definition of the timber harvesting land base

Table A-3. Percent area reductions for environmentally sensitive areas

ESA Code	ESA Description	Percent Area Reduction
Es 1	High soil sensitivity	90
Ep 1	High concern for regeneration problems	90
Ea 1	High avalanche concern	90
Er 1	High recreation value	90
Eh 1	High watershed values or concerns	90
Ew 1	High wildlife value	90
Er 2	Moderate recreation value	10
Eh 2	Moderate watershed values or concerns	10
Ew 2	Moderate wildlife value	10

These reductions reduce the net area available for timber harvesting by about 21 000 hectares. It should be noted that over 90% of the total area excluded is due to high ratings for soil sensitivity (71 %) and regeneration concerns (20 %).

A.3.4 Problem Forest Types

Some stands are not currently used because they either cannot be harvested economically or they contain mostly non-commercial tree species. Examples include older stands that contain low net timber volumes or poor quality trees and stands dominated by deciduous species. Areas of low site quality are also excluded because projected growth rates for second-growth forests are too low. Table A-4 lists the problem forest types for the Revelstoke TSA and the percentage reductions applied for category. The low site reduction was based on new site class (NSITE) except when modified by special site (SSITE).

Table A-4. Percent area reductions for problem forest types

Inventory Type Group	Species Groups	Site Class	Age Class	Percent Area Excluded
9-11	cedar	all	8-9	5
12	pure hemlock	"	8-9	80
13-17	hemlock	"	8-9	10
18-19	balsam	"	8	10
18-19	balsam	"	9	80
20	balsam/spruce	"	8-9	10
27	white pine	"	7-9	10
35-42	deciduous	"	all	100
all	all	low	all	100

A.3.5 Not Satisfactorily Restocked Areas

All areas on the inventory file assigned a type identity of 4, 7, or 9 were initially excluded from the land base. Most of this area is subsequently added back into the timber harvesting land base (the additions are described in Section A.4.5).

A.3.6 Existing Unclassified Roads, Trails and Landings

Past timber harvesting operations have resulted in a loss of productive forest land. However many of the existing roads, trails, landings and related disturbances are not accounted for in the inventory file. To account for this loss in the area available for timber harvesting an 11 % reduction was applied to all areas

A.3 Definition of the timber harvesting land base

younger than 80 years old (the areas assumed to have a logging history).

The 11 % reduction was obtained by summing the following three percentages:

1. Main Road Deduction = 3 %
 - Includes nearly all roads since very few are identified in the inventory.
 - Based on soil disturbance surveys from various TSAs in the Nelson Region; a road area sample from Kootenay Lake TSA; and on the *Interim Harvesting Guidelines for the Nelson Forest Region*.
2. Landings = 3 %
 - Represents one landing (0.25 ha) every 8 ha.
 - Same sources as above.
3. Skid roads and trails = 5 %
 - The estimate was based on the soil disturbance surveys and interim harvesting guidelines previously referred to.

A.3.7 Future Roads, Trails and Landings

There will also be losses in productive area as future harvesting occurs. All existing stands currently over 80 years old will be subject to these losses which are assumed to be the same as for past harvesting (11%). The area that will eventually be lost is not initially excluded from the land base. The B.C. Forest Service timber supply model simply reduces the areas by 11 % the first time all stands currently over 80 years old are harvested.

A.3.8 Exclusions for Specific Areas and Riparian and Avalanche Zones

Table A-5 summarizes the remaining areas that were excluded from the timber harvesting land base. The total areas shown in Table A-5 are for the gross land base before any deductions are applied. The last column is the area deducted as given in Table 1 of the main report. Prior deductions, such as inoperable and ESAs, account for the difference between these two columns.

Table A-5. Area exclusions

Exclusion	Mapsheets (1:20,000)	Total area	Land base deducted
Greeley Creek watershed	82K091, 82L100 and 82M010	4 625	708 ha
Mount MacKenzie	82L100	4 032	1 552 ha
Riparian and avalanche chutes	all	2 %	1 135 ha

The Greeley Creek watershed is one of two major community watersheds in the Revelstoke TSA. The watershed is considered to be inoperable because of low value timber and high environmental sensitivity. The west face of Mount MacKenzie was excluded because of the high probability of a major ski-hill development in that area. Revelstoke Forest District staff provided a list of the forest cover polygons contained within these two geographic areas. That information was used to identify them on the inventory file so that they could be removed from the timber harvesting land base.

Revelstoke Forest District staff also felt it was important to recognize major riparian areas and avalanche chutes in the analysis. Because no detailed surveys were available, staff reviewed recent development plans to estimate the percentage of the area that would be excluded because of riparian zones and avalanche chutes.

Originally it was intended that the Serenity Peaks Study Area (part of the Protected Areas Strategy) would also be excluded. However such areas are not deducted until they are actually designated as protected areas. This does not imply that study areas will be ignored however as they will be considered in the framework provided by 1992 changes to the *Forest Act* (amended as Bill 78).

A.3 Definition of the timber harvesting land base

A.3.9 Timber Licence Reversions

Table A-6 summarizes the timber licence (TL) reversion information for the Revelstoke TSA. The total shown (4 641 ha) is less than the total reverting (6 507 ha) because some of the area reverting is not operable. The reversion dates shown are subject to uncertainty because actual timing is largely determined by market conditions. Table A-6 was derived from liquidation schedules provided by each licensee.

Table A-6. Timber licence reversions

Analysis Unit	Age class at reversion	Reversion Year		
		1986-91	1996	2025
1	NSR		77	
	10	30	377	
	50		10	25
	90	32	41	
3	10	6	304	
	70			26
6	NSR	92		
	10	66	655	
	30	5	60	
	50	10		3
	70			55
	90	20		
8	NSR	5	93	136
	10	117	413	509
	30			1 115
	50			335
	70			17
9	70			7
Sub-Total		383	2 030	2 228
Total				4 641

The areas reverting in the year 2025 are all located in the Timber Zone (Zone 1). However the areas that have reverted already (but are not yet included in the inventory file) and those reverting in 1996 occur in Zones 1, 2 and 3. The location by zone for all timber licences currently defined on the inventory file was used to distribute the decade one reversion areas across zones. Table A-7 shows how the analysis unit areas given in Table A-6 were distributed to the three zones.

Table A-7. Distribution of current timber licence reversions to zones

Analysis Unit	Percent of area assigned to:		
	Zone 1	Zone 2	Zone 3
1	32	20	48
3	46	1	53
6	35	22	43
8	77	3	20

A.4 Forest management assumptions

A.4.1 Minimum Harvest Ages for each Analysis Unit

Table A-8 shows the minimum harvest ages for each analysis unit. The minimum harvest age given in the Development Plan Criteria is 120 years. This age was set to encourage harvest of older stands which represent a large part of the TSA. In this way losses due to stand deterioration are minimized. Therefore, this age was used for existing timber. The ages for regenerated stands, except for the selection zone, were based on work done in 1991 in preparation for a planned re-analysis of the timber supply for the Revelstoke TSA. At that time minimum ages were set by considering a number of factors including, but not limited to, culmination age and a minimum volume requirement of 150 m³/ha. As new yield tables, based on VDYP, were developed for this analysis, the volume-age relationships used in 1991 (based on Ek-Payendah volumes) are no longer valid. However, those ages were used in the development of a base case for the analysis. Impacts of different harvest age assumptions on timber supply were then evaluated using sensitivity analysis.

Table A-8. Identification of minimum harvest age for each analysis unit

Analysis Unit	Culmination Age	Minimum harvest ages for:	
		Existing Stands	Regenerated Stands
1	110	120	100
2	150	120	130
3	80	120	125
4	100	120	130
5	100	120	110
6	90	120	110
7	150	120	120
8	110	120	100
9	160	120	140
10	100	120	120

Culmination ages given here are for reference only. See Table A15

A.4.2 Harvest Profile

Table A-9 is a summary of the desired harvest profile for the first few decades for the Revelstoke TSA. Although this information provides a useful reference point, there was no explicit attempt made to achieve the desired profile.

Table A-9. Desired harvest profile

Analysis Unit	Percent of total harvest volume
1	2.7
2	0.3
3	30.0
4	2.0
5	3.0
6	28.0
7	4.0
8	17.7
9	12.3

A.4 Forest management assumptions

A.4.3 Forest Cover Requirements

Table A-10 specifies the forest cover requirements needed to achieve the forest management objectives for each zone.

Table A-10. Forest cover requirements

Zone	Definition of Green-up	Green-up period (yrs)	Maximum area less than green-up
1 Timber	3 m	18	33 %
2 VQO	5 m	25	18 %
3 Wildlife	40 years	40	25 %
4 Selection	n/a	n/a	n/a

The years required to achieve the various heights were based on area weighting the time required to achieve the specified green-up heights for each AU. The average site indices were obtained from the inventory file and then TIPSy was used to project the required height-age relationships.

Further information by zone follows:

Timber Zone:

A 3 m green-up was required to satisfy free-to-grow standards and wildlife summer range requirements. A 3 pass harvesting system reflects current management practices although the district is having some difficulty in achieving it.

Wildlife Zone:

The green-up figure given is based on the Development Plan criteria which state that green-up is a minimum of 40 years and also requires a crown closure of 60%. Work with TIPSy indicates that the 40 year guideline corresponds quite closely to a height of 10 to 11 meters. It should be noted that the 60% crown closure requirement is not being explicitly modelled. Rather it is assumed that such crown closures will be generally achieved by year 40.

VQO Zone:

There has been considerable work done in recent months by Recreation Branch and Regional Landscape Foresters to refine VQO guidelines. As a result of this work, a single 5 m visually effective green-up (VEG) was used for the VQO zone. In addition, the basic forest cover constraint for partial retention areas in the district, 15%, has been adjusted upward to 18%. This adjustment recognizes viewscape dispersion and the contribution of inoperable areas to VEG, both of which impact visual absorption capability.

A.4.4 Unsalvaged Losses

Unsalvaged losses are timber volumes destroyed or damaged by natural causes such as fire and disease. Estimated annual losses are deducted from the gross timber supply to determine the projected net volumes that will be harvested over time. Table A-11 shows the estimated average annual loss for the Revelstoke TSA.

A.4 Forest management assumptions

Table A-11. *Unsalvaged losses*

Cause of loss	Gross losses (m ³ /year)	Unsalvaged losses (m ³ /year)
Fire	31 640	15 820
Insects	8 000	3 000
Disease	3 000	1 000
Windthrow	40 000	10 000
Total		29 820

This information was collected in 1991 in anticipation of a new timber supply analysis. It was subsequently reviewed by the forestry subcommittee for the TSA in 1992. Notes on specific loss estimates follow:

1. Fire: Losses are based on the 10 year average from 1979-89.
2. Insects: Figure is based on district and regional protection staff interpretations of *Forest Insect and Disease Impacts in Timber Supply Areas*.
3. Disease: Source of information is the above document. Main losses are from Armillarea, laminated root diseases and white pine blister rust.
4. Windthrow: This estimate is based on discussions with district protection and timber staff. Windthrow has become a persistent problem in the TSA. As an example, one licensee's entire 1990 cut was obtained from salvage of blowdown.

A.4.5 Not Satisfactorily Restocked (NSR) Areas

Table A-12 summarizes the total area of current and backlog NSR currently existing in the timber harvesting land base for the Revelstoke TSA. It was assumed that restocking of backlog areas will occur within five years. NSR areas were distributed to Zones 1 to 3 in the same proportions as exist for the timber harvesting land base as defined on the inventory file. It was assumed that there has been no previous harvesting in Zone 4.

Table A-12. *Not satisfactorily restocked (NSR) areas*

Analysis Unit	Backlog				Current NSR				Total NSR (ha)
	Zone			Total (ha)	Zone			Total (ha)	
	1	2	3		1	2	3		
1	4	3	1	8	5	3	2	10	18
2	0	0	0	0	0	0	0	0	0
3	698	46	252	996	276	18	99	393	1 389
4	42	7	27	76	76	14	49	139	215
5	439	126	162	727	371	106	136	613	1 340
6	48	10	22	80	29	6	13	48	128
7	60	5	19	84	71	6	23	100	184
8	396	18	21	435	346	15	18	380	815
9	76	1	5	82	34	1	2	36	118
Total	1 764	216	508	2 488	1 258	169	343	1 720	4 208

A.4 Forest management assumptions

In Table 1 of the main report 4 629 ha of NSR was deducted. However, this area should be reduced to 4 208 ha to account for existing productivity losses and the riparian and avalanche chute exclusion. Silviculture records showed that in 1992 the TSA had 2 488 ha of backlog NSR and 1 610 ha of current NSR for a total of 4 098 ha. The 110 ha difference between these two totals (4 208 and 4 098) was added to the current NSR total and then prorated to each analysis unit. At the beginning of the timber supply analysis it is assumed that the age for current NSR is zero.

Table A-13 summarizes how NSR areas as well as timber licence reversions are distributed by zone. The table shows the initial timber harvesting land base that is input to the B.C. Forest Service timber supply model as well as the long-term timber harvesting land base that exists after productivity losses from future roads, trails and landings are deducted.

Table A-13. Final timber harvesting land base, Revelstoke TSA

Zone	Area before additions	TL areas added	Net NSR added	Initial harvesting land base	Long-term harvesting land base
1. Timber	37 230	3 353	2 972	43 555	40 441
2. VQO	6 049	335	385	6 769	6 311
3. Wildlife	10 098	953	851	11 902	11 140
4. Selection	499			499	450
Total	53 877	4 641	4 208	62 725	58 342

A.4.6 Basic Silviculture and Regeneration Assumptions

The following table shows what analysis units are created after harvesting occurs in existing AUs in the Revelstoke TSA. Originally the intent was to create managed stand yield tables that would reflect the proportions identified in the second column of Table A-14. However, because of problems in obtaining accurate site indices from the inventory file, it became necessary to use VDYP-based yield tables for regenerated stands. Therefore, each existing AU was regenerated back to the same AU and yield curve.

Table A-14. Regeneration assumptions

Existing AU	Regenerated AUs in actual practice (with percentages):	Regenerated AU as modelled
1	1 (80%), 8 (20%)	1
2	2 (100%)	2
3	3 (40%), 8 (60%)	3
4	2 (80%), 9 (20%)	4
5	2 (20%), 3 (20%), 8 (60%)	5
6	3 (30%), 6 (10%), 8 (50%), 9 (10%)	6
7	2 (60%), 9 (40%)	7
8	8 (100%)	8
9	9 (100%)	9
10	10 (100%)	10

Common Assumptions: For all AUs, it was assumed that 100% of all harvested sites would be planted at an initial density of 1 400 stems per ha with a one year regeneration delay.

There are currently no rehabilitation plans for problem forest types or brush and non-commercial areas in the Revelstoke TSA.

A.5 Yield estimates for existing and regenerated stands

A batch version of the Variable Density Yield Projection (VDYP) model, developed by the Inventory Branch of the B.C. Forest Service, was used to predict volume yields for both existing and regenerated stands. The yield model generates a net yield table for each stand on the inventory file that is in the timber harvesting land base and then all yield tables belonging to the same analysis unit (and zone if applicable) are aggregated to produce AU level yield tables.

For the Revelstoke TSA, 28 existing yield tables were produced: each of Zones 1, 2 and 3 had nine AUs for a total of 27 yield tables and Zone 4 had one AU and therefore only one yield table. To generate regenerated yield tables, differences among Zones 1, 2 and 3 were ignored so 9 regenerated yield tables were produced for the AUs in those zones.

During the project no suitable volume estimation model was found for predicting volumes for the selection management zone. Therefore a VDYP - based yield table was produced for that zone. It was then assumed that the average volume harvested each decade would be about the same as the long-term average harvest if the area was managed using even-aged silvicultural systems.

All the yield tables are shown below (Table A-15).

A.5 Yield estimates for existing and regenerated stands

Table A-15. Volume estimates for existing and regenerated stands

Age	Analysis Unit 1				Analysis Unit 2			
	Fir/Larch/Pine: Good & medium sites				Fir/Larch/Pine: Poor sites			
	Existing stand volumes			Regen	Existing stand volumes			Regen
	Zone 1 (timber)	Zone 2 (vqo)	Zone 3 (wildlife)	Zones 1-3	Zone 1 (timber)	Zone 2 (vqo)	Zone 3 (wildlife)	Zones 1-3
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	5.2	7.0	2.4	5.3	0.0	0.0	0.0	0.0
40	34.2	40.6	25.6	34.8	2.0	1.0	1.3	1.6
50	73.9	88.1	65.0	77.0	12.0	15.3	6.9	12.1
60	113.2	133.9	104.5	118.5	29.1	34.3	20.1	29.0
70	150.7	177.4	141.9	158.0	49.7	54.4	37.9	49.0
80	186.3	218.4	177.0	195.2	70.0	74.4	56.7	69.0
90	218.7	255.2	208.3	228.9	89.0	93.1	74.7	87.7
100	248.3	288.3	236.8	259.5	106.9	110.4	91.6	105.3
110	275.3	317.2	262.7	286.9	123.6	126.5	107.6	121.7
120	298.6	342.1	284.6	310.5	138.4	140.6	121.7	136.2
130	321.5	367.1	306.8	333.9	153.0	154.6	135.4	150.4
140	342.1	389.9	327.4	355.2	166.3	167.3	148.2	163.5
150	360.5	410.9	346.4	374.6	178.4	178.8	159.9	175.4
160	377.1	430.2	363.8	392.3	189.4	189.3	170.5	186.2
170	392.2	448.0	379.9	408.5	199.2	198.6	180.2	195.8
180	406.5	464.8	395.5	423.8	209.0	207.8	190.0	205.4
190	419.7	480.4	409.9	438.0	218.2	216.5	199.4	214.5
200	432.4	495.4	423.6	451.7	227.3	224.8	208.6	223.4
210	444.5	509.6	436.7	464.6	236.0	232.7	217.4	231.9
220	456.0	523.1	449.2	477.0	244.4	240.3	226.0	240.1
230	466.9	536.0	461.1	488.7	252.4	247.6	234.0	247.9
240	477.4	548.2	472.6	499.9	260.1	254.6	241.8	255.4
250	487.4	559.8	483.6	510.7	267.5	261.3	249.3	262.6
260	488.4	561.6	485.0	512.0	268.9	262.4	249.9	263.8
270	489.3	563.1	486.2	513.1	270.1	263.5	250.6	264.9
280	490.0	564.4	487.3	514.2	271.3	264.5	251.2	265.9
290	490.8	565.7	488.3	515.1	272.5	265.3	251.7	266.9
300	491.4	566.8	489.2	516.0	273.6	266.2	252.3	267.8
310	492.0	567.9	490.1	516.8	274.6	266.9	252.8	268.7
320	492.5	568.9	490.9	517.5	275.5	267.7	253.2	269.5
330	493.0	569.8	491.6	518.2	276.4	268.3	253.6	270.2
340	493.5	570.6	492.2	518.8	277.3	268.9	254.1	270.9
350	493.8	571.4	492.8	519.3	278.0	269.5	254.4	271.6

A.5 Yield estimates for existing and regenerated stands

Table A-15. Volume estimates for existing and regenerated stands (continued)

Age	Analysis Unit 3				Analysis Unit 4			
	Cedar: Good & medium sites				Cedar: Poor sites			
	Existing stand volumes			Regen Zones 1-3	Existing stand volumes			Regen Zones 1-3
	Zone 1 (timber)	Zone 2 (vqo)	Zone 3 (wildlife)		Zone 1 (timber)	Zone 2 (vqo)	Zone 3 (wildlife)	
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	1.8	2.6	2.1	2.0	0.1	0.0	0.1	0.1
40	43.0	39.7	45.4	43.4	4.5	2.7	1.8	3.4
50	94.4	76.1	97.5	94.3	35.3	23.5	26.6	31.1
60	141.3	109.1	145.2	140.8	69.8	48.3	57.9	63.5
70	183.0	138.1	187.8	182.1	101.0	70.3	86.9	93.0
80	221.0	164.5	226.8	219.8	129.5	90.4	113.5	120.0
90	248.4	184.1	254.9	247.1	151.4	106.3	134.1	140.9
100	270.3	200.2	277.4	268.8	169.4	119.7	151.3	158.1
110	287.9	213.4	295.4	286.3	184.3	131.1	165.5	172.4
120	301.2	223.9	309.0	299.6	196.0	140.5	176.8	183.8
130	323.6	239.5	332.3	321.9	213.2	152.6	193.0	200.1
140	345.5	254.4	355.0	343.6	229.8	164.0	208.6	215.8
150	365.9	268.3	376.3	364.0	245.3	174.6	223.3	230.5
160	385.0	281.1	396.3	383.1	259.8	184.3	237.0	244.3
170	402.8	293.1	414.9	400.8	273.3	193.3	249.7	257.1
180	419.8	304.4	432.8	417.7	286.3	201.8	262.0	269.3
190	435.8	315.0	449.7	433.7	298.5	209.8	273.6	280.9
200	451.7	325.5	466.4	449.6	310.6	217.7	285.1	292.4
210	467.0	335.5	482.6	464.9	322.3	225.4	296.3	303.5
220	484.8	347.1	501.3	482.6	335.7	234.3	308.9	316.2
230	502.3	358.3	519.7	500.0	349.1	243.1	321.7	328.9
240	519.4	369.1	537.6	517.0	362.2	251.8	334.1	341.4
250	535.9	379.4	554.9	533.4	375.2	260.3	346.4	353.6
260	537.5	380.5	556.3	535.0	377.3	262.4	348.2	355.7
270	539.0	381.6	557.6	536.4	379.3	264.4	350.0	357.6
280	540.2	382.5	558.6	537.5	381.0	266.2	351.6	359.3
290	541.3	383.3	559.6	538.6	382.6	268.0	353.2	360.9
300	542.3	384.1	560.4	539.5	384.1	269.7	354.7	362.4
310	543.2	384.8	561.2	540.4	385.4	271.2	356.0	363.7
320	544.1	385.4	561.9	541.2	386.5	272.5	357.1	364.9
330	544.8	386.1	562.5	541.9	387.6	273.7	358.2	365.9
340	545.5	386.6	563.1	542.6	388.6	274.7	359.1	366.9
350	546.2	387.2	563.6	543.2	389.5	275.8	360.0	367.9

A.5 Yield estimates for existing and regenerated stands

Table A-15. Volume estimates for existing and regenerated stands (continued)

Age	Analysis Unit 5				Analysis Unit 6			
	Pure Hemlock: all sites				Hemlock: Good & medium sites			
	Existing stand volumes			Regen Zones 1-3	Existing stand volumes			Regen Zones 1-3
	Zone 1 (timber)	Zone 2 (vqo)	Zone 3 (wildlife)		Zone 1 (timber)	Zone 2 (vqo)	Zone 3 (wildlife)	
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.7	0.4	0.3	0.5	1.1	3.1	1.9	1.5
40	18.9	21.2	31.1	22.0	21.9	36.8	32.7	26.6
50	53.7	57.3	83.2	60.9	69.0	83.7	83.4	74.7
60	92.8	96.9	134.7	102.9	117.3	127.7	132.3	122.6
70	131.3	136.2	182.0	143.4	160.7	167.1	176.4	165.8
80	169.3	171.9	225.4	182.2	200.0	202.6	216.2	204.8
90	200.6	201.4	260.2	213.9	230.8	230.2	246.5	235.0
100	227.3	226.7	289.5	241.0	256.5	253.3	271.3	260.2
110	250.3	248.7	314.4	264.3	278.2	272.7	292.0	281.3
120	270.0	267.6	335.6	284.2	296.0	288.7	308.6	298.5
130	293.2	289.3	361.3	307.7	319.5	309.6	332.1	321.8
140	313.6	308.6	383.9	328.3	341.1	328.7	353.8	343.1
150	331.8	325.8	404.3	346.9	361.1	346.1	373.9	362.8
160	348.2	341.2	422.5	363.5	379.3	362.1	392.4	380.8
170	362.8	355.0	438.4	378.2	395.9	376.6	409.1	397.2
180	375.8	367.2	452.1	391.3	411.2	390.1	424.5	412.4
190	387.3	377.9	464.2	402.8	425.2	402.5	438.7	426.2
200	399.2	388.9	476.3	414.5	439.2	414.6	452.9	440.0
210	410.6	399.2	487.6	425.7	452.7	426.0	466.5	453.3
220	421.4	408.9	498.2	436.3	465.6	436.8	479.4	466.0
230	431.4	417.8	507.9	446.1	477.9	447.1	491.6	478.0
240	440.6	426.1	516.8	455.0	489.4	456.9	503.1	489.3
250	449.2	433.9	525.0	463.4	500.1	466.1	514.0	499.9
260	456.0	439.9	531.6	470.0	504.8	469.8	518.0	504.2
270	462.2	445.1	537.5	475.9	508.8	473.1	521.5	508.1
280	467.9	449.9	542.8	481.4	512.5	476.2	524.8	511.6
290	473.1	454.3	547.8	486.4	516.0	479.1	527.7	514.8
300	477.9	458.5	552.3	491.1	519.2	481.8	530.5	517.8
310	482.3	462.2	556.5	495.3	522.1	484.3	533.1	520.6
320	486.5	465.6	560.4	499.3	524.9	486.6	535.4	523.2
330	490.3	468.8	563.9	502.9	527.5	488.8	537.6	525.6
340	493.9	471.8	567.1	506.4	529.9	490.8	539.7	527.9
350	497.3	474.7	570.1	509.6	532.1	492.7	541.5	530.0

A.5 Yield estimates for existing and regenerated stands

Table A-15. Volume estimates for existing and regenerated stands (continued)

Age	Analysis Unit 7				Analysis Unit 8			
	Pure Hemlock: Poor sites				Spruce/Balsam: Good & medium sites			
	Existing stand volumes			Regen	Existing stand volumes			Regen
	Zone 1 (timber)	Zone 2 (vqo)	Zone 3 (wildlife)	Zones 1-3	Zone 1 (timber)	Zone 2 (vqo)	Zone 3 (wildlife)	Zones 1-3
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.3
40	0.7	6.0	0.4	0.9	12.3	6.3	12.1	12.1
50	9.7	27.7	10.5	11.0	41.7	30.1	42.1	41.3
60	34.7	62.3	40.8	37.8	87.8	70.8	97.3	87.6
70	63.6	95.8	75.8	68.4	131.6	111.4	147.1	131.5
80	90.5	127.5	108.2	96.9	169.1	146.3	191.0	169.3
90	113.1	153.7	134.8	120.6	200.7	176.1	228.0	201.0
100	132.5	176.2	157.6	141.0	227.6	202.2	259.6	228.1
110	149.3	195.9	177.3	158.6	250.5	225.0	286.6	251.3
120	163.8	212.5	193.8	173.7	270.0	244.7	309.4	270.9
130	180.7	232.4	214.0	191.5	289.4	264.5	332.1	290.4
140	196.3	250.7	232.7	208.0	306.8	282.4	352.4	308.1
150	210.7	267.6	249.9	223.2	322.4	298.6	370.5	323.8
160	224.0	283.1	265.9	237.2	336.4	313.3	386.6	337.9
170	236.2	297.2	280.5	250.1	348.8	326.6	400.8	350.5
180	247.5	310.4	294.0	262.1	360.2	338.9	414.0	362.0
190	257.9	322.6	306.4	273.0	370.6	350.4	426.0	372.4
200	268.4	335.0	319.2	284.1	380.1	361.1	437.1	382.1
210	278.6	347.0	331.6	294.9	388.8	371.0	447.3	390.9
220	288.5	358.6	343.6	305.4	396.9	380.2	456.6	399.1
230	298.1	369.7	355.2	315.6	404.3	388.9	465.3	406.6
240	307.3	380.2	366.6	325.4	411.2	397.0	473.3	413.6
250	316.3	390.4	377.6	334.9	417.5	404.7	480.9	420.1
260	321.4	395.3	383.8	340.2	420.2	407.6	483.7	422.8
270	326.1	399.9	389.4	345.1	422.6	410.3	486.3	425.2
280	330.2	404.3	394.6	349.5	424.6	412.7	488.5	427.2
290	333.9	408.2	399.1	353.4	426.4	414.8	490.3	429.0
300	337.3	411.6	403.4	357.0	427.9	416.8	491.9	430.5
310	340.5	414.8	407.3	360.3	429.2	418.5	493.3	431.9
320	343.4	417.8	411.0	363.5	430.3	420.1	494.4	433.0
330	346.2	420.6	414.3	366.3	431.3	421.4	495.3	434.0
340	348.7	423.3	417.4	369.0	432.1	422.7	496.1	434.8
350	351.2	425.9	420.3	371.6	432.8	423.8	496.8	435.5

A.5 Yield estimates for existing and regenerated stands

Table A-15. Volume Estimates for Existing and Regenerated Stands (concluded)

Age	Analysis Unit 9				Analysis Unit 10	
	Spruce/balsam: Poor sites				all species & sites	
	Existing stand volumes			Regen	Existing	Regen
	Zone 1 (timber)	Zone 2 (vgo)	Zone 3 (wildlife)	Zones 1-3	Zone 4	Zone 4
10	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	4.9	4.9
40	0.2	5.8	0.0	0.3	34.3	34.3
50	2.5	20.1	0.1	2.5	71.6	71.6
60	10.6	39.1	10.5	10.9	110.1	110.1
70	39.6	62.7	47.6	40.4	147.5	147.5
80	70.7	84.8	88.1	71.9	182.1	182.1
90	100.7	104.5	125.0	102.2	212.3	212.3
100	127.4	122.1	158.7	129.3	238.6	238.6
110	151.1	137.9	188.4	153.2	261.8	261.8
120	171.9	152.2	214.1	174.3	281.6	281.6
130	192.4	167.7	240.1	195.1	303.0	303.0
140	211.1	182.7	264.0	214.1	322.5	322.5
150	228.2	196.9	285.7	231.4	340.1	340.1
160	243.8	210.4	305.5	247.3	356.2	356.2
170	258.0	223.3	323.5	261.7	370.8	370.8
180	271.0	235.6	340.0	274.9	384.5	384.5
190	282.9	247.4	355.2	287.0	397.2	397.2
200	294.0	258.6	369.5	298.3	409.3	409.3
210	304.3	269.3	382.9	308.8	420.8	420.8
220	313.9	279.6	395.5	318.5	431.9	431.9
230	322.8	289.5	407.2	327.6	442.4	442.4
240	331.0	299.0	418.4	336.1	452.3	452.3
250	338.7	308.2	428.8	344.0	461.7	461.7
260	342.8	310.0	434.2	348.0	463.2	463.2
270	346.4	311.7	438.9	351.7	464.6	464.6
280	349.7	313.3	443.2	355.0	465.8	465.8
290	352.6	314.8	447.0	358.0	466.9	466.9
300	355.2	316.2	450.4	360.6	467.8	467.8
310	357.5	317.5	453.4	363.0	468.5	468.5
320	359.6	318.7	456.0	365.1	469.1	469.1
330	361.4	319.9	458.4	367.0	469.5	469.5
340	363.1	320.9	460.6	368.6	469.9	469.9
350	364.5	321.9	462.6	370.1	470.2	470.2