

Fraser TSA Silviculture Strategy (Type 2)

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Summary

This report documents a forest-level modeling study that examines the implications of silviculture regime options proposed by the Chilliwack Forest District for implementation on the Fraser TSA. The objective of the project is to provide strategic direction to the district silviculture staff in the design of their silviculture program.

Benefits are evaluated against the TSR base case

A silvicultural planning model was developed using the Woodstock (Remsoft, 1997) modeling language that is consistent with the current TSR model and base case for the TSA, and also fully represents the additional forest-level objectives and silvicultural activities required for silvicultural planning. The landbase and management parameters, described in AAC Rationale for Fraser TSA (April 1999), are the basis of the silviculture planning model implemented for this study. Using the TSR base case as the point of departure ensures that benefits from incremental silviculture are modelled in a management context consistent with the Chief Forester's assumptions when he set the AAC.

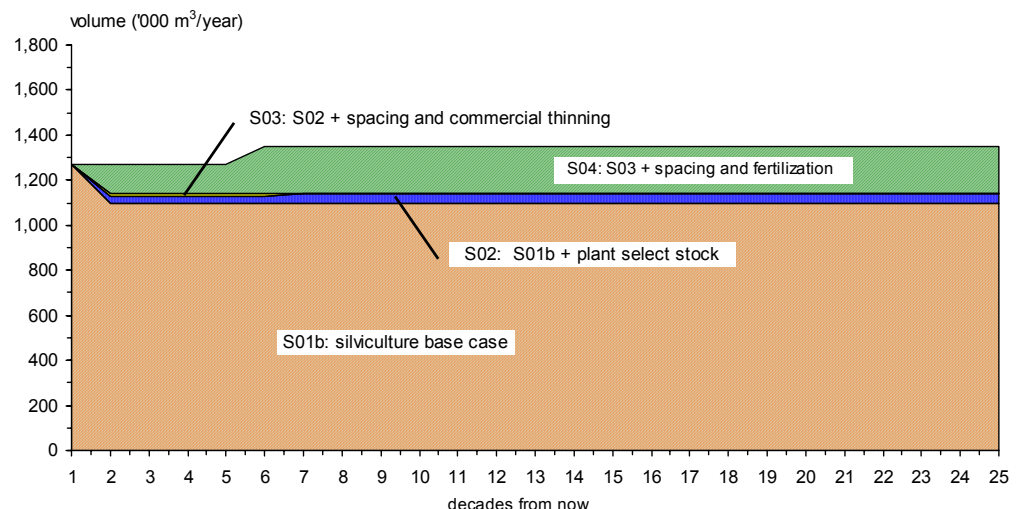
Quantity and quality objectives are evaluated

Scenarios were evaluated for their impacts on three forest-level management objectives: maximizing total timber supply, maximizing the supply of larger dimension logs, and maximizing the supply of solid-clear wood.

28% increase in harvest in long term

Figure E-1 shows the impact of intensification of management on timber supply. In the long term, planting select stock will increase harvest levels by 4%, and spacing and fertilization increase the harvest level by 19%. Commercial thinning contributes only 1% to the early mid term (decades 3-7) and has no independent benefit in the long term. However, commercial thinning is employed extensively in the spacing and fertilization scenarios and probably contributes to the 19% benefit by allowing optimal timing of the harvest.

Figure E-1. Impact of planting select stock, commercial thinning, spacing and fertilization on the forecast harvest.





The model puts the highest priority on maximizing harvest levels in decade 2, then in the mid term (decades 3-15), and finally in the long term (decades 16-25). Therefore the model implements commercial thinning to bring timber forward in the harvest queue in order to reduce falldown in decade 2 and fill the mid-term trough. Fertilization and genetic gain produce timber quantity benefits in the late mid term and early long term which are conveyed forward in the harvest queue by commercial thinning.

600% increase of 65+ cm logs

The analysis showed that volume harvested in the long term of stems 65+ cm can be increased 600% by lengthening rotation ages past culmination age — but at a cost of reducing the long-term harvest level by 6%. In addition to longer rotations, there was a shift to spacing to lower densities.

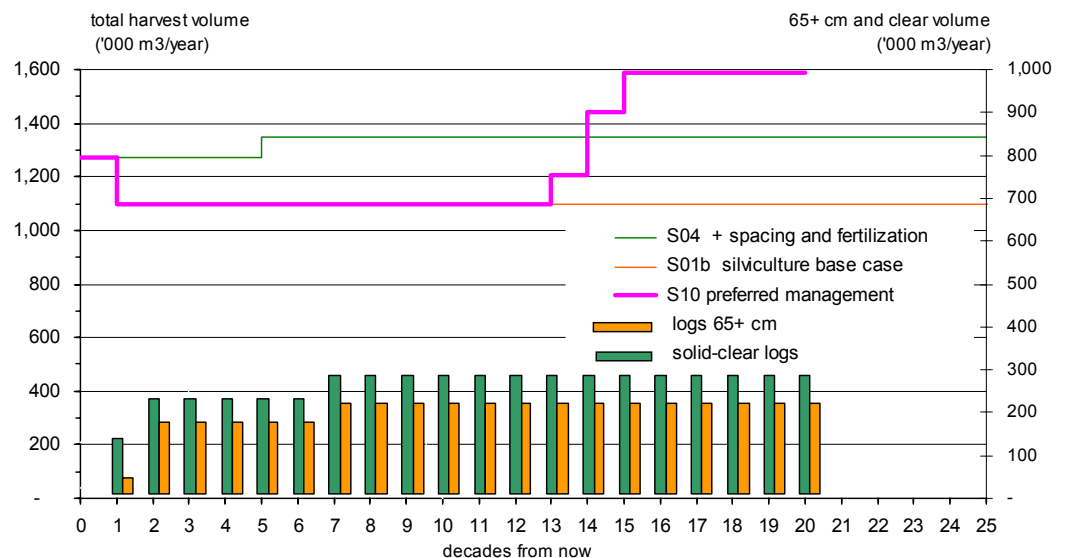
3%-19% of cut in solid-clear wood

An aggressive program of pruning can increase the long-term harvest of solid-clear wood from zero to 3% of the total harvest without forgoing the volume gains obtained with incremental silviculture. The percent of clear wood can be increased to 19% of the harvest by reducing the long-term harvest level by 12% and the deepening the mid-term trough by 32%.

“Preferred management” scenario

The preferred management scenario (Figure E-2) results in a reduction of harvest in the mid-term, allowing the managed stands to be harvested on longer rotations and yield the larger logs and solid-clears required by the scenario. However, at the end of the transition (decades 13-15), the harvest rises to exceed the S04 level and maintains this annual harvest (1.59 million m³) until the end of the forecasting period. It is unlikely that this accelerated harvest level could be sustained as the operable inventory drops by 50% between decade 15 and 20.

Figure E-2. Total harvest and harvest of solid-clear and large dimension logs, preferred management scenario.





First decade priorities: commercial thin, fertilize, then space	Silvicultural activities were ranked by sorting the shadow prices associated with each treatment in ascending order. In general, commercial thinning and fertilization activities rank the highest, followed by juvenile spacing. Note that juvenile spacing is intrinsic to most of the fertilization and commercial thinning activities. These rankings assume that the operable management objective is to maximize the harvest; silvicultural activities were not ranked according to pruning objectives.
Limitations of the study	<p>The main limitations of the study are issues regarding the validity of the TASS managed stand yield tables, the difficulty of incorporating the silvicultural history in the landbase dataset, and the scope and accuracy of the representation of the silvicultural regimes in the model.</p> <p>This study quantifies the change in productive capacity of the Fraser TSA with intensification of management, various levels of expenditure, and alternative management objectives. It does not provide prescriptions or statements about the appropriate level of management intensity and level of expenditure, nor which management objectives should be pursued.</p>
Prescriptive studies should follow confirmation of the descriptive model	The critical components of the physical production model (yield curves, silviculture history, and regime diagrams) should be confirmed before addressing the question of the appropriate level of silviculture investment.





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Fraser TSA Silviculture Strategy Analysis



1.0 Introduction

This report documents a forest-level modeling study that examines the implications of silviculture regime options proposed by the Chilliwack Forest District for implementation on the Fraser TSA. The objective of the project is to provide strategic direction to the district silviculture staff in the design of a silviculture program.

A silvicultural planning model was developed that is consistent with the current TSR model and base case for the TSA, and also fully represents the additional forest-level objectives and silvicultural activities required for silvicultural planning.

The TSR base case is the appropriate "point of departure" for the silviculture analysis because it:

- reflects the management unit's current land base, inventory, growth and yield, and management practices;
- is the schedule of timber supply from the base case data set that conforms to Ministry of Forests' conventions regarding harvest flow, and any departures from the standard harvest flow conventions that may have been deemed appropriate by the TSR;
- ensures that the silvicultural planning model is based on the timber supply assumptions for the TSA that the Chief Forester considered (or will consider) in setting the AAC for that TSA.

A major difference between the TSR analyses and this analysis is the choice of forest-level model. The TSR uses the simulation model FSSIM while this analysis was undertaken with a linear programming (LP) model developed using the Woodstock (Remsoft, 1997) modeling language. The LP formulation was selected because of its flexibility and comprehensiveness in representing silviculture activities, its ability to incorporate complex and multiple objectives, and its facility and consistency with economic reasoning. The LP model is referred to in subsequent sections of this report as the Fraser Silviculture Planning Model (FSPM).

After this introduction, Section 2.0 of this report describes the information requirements for the analysis with special emphasis on changes to the TSR data base and additional information required for the silvicultural analysis. The next section (Section 3.0) describes the results of modelling the scenarios constructed to explore the implications of intensification of management. Section 4.0 reports the long-term silviculture strategy for the TSA-- the regimes selected to achieve the forest-level objectives -- and ranks silvicultural treatments with respect to their contribution to forest-level objectives. Some of the limitations of the study are discussed in Section 5.0.



2.0 Data and Management Assumptions

This section describes the data and assumptions used in this analysis that differ from those documented TSR2 or are additional inputs that are required for the silvicultural analysis. Other forest management assumptions-- including forest cover requirements, utilization levels and standards, unsalvaged losses and green-up assumptions-- are unchanged from the TSR2 timber supply analysis.

2.1 Changes to the TSR2 Landbase

The data set provided to the project team by Timber Supply Branch comprised 281 480 ha of operable forest, including backlog NSR and Timber Licences (which will revert to Crown management in the future). On the advice of the TSR2 timber supply analyst, 1 480 ha of marginal stands were eliminated from the landbase. The total operable forest used for the FSMP is 280 000 (Table 2-1).

Of the 22 945 ha of NSR (current and backlog) on the inventory file, 12 845 ha were reclassified as regenerated ages 1-10. The remaining 10 100 ha were added to the current NSR (age 0) on the inventory file.

Table 2-1. Summary of changes to the timber harvesting land base, Fraser TSA

Classification	TSR2 ¹	Current Study ²
Current THLB	281 481	280 000[DW1]
NSR (current and backlog)	22 945	10 957
Timber Licences (operable)	3 108	3 096

¹ Source: Fraser TSA Timber Supply Analysis 1998

² Source: Timber Supply Branch, January 28, 1999

Future roads, trails and landings are not removed from the THLB

Loss of productive land to future roads, trails and landings are modelled explicitly with the FSPM, in that a specified percentage of land harvested for the first time is removed from the productive land base. Losses to roads and landings occur at a rate of 1% from harvested natural stands between the age of 70 and 90 [DW2]years.

2.2 Silviculture Analysis Units

The 17 analysis units defined for TSR2 were aggregated by District staff into 12 silviculture analysis units (SAUs) deemed appropriate for the silviculture regimes contemplated for the TSA (see Table 2-2). Mean site index (metres at 50 years) for each SAU was calculated as the area weighted average of the indices of its constituent TSR2 analysis units.



Fraser TSA Silviculture Strategy Analysis

Section 2 — Data and Assumptions

Table 2-2. Definition of the silvicultural analysis units.

SAU # ¹	Types	ITG	FSPM (ha)	Mean Site Index ¹
1	Fd leading	1-8	17,870	31.01
2	Fd leading	1-8	25,332	26.8
3	Fd leading	1-8	10,515	23.4
4	Fd leading	1-8	39,966	18.9
5	Fd leading	1-8	5,692	15.7
6	H,B leading	12-20	11,610	27.4
7	H,B leading	12-20	100,065	18.9
8	Cw leading	9-11	5,402	22.9
9	Cw leading	9-11	6,283	15.3
10	S,PI leading	21-32	14,342	14.5
11	H,B leading	12-20	33,950	11.6
12	Deciduous	37-39	8,974	14.4
Total			280,000 [DW3]	

Notes

1. Mean site indices are the area-weighted average site indices of the ITG groupings.

2.3 Silvicultural State of the Landbase

The silviculture state of a stand records the information that the manager needs in order to determine what silviculture activities are immediately feasible (not including operational considerations such as harvesting restrictions, accessibility, terrain, or markets). For example, species mix, age, density, basal area, crown closure may be the variables that the silviculturalist considers when deciding the treatment of a stand. These state variables change over time with the development of the stand (growth, competition, mortality) and with silviculture actions (e.g., juvenile spacing).

The TSR timber supply analysis differentiates between stands that are in natural and managed states in order to assign appropriate yield curves. A silvicultural analysis requires a more complex definition of the silvicultural state of each stand in order to determine feasible management actions and appropriate managed stand yield curves.

Describing the silvicultural state in terms of the variables utilized by the silviculturalists may be appropriate for operational (tactical), program-level planning, but is too detailed for strategic planning with a forest-level model. For the purposes of this project, the silviculture state of (aggregations of) forest stands was developed from the ISIS and MLSIS data bases and is described in Appendix A.



2.4 Management Practices

In addition to the harvesting methods included in the TSR analysis (conventional clearcutting), this study explicitly models commercial thinning.

Harvesting operability responds to silviculture

However, instead of assigning a minimum harvest age for clearcutting, minimum operable volumes were calculated from the height, diameter and volume criteria described in the TSR analysis report. Specifying minimum operable volumes allows the model to reduce harvesting ages in response to volume benefits of intensification of management.

Commercial thinning is single entry, 3 possible ages

The development of stands post commercial thinning was simulated with TASS, according to residual stand criteria (trees per hectare, target volume removal) and method (single entry, from below, leaving the largest well-spaced trees) supplied by the district. The district specified one age of entry; after reviewing the results of the TASS simulations, two more ages of entry were added, typically 10 and 20 years after the age specified by the district. Alternate ages of entry were included in order to provide additional flexibility in re-ordering the harvest queue.

1st decade harvest profile is imposed on the model

The harvest profile for the first decade is imposed on the silviculture model to ensure that silviculture activities selected by the model reflect current operations. The distribution of the first-decade harvest shown in Table 2.3 was constructed from an analysis of recent forest development plans for the Fraser TSA. Commercial thinning is limited to operable percentages supplied by the Chilliwack Forest District. For SAU01 the operable percentage is 75%; for SAU02 and SAU03 it is 50% of the area of the SAU.

Base case scenario assumes basic silviculture

The base case scenario for this study assumes basic silvicultural practices and models these practices in a manner identical to the TSR timber supply analysis. The remaining scenarios of this study require the simulation of complex silvicultural regimes including spacing, pruning, fertilization and commercial thinning.

Alternative management regimes incorporating these incremental silviculture activities and commercial thinning were specified for each SAU by District staff and regime diagrams were constructed that delineate the alternative silvicultural states of each SAU and the feasible transitions between these states. These regime diagrams are useful for communicating the possible development states implied by sets of alternative regimes, and for specifying yield tables required for stands in harvestable states. The regime diagrams for each SAU are included in Appendix B.



Fraser TSA Silviculture Strategy Analysis

Section 2 — Data and Assumptions

Table 2-3. Harvest profile (% volume harvested) in the first decade.

SAU Description	SAU	SI	% Total Harvest Volume	
			Conventional Immature Age 1-100	Conventional Mature 101-750
Fd leading	SAU01	31	8	0
Fd leading	SAU02	27	8	0
Fd leading	SAU03	23		0
Fd leading	SAU04	19		0
Fd leading	SAU05	16		0
H,B leading	SAU06	27	2	0
H,B leading	SAU07	19	2	16
Cw leading	SAU08	23	0	14
Cw leading	SAU09	15		
S,P,L leading	SAU10	14		
H,B leading	SAU11	12	0	48
Deciduous	SAU12	14	0	2
			20	80

Source: Wickland, Chilliwack Forest District.

Managed stand yield tables are simulated with TASS

Each harvesting activity represented in the regime diagrams requires a yield table corresponding to the silvicultural state that it is acting on. Managed stand yield tables were created by Research Branch using TASS. Yield tables for existing natural stands (state N) and TSR2 managed stands (state A) were obtained directly from the TSR2 data files. The yield tables for each SAU are included in Appendix E.

Costs and labour requirements for implementing the silvicultural treatments are listed in Table 2.4.

Table 2-4. Cost and labour assumptions for silviculture treatments.

Activity	\$/ha	P-day/ha
plant	481	2
space	929	5
spacePrune	3107	23
pruneOnly	2178	18
spacePruneFert	3330	23.1
fertOnly	223	0.1

Source: Fraser TSA Workshop, July 22-23, 1998



2.5 Select Stock and Genetic Gain

The benefits from planting select stock in the Fraser TSA are evaluated in this study. The genetic gain for each planting mix specified by the District is listed in Table 2.5 and the calculation of these gains is detailed in Appendix C.

Table 2-5. Genetic gain assumptions for the Fraser TSA.

Species Planted	Genetic Gain
Fd	10.5
HwBa	6.2
Cw	11.6
S,PI	3.9

Source: R. Plandon, MoF Tree Improvement Branch.



3.0 Analysis Results

This section presents the results of the analysis of eight scenarios designed to quantify the impact of silvicultural practices under different assumptions and objectives. The scenarios are described in detail in Appendix D.

3.1 Base Case

Only two silviculture activities are included in the base case – harvesting and planting, including basic silviculture. No incremental silviculture (spacing, pruning, or fertilization) or commercial thinning is included.

The base case is modelled for two reasons. It demonstrates the consistency of the TSR representation of the TSA's timber supply with that of the silviculture model used in this study. With the validity of the silviculture model established, scenarios with intensified management or different management objectives can be compared to the base case results and differences can be quantified and attributed to management assumptions.

Base Case Harvest Forecast

Figure 3-1 compares base case harvest forecasts determined for this study with the TSR2 base case harvest forecast.

Figure 3.1,
S01a TSR2 landbase

The harvest schedule labeled S01a corresponds to the base case management assumptions applied to the TSR2 landbase supplied to this project. From the initial harvest level (AAC, April 1999) it declines 11% in decade 2 and maintains this level (1 140 000 m³ per year) through the remainder of the planning horizon. Note that the TSR2 harvest forecast declines 19% to 1 020 000 m³ per year in the second decade and maintains that level until decade 10, where it rises to 1 200 000 million m³ per year and maintains this harvest level for the remainder of the planning horizon.

Figure 3.1,
S01b Silvicultural
history landbase

The harvest schedule labeled S01b corresponds to the base case management assumptions applied to the silvicultural history landbase (described in Appendix A). The silvicultural history landbase more accurately represents the silvicultural state of existing managed stands. This schedule maintains a harvest level of 1 100 000 m³ per year out to the planning horizon.

The differences between the S01a and TSR2 base case harvest schedules may be due to aggregation of the landbase into different analysis units with different associated yield tables.

Figure 3-1. Base case harvest forecasts.

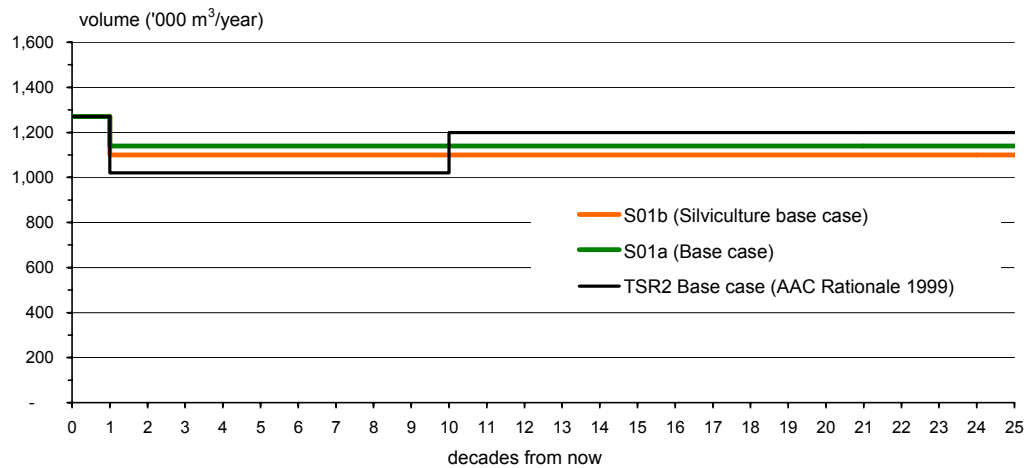


Figure 3-2. Composition by leading species, silviculture base case (S01b).

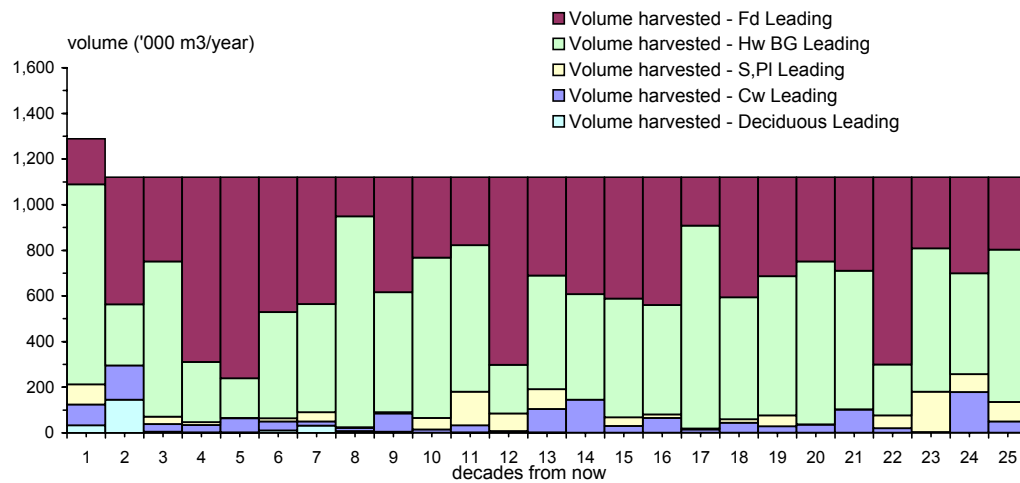
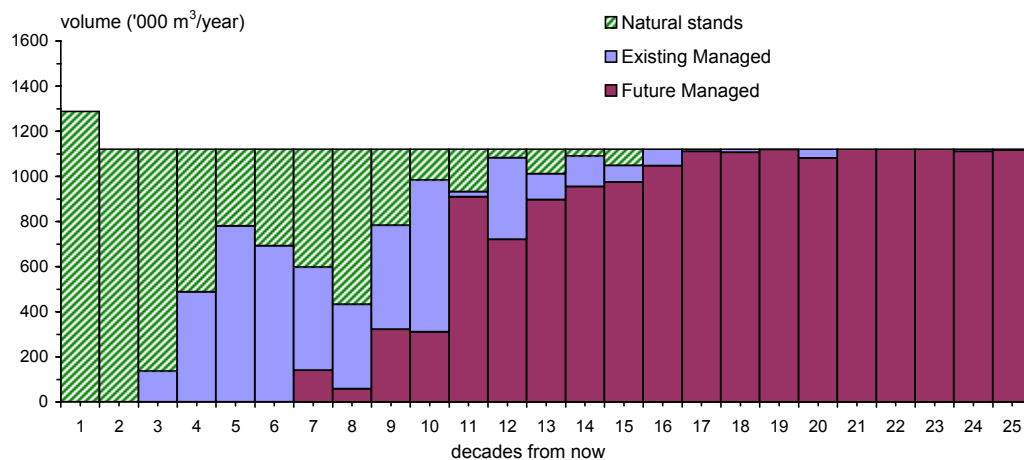


Figure 3-3. Composition by existing natural and managed stands of harvest forecast, silviculture base case (S01b).





Fraser TSA Silviculture Strategy Analysis

Section 3—Analysis Results

Schedule S01b, based on the silvicultural history landbase, forecasts a harvest level that is below the S01a schedule in decades 2-25. This difference suggests that the existing managed stands in this study are assigned yield curves of lower productivity than are assumed in TSR2. Both S01a and S01b show increases over the TSR2 schedule in the mid-term trough (decades 3-10) while underperforming TSR2 in the long term (by 8.3%). This is partly due to the model solution process, which assigns a higher priority to the maintenance of the initial harvest level for as long as possible and the reduction of depth of the mid-term trough, and a lower priority on maximizing the long-term harvest level.

S01b is the silvicultural base case harvest schedule

After consideration of these issues, the schedule S01b was accepted as the basis for evaluating the harvest volume effects of incremental silviculture, and will be subsequently referred to as the silvicultural base case.

Figure 3-2 shows the composition of the base case harvest by leading species. The harvest in decade 1 reflects the harvest profile specified by the District (section 2.4) but the mix of species in subsequent decades is determined by the model.

Figure 3-3 shows the composition of the base case harvest in terms of natural stands, existing managed stands, and future managed stands. The harvest is composed of existing stands until decade 6, and is not totally dependent on managed stands until decade 16.

Response framework

The end of the transition to managed stands (decade 15) is referred to in this study as the end of the mid-term, and the beginning of the long term. The short term is arbitrarily set as decades 1 and 2.

Figures 3-4, 3-5

The harvest forecast from managed stands by grade and diameter limit are plotted in Figures 3-4 and 3-5, respectively. In both figures the harvest from natural stands is not differentiated by grade or diameter due to limitations of the yield tables. Note that the quadratic mean diameter of the harvested managed stands, plotted against the right-hand axis on Figure 3-5, drops steeply while harvesting is concentrated on older existing managed stands. The quadratic mean diameter drops to a minimum of 23 cm in decade 8 and then remains relatively constant between 25-30 cm from decade 9 out to the planning horizon.

Figure 3-6 plots the area harvested on the left-hand axis, and the harvest volume per hectare on the right-hand axis. Volume per hectare increases during the first 5 decades while the model harvests older higher volume stands. The trend then decreases and levels out in the long term (decades 16 to 25) while harvesting is focused on younger managed stands. Note that there is no commercial thinning in the base case.

Figure 3-4. Composition by grade of forecast harvest of managed stands, silviculture base case (S01b).

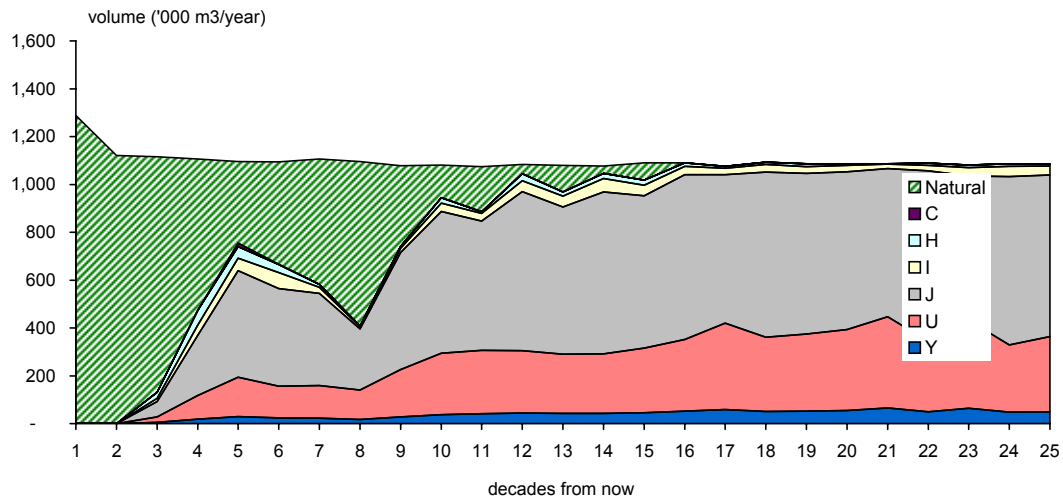


Figure 3-5. Composition by dimension of forecast harvest of managed stands, silviculture base case (S01b).

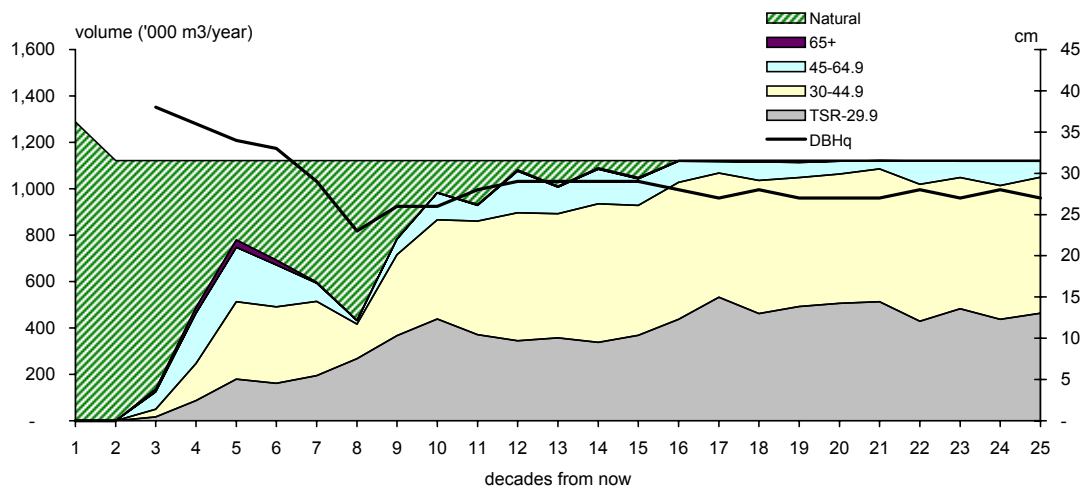


Figure 3-6. Total area and volume per unit area of the forecast harvest, silviculture base case (S01b).

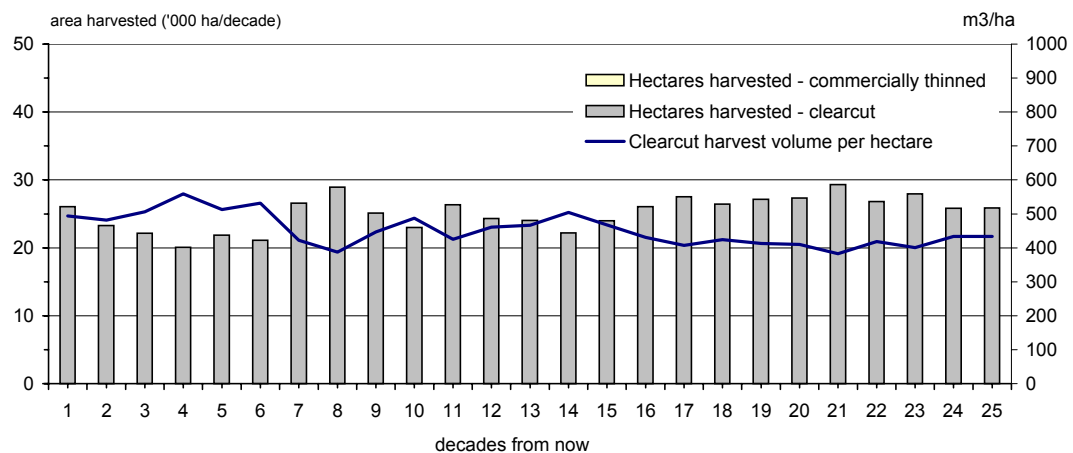


Figure 3-7. Total and operable growing stock forecast, silviculture base case (S01b).

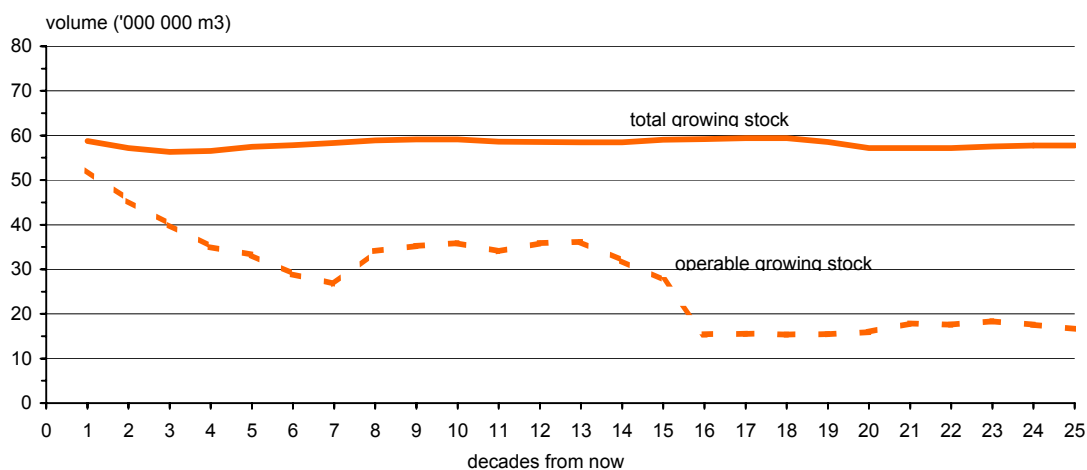


Figure 3-8. Percent disturbed (not greened-up) by constraining management zones, silviculture base case (S01b).

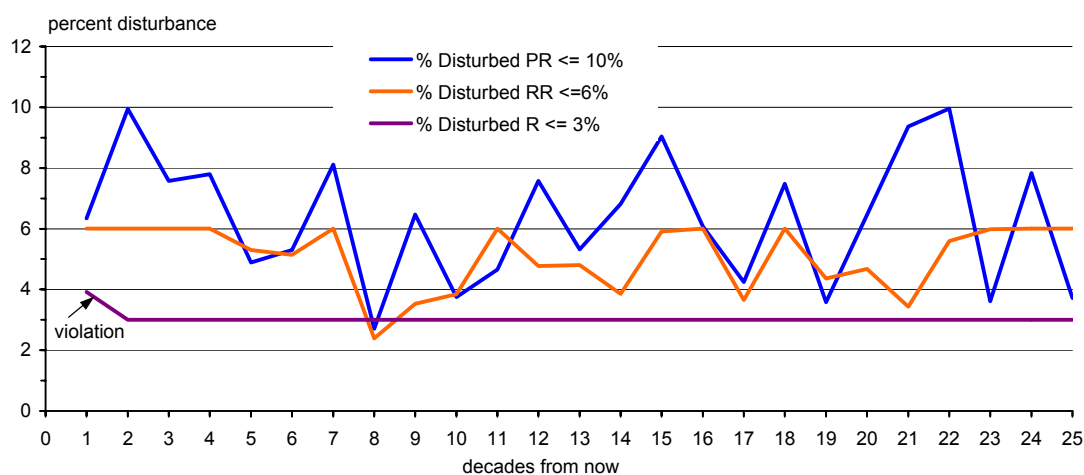
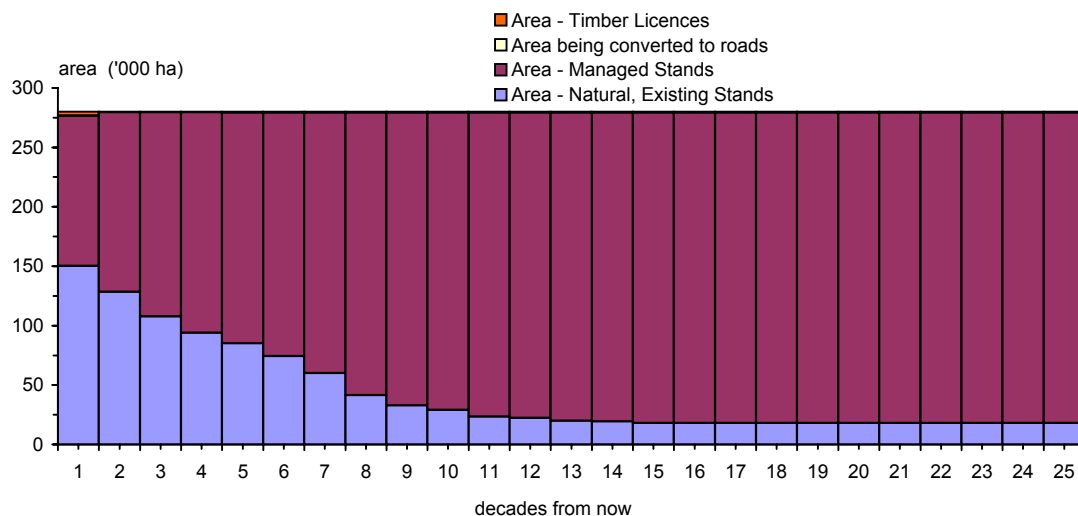


Figure 3-9. Aggregate silviculture state area forecast, silviculture base case (S01b).





Changes in the Silvicultural State of the Base Case

Stable inventory measures indicates sustainable LTHL

Figure 3-7 plots the total and operable growing stock over the planning horizon. The total growing stock rises from its initial level, before leveling out. The operable growing stock declines through the transition to managed stands and remains relatively constant in the long term (decades 16-25). The stability of these inventory measures indicates that the long-term harvest level (LTHL) is likely to be sustainable.

All retention disturbance constraints are tight

Three of the green-up constraints are tight (constraining) across the planning horizon. Figure 3-8 tracks the disturbance (percent not greened-up) for the all management zones. Green-up requirements in the retention zone ($\leq 3\%$) are tight in decades 2-25. The retention/partial retention zone is at its disturbance limit ($\leq 6\%$) in decades 1-4, 7, 11, 15-16, and decades 22-25. The partial retention zone reaches the upper limit ($\leq 10\%$) in decades 2, 15, and 22.

Some poor site fir and hemlock balsam is not harvested

Figure 3-9 tracks the change in silvicultural state of the THLB over the planning horizon. At the end of the first decade, the THLB is composed of approximately 150 000 ha of natural existing stands, 129 000 ha of existing and future (created by the model) managed stands, and about 3 000 ha of Timber Licences. The Timber Licences are harvested and regenerated as managed stands by the end of decade 1, and the area of natural stands and existing managed stands are steadily reduced as harvesting and regeneration convert them to future managed stands. The area converted to roads is too small to be apparent on the figure. Note that at the end of decade 25 there remains approximately 17 000 ha of natural stands that have not been harvested. These natural stands are predominantly poor site fir, and poor site hemlock/balsam.

The model considers the objectives over the entire planning horizon

The reason why the model leaves the low productivity stands is logical. The model selects stands for harvesting that optimize its timber supply objectives across the entire planning horizon, namely to maximize short, medium and long term-timber supply (in that order). It has calculated that harvesting the low site stands will return a small yield and that the stand will not attain operable volume (350 m³/ha) again for a long time (approximately 110 years for cedar, 130 years for fir, and 170 for the hemlock balsam). The stand may not be accessible again within the planning horizon. Focusing harvesting on higher site stands with shorter rotations increases the productivity of the THLB and increases timber supply over the planning horizon.

Simulation models, such as FSSIM, use a simple harvest selection rule, such as oldest first, and cannot consider the future implications of harvesting a stand. This is a significant difference between simulation and LP models and underlines the importance of having a clear objective when forecasting timber supply.

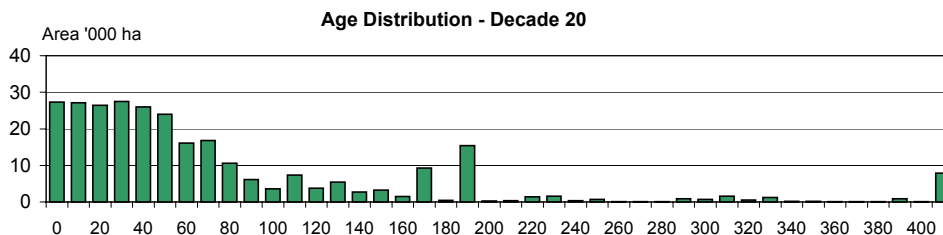
Figure 3-10

Figure 3-10 shows the progression of the age class distribution of operable timber on the TSA over the planning horizon. Age class 250 includes all stands 250 years or older, although the model tracks stands for 700 years before converting them to the regenerating state. By decade 25, almost all of the stands age class 230 or older are poor site fir, cedar or hemlock.

Figure 3-10. Forecast distribution of operable area for total inventory, silviculture base case (S01b).



Figure 3-3. Composition by existing natural and managed stands of harvest forecast, silviculture base case .





3.2 Management for Timber Quantity

This section presents the results of incorporating the district-supplied management regimes into the silviculture planning model, and explores the implications of alternative levels of expenditure on incremental silviculture.

Incorporating the district-supplied management regimes requires three types of changes to the model. First, the set of allowable silviculture activities is expanded from the base case (harvesting and planting) to include the incremental silviculture activities of planting, spacing and fertilization. Second, harvesting is expanded to include commercial thinning.

Select Stock, Commercial Thinning and Intensive Silviculture Scenarios

Figure 3-11

Figure 3-11 shows the incremental benefits from planting select stock (S02), commercial thinning (S03) and spacing and fertilization (S04). These scenarios were implemented with the management objective of maximizing the quantity of timber harvested, and assumed an unlimited silviculture budget.

S02 Select stock

Volume benefits from planting select stock —3% increment over the base case S01b— are first apparent in decade 2, due to the effect of releasing for harvest in decade 2 stands that are mature but were rationed for later harvest under S01b. An additional 1% increment (4% in total) is available as early as decade 7, due to future managed stands planted with select stock becoming available for harvesting.

The long-term benefit to the harvest is lower than one might expect given the genetic gain assumptions listed in Table 2-5. The explanation is that some the volume benefit from planting select stock is left in the inventory—not cut. Figure 3.12 (discussed more fully below) shows that over decades 20-25 the total inventory contains 6 400 000 m³ of harvest above the base case inventory levels.

S03 Commercial thinning

Commercial thinning regimes, including the juvenile spacing activities intrinsic to those regimes, increase the harvest in decades 2-6 by 1%.¹ In accordance with the model's schedule of priorities, commercial thinning is used to bring harvest forward to fill the mid-term trough. Note that this scenario applies commercial thinning to the base case with select stock (S02) and does not reflect the commercial thinning that might occur when fertilization regimes are employed (S04).

S04 Spacing and fertilization

Implementing spacing and fertilization regimes, in addition to select stock and commercial thinning regimes, allows the current AAC to be maintained until decade 5 (14% increase over S01b). After this time S04 returns an increment of 19% starting in decade 6 and this level is sustainable through the long term. The total increment above the base case from the intensification of management (plant select stock, space and fertilize, commercially thin) is 14%, beginning in decade 2 with a larger increment (19%) realized over decades 6-25.

¹ Unless otherwise described, all increment percentages in this report are calculated with reference to the silviculture base case harvest level (S01b).

Figure 3-11. Impact of planting select stock, commercial thinning, spacing and fertilization on the forecast harvest.

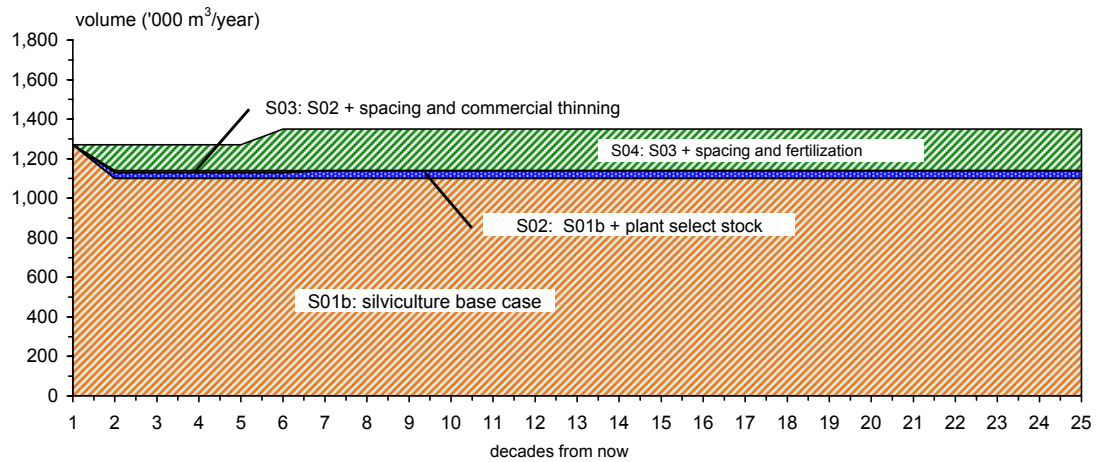


Figure 3-12. Total and operable growing stock forecasts with intensification of management.

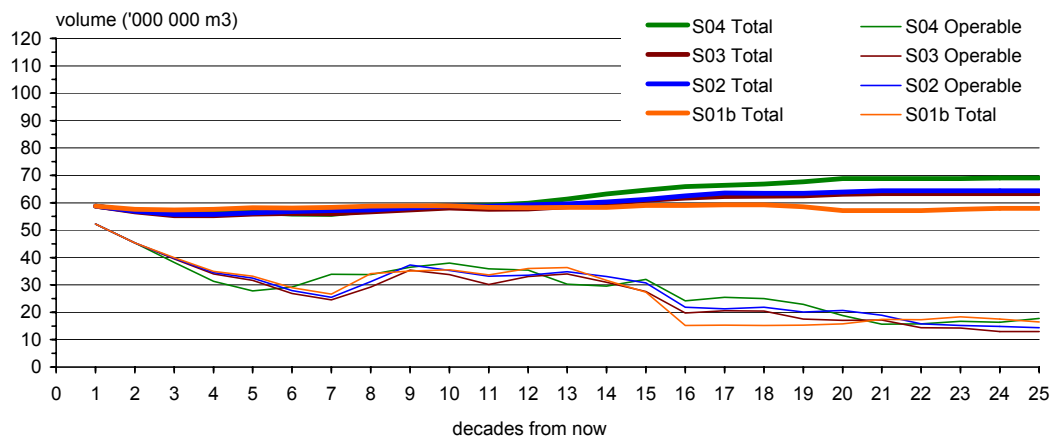


Figure 3-13. Composition of forecast harvest by existing natural and managed stands, maximum intensive management scenario (S04).

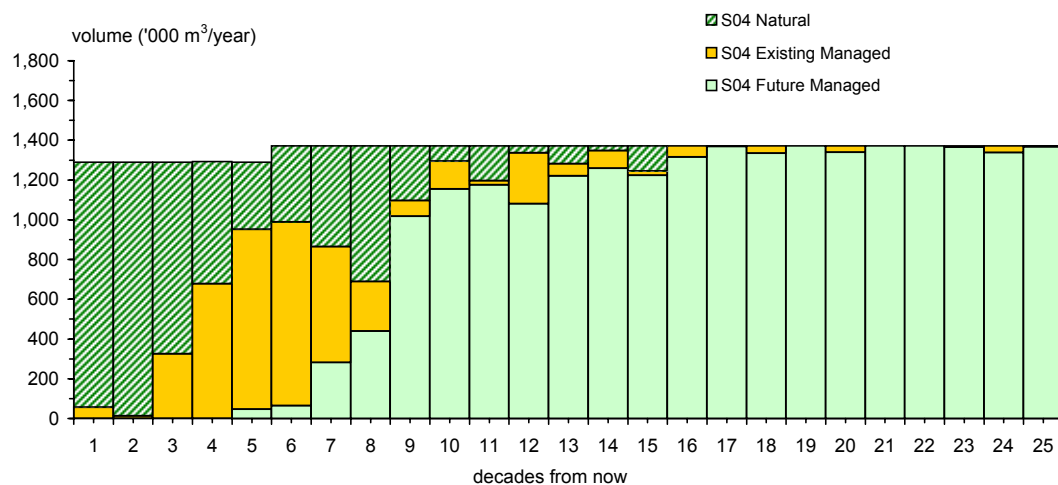




Figure 3-12
Growing stock

Figure 3-12 plots the total and operable growing stock level for each of the scenarios. The criterion for sustainability (of timber supply) noted in the discussion of the base case, that total and operable growing stock should be non-declining in the long term, is met.

Both total and operable growing stock increase with intensification of management – inventory levels for the select stock scenario are higher than the base case (as noted above) and scenarios that include spacing and fertilization regimes increase inventory levels further. Commercial thinning has little effect on growing stock, except to reduce operable growing stock in decades 9-16. This reduction is due to the model employing commercial thinning to “borrow from the future”, i.e., drawing down inventory via commercial thinning and clearcutting the residual stand at a later date.

Figure 3-13
Transition to
managed stands

Figure 3-13 shows the transition in the timber supply from natural stands to managed stands for the maximum intensive management scenario (S04). Comparing this figure with the base case transition plotted in Figure 3-3, the transition is completed sooner (decade 10 versus decade 15) with the intensification of management. Also, continued management (especially repeat fertilization) of existing managed stands has increased the yield from these stands, allowing the initial harvest of future managed stands to be delayed from decade 6 to decade 8.

Figure 3-14
Clearcut vs
commercial thinning

Figure 3-14 compares the area harvested by clearcutting versus commercial thinning. Over the entire planning horizon the area commercially thinned is constrained to be less than 75%, 50% and 50% for SAU01, SAU02, and SAU03, respectively, of the operable stands available for commercial thinning. The area commercially thinned increases slowly from periods 1 to 5. The model does not employ commercial thinning during this time since it is focused on clearcutting existing stands, which enables regeneration to higher yield managed stands. Commercial thinning becomes more extensive in decade 7 due to scarcity of operable timber. These higher levels of commercial thinning allow the model to increase the harvest level in decade 6, before the end of the transition to dependence on managed stands.

Figure 3-15
Composition of
harvest by diameter
limit.

Figure 3-15 shows the composition by diameter limit of the harvest from managed stands. Comparing this figure with the equivalent base case Figure 3-5, the largest increment is in the 30-44.9 cm diameter category, i.e., stems with dbh exceeding the TSR upper limit (generally 29.9 cm).

Figure 3-16
Composition of
harvest by grade.

Figure 3-16 shows the composition by grade of the harvest from managed stands. Comparing this figure with the equivalent base case Figure 3-4, there is no discernable shift in grade for the regimes implemented by the model. This result is not unexpected, given that the objective of this scenario was to maximize harvest volume, although harvest grades and dimension are reported.

The portion of the harvest labeled “not graded” is due to missing or incomplete TASS managed stand yield tables.

Figure 3-14. Total area and volume per unit area of the forecast harvest, maximum intensive management scenario (S04).

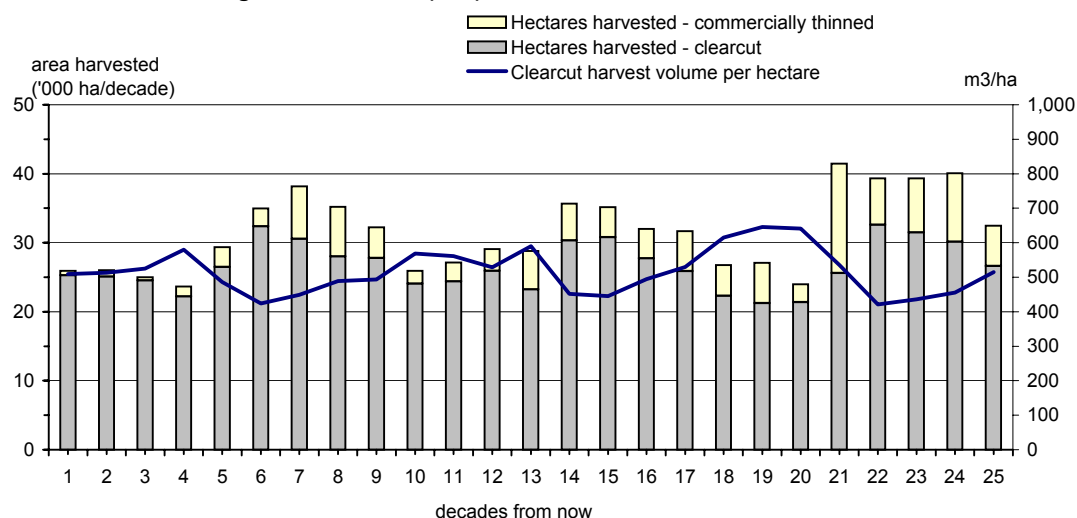


Figure 3-15. Composition by diameter limit of forecast harvest of managed stands, maximum intensive management scenario (S04).

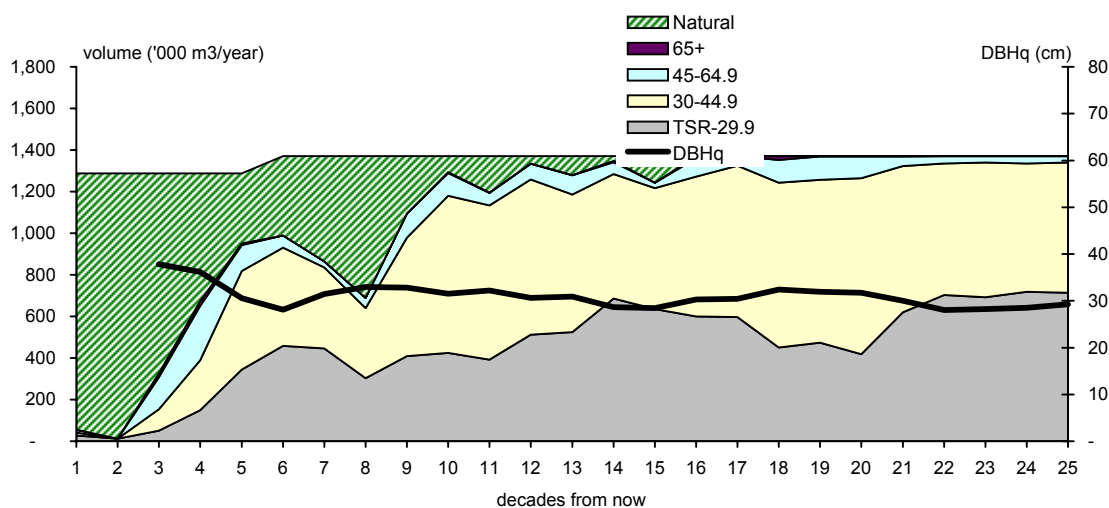
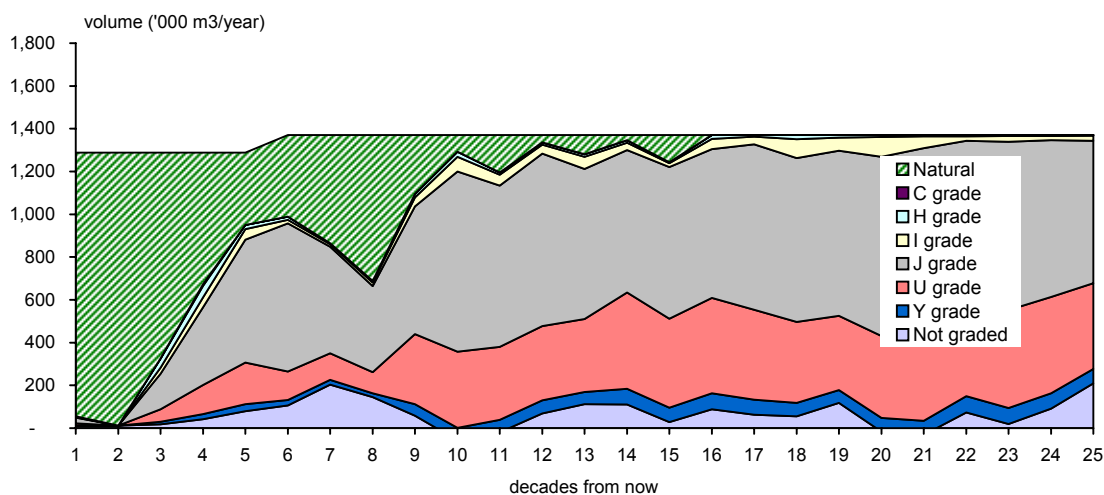


Figure 3-16. Composition by grade of forecast harvest of managed stands, maximum intensive management scenario (S04).





Optimal Management for Maximizing Harvest Quantity

Figures 3-17, 3-18, and 3-19 plot the area by treatment, treatment costs, and direct silviculture employment benefits, respectively, for the harvest maximization scenario.

Figure 3-17
Treatment area

Figure 3-17 shows that the fertilization program increases in size from 700 ha per year in decade 1 to an average of 5300 ha per year in decades 7-25. The area juvenile spaced per year remains relatively steady with 1930 ha spaced per year in decade 1 to an average of 1980 ha spaced per year in decades 7-25. Note that the first decade planting activity includes 9825 ha of NSR and 3109 ha of timber lease conversion.

Figure 3-18
Treatment cost

The cost of spacing and fertilization (Figures 3-18) and the silviculture employment outputs of these programs (Figures 3-19) follow a similar pattern. The average cost of spacing and fertilization over the planning horizon is \$2 768 000 per year.

Figure 3-19
Employment

The regimes implemented to achieve the quantity benefits described in this section will be discussed in Section 4.

Management Intensity and Levels of Funding

S05 Levels of
funding

The timber supply benefits and management information described above and plotted on Figures 3-11 through 3-19 are the results of a scenario that maximizes harvest quantity (volume) without limiting annual expenditure (S04). In scenario S05, the annual expenditure is constrained to percentages (10%, 20%, 30%, 50%, and 75%) of the maximum average expenditure (\$2 768 000 per year).

Figure 3-20
Volume increments vs
annual expenditure

Figure 3-20 shows how the increment of harvest (above the base case) resulting from spacing and fertilization changes with increasing annual expenditure. The response is plotted for three time intervals: decade 2, decade 3-10 (transition) and 11-25 (long term). Note that it is assumed that the level of expenditure along the horizontal axis is maintained over the planning horizon.

The increment of harvest volume in decade 2 attributable to spacing and fertilization rises sharply to 140 000 m³ per year as the annual expenditure rises to \$1 400 000 per year. Additional funds will not increase the harvest in decade 2 because the harvest is restricted to be less than or equal to the decade 1 harvest (current AAC) by the TSR harvest flow rules.

In decades 3-10, the increment of harvest volume attributable to spacing and fertilization also rises sharply, to 168 000 m³ per year at a funding level of \$1 400 000 per year, and then continues to rise to 219 000 m³ at \$2 700 000 per year.

Classic declining
returns to scale in
the late mid and
long term

In the mid term and long term (decades 3-25), the response of incremental harvest volume to increasing annual expenditure demonstrates that rate of increase of the volume benefit declines as the annual expenditure rises. Note that the average annual expenditure for spacing and silviculture over 1991-1996 is \$1 594 000 per year.

Figure 3-17. Treatment area forecast, maximum intensive management scenario (S04).

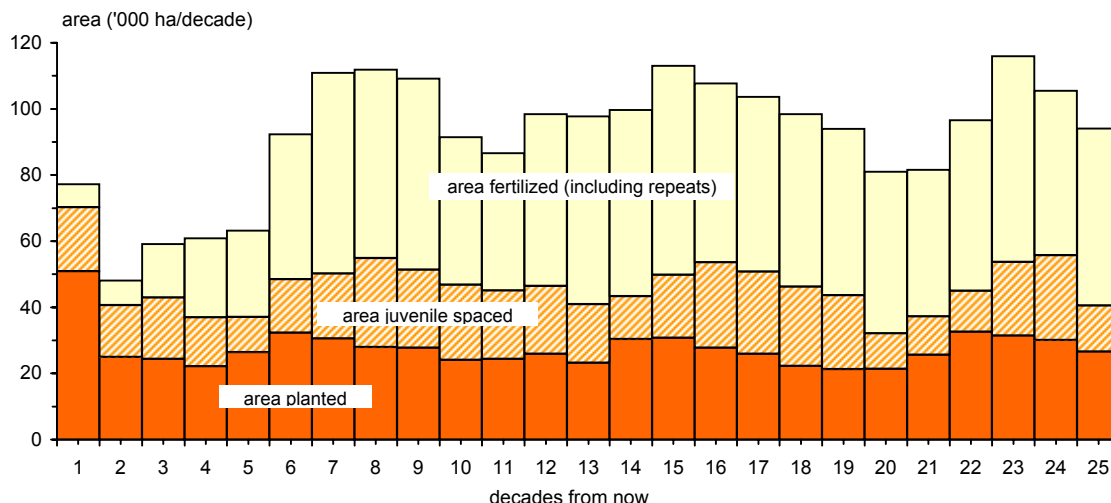


Figure 3-18. Treatment cost forecast, maximum intensive management scenario (S04).

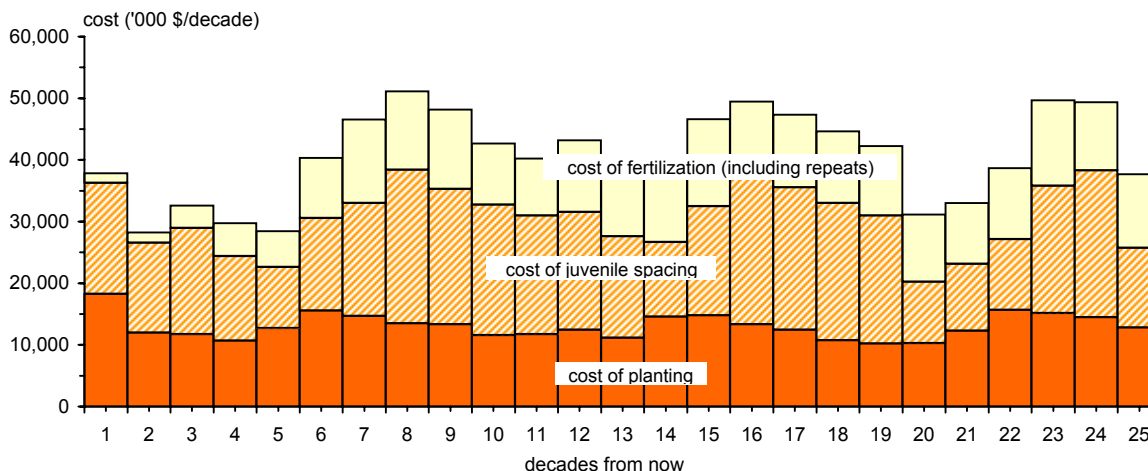


Figure 3-19. Silviculture direct employment forecast, maximum intensive management scenario (S04).

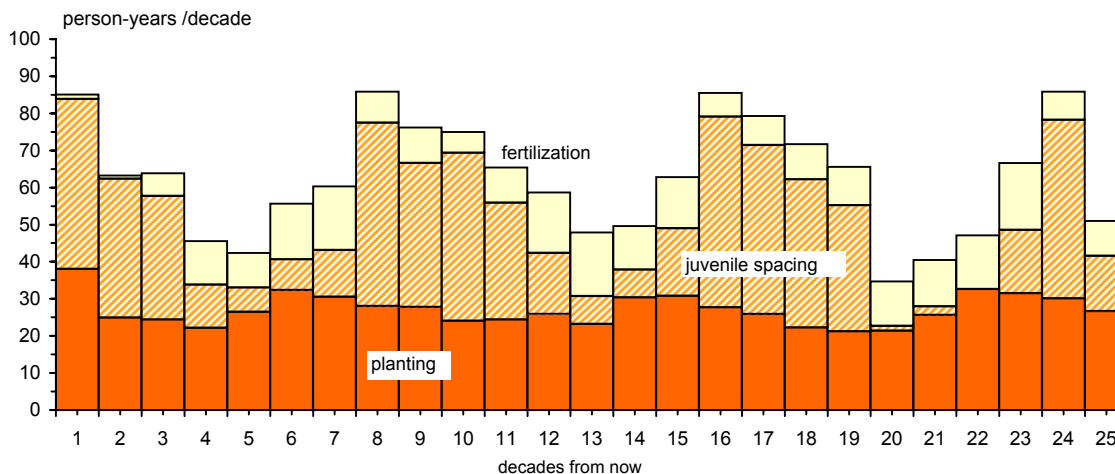


Figure 3-20. Incremental harvest volume from annual expenditures on spacing and fertilization, levels of funding scenario (S05).

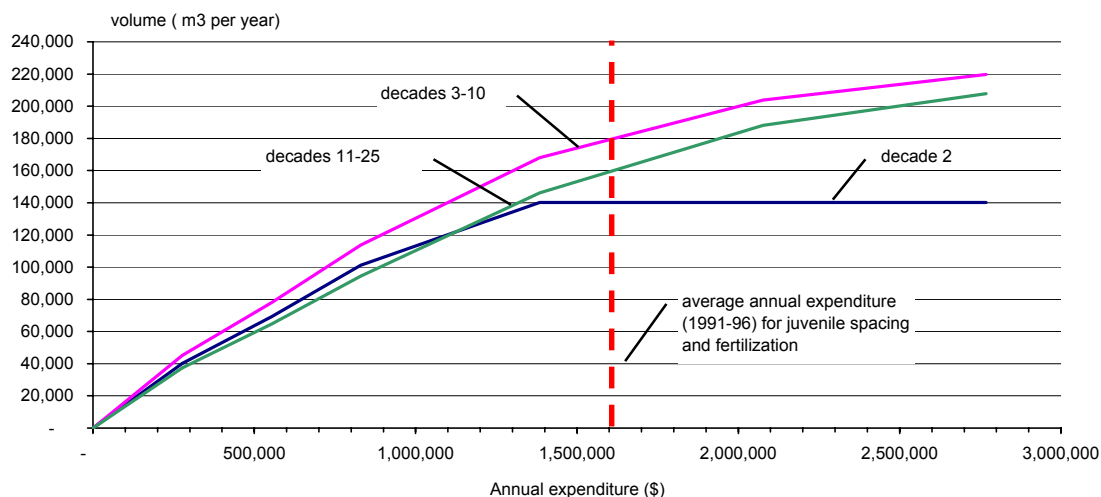


Figure 3-21. Area juvenile spaced at increasing levels of annual expenditure, levels of funding scenario (S05).

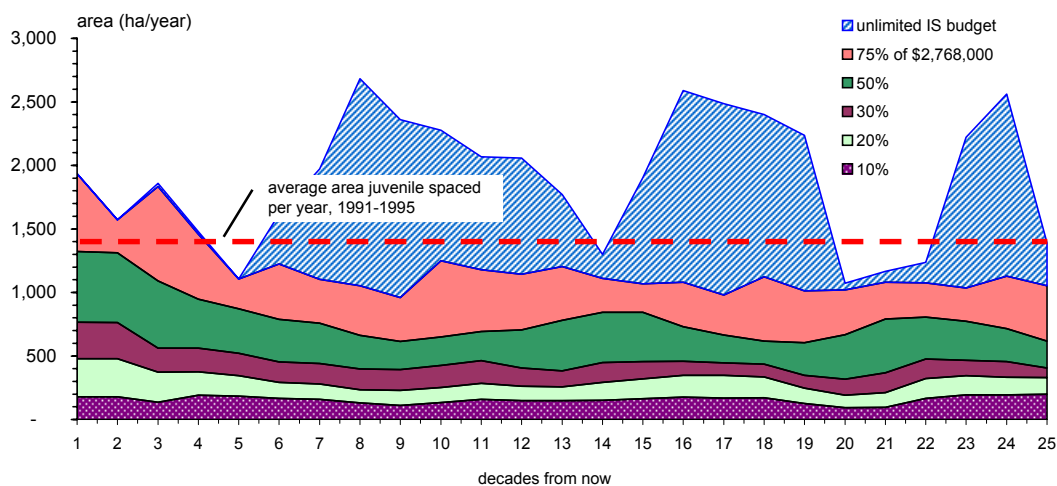


Figure 3-22. Area fertilized at increasing levels of annual expenditure, levels of funding scenario (S05).

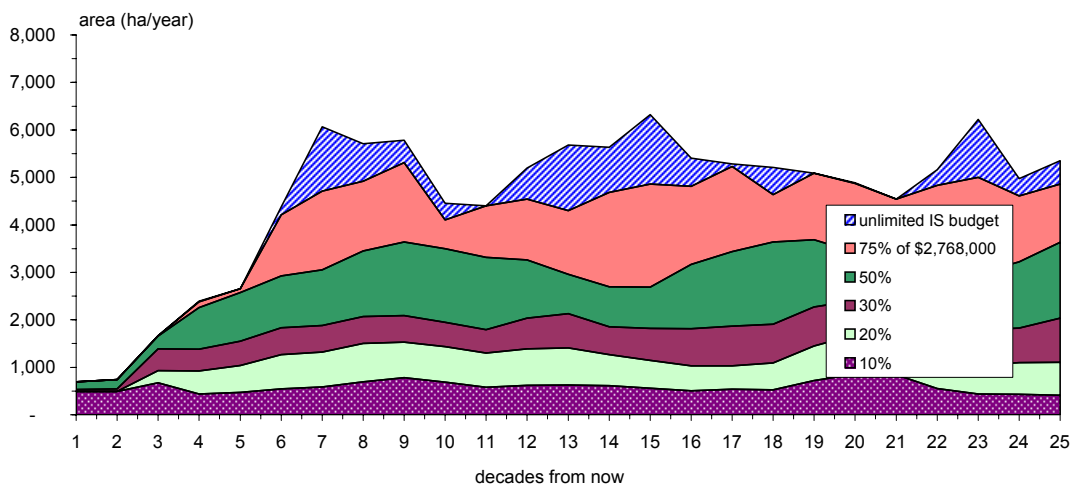




Figure 3-21
Spacing vs annual
expenditure

Figure 3-22
Fertilization vs annual
expenditure

Figure 3-21 and 3-22 plot the area of juvenile spacing and fertilization, respectively, undertaken annually for increasing levels of expenditure.

The relative width and variation of the plotted bands corresponding to activity levels are determined by the silviculture opportunities encountered by the model, and by variations in treatment costs. The model allocates funds to spacing (\$929 per hectare) and fertilization (\$223 per hectare).

3.3 Management for Timber Quality – Solid-Clear Wood

This section presents the results of two scenarios that implement silviculture treatments in order to achieve timber quality objectives. The objectives are to maximize the yield of solid clear wood (scenario S09) and the yield of large logs (scenario S06). Both scenarios maximize the quality objective in the long term and assume that sufficient silviculture can be undertaken in the short and medium term to establish a sustainable long- term output.

S09:
Max solid-clear
wood

The harvest of solid-clear wood was not maximized directly by the model. The volume of wood from pruned stands in the long term (decades 16-25) was maximized and the average expenditure on pruning was noted (\$526 984). Note that the harvest schedule was constrained to be equal to the maximum harvest schedule forecast in scenario S04. Spacing, fertilization and commercial thinning activities were scheduled as required to maximize the models objectives and meet the constraints.

Figure 3-23
Volume of solid-clear
wood vs expenditure

Figure 3-23 shows the relationship between the incremental volume of solid-clear wood and annual expenditure on pruning. The straight-line relationship infers that the investment in today's dollars for a cubic metre of solid clear wood in decade 11 is \$14.50. Assuming a discount rate of 4%, the future value of this investment in 100 years is \$736 per cubic metre.

Figure 3-24
Schedule of solid-clear
wood by expenditure

Figure 3-24 shows the schedule of increments of solid-clear wood harvested with increasing levels of annual expenditure on pruning. These increments are calculated only for existing managed and future managed stands, and cannot be calculated for natural stands. The increment of solid clear available with no further investment (labeled \$0) is the product of historical pruning activity, i.e., existing pruned stands.

The harvest of pruned stands is constrained to an even-flow in decades 11-20 in order to facilitate comparison of the levels of pruning expenditure. The production of solid-clear wood, as depicted in Figure 3-24, varies slightly from even flow due to variations in the yield of solid clear between pruned stands.

Figure 3-25
Schedule of area
pruned by expenditure

Figure 3-25 shows the schedule of area pruned at increasing levels of annual expenditure. Only pruning activity in the short and mid term is plotted because the model's objective is to maximize the production of clear wood in the long term. Since pruning activity undertaken in the long term will result in few harvestable stands within the planning horizon, modeled pruning activity in the long term is erratic.

Figure 3-23. Incremental harvest volume (long term) of solid-clear wood with increasing expenditure on pruning (\$09).

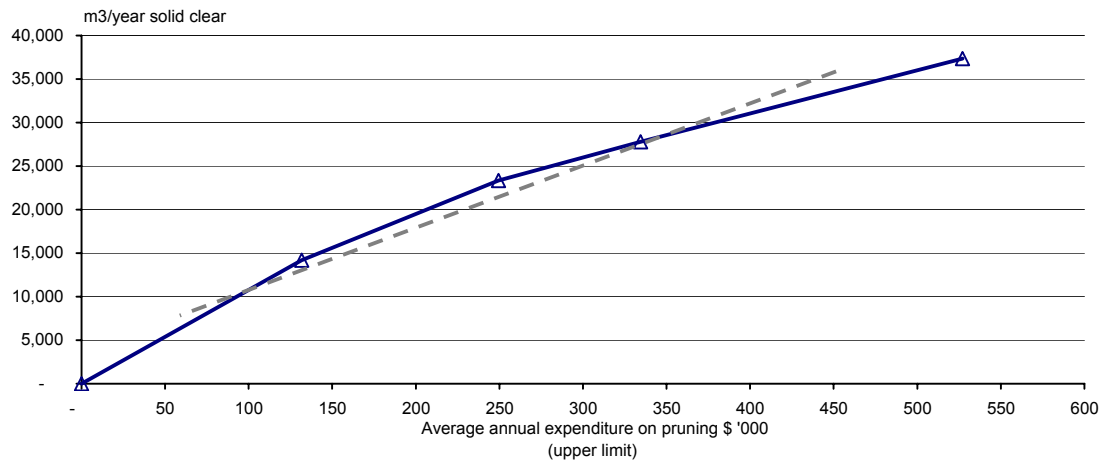


Figure 3-24. Forecast harvest of solid-clear wood with increasing levels of annual expenditure on pruning (\$09).

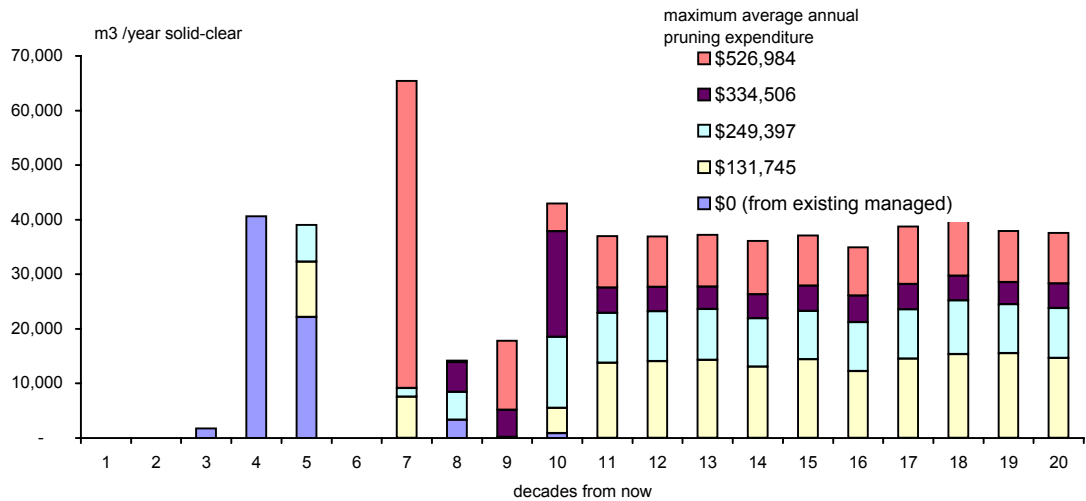
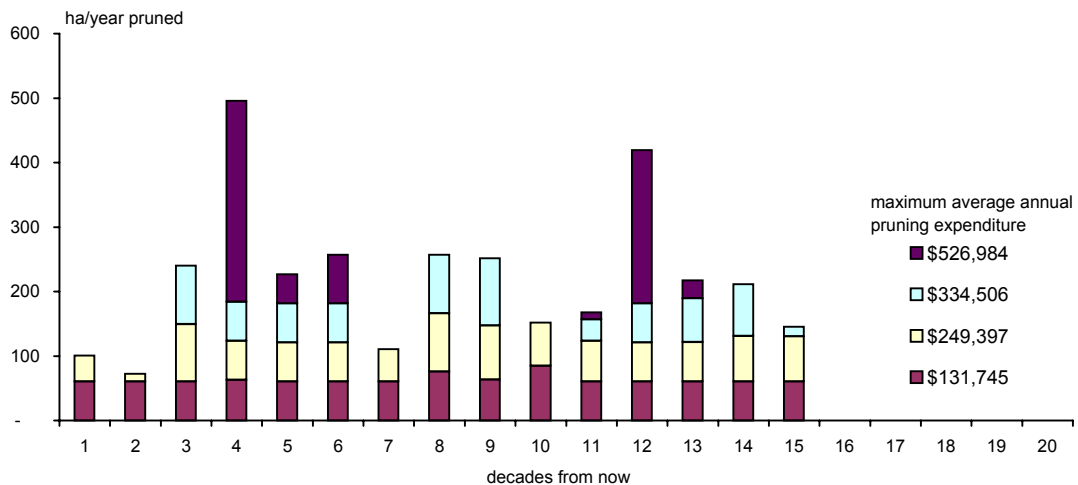


Figure 3-25. Area pruned at increasing levels of annual expenditure (\$09).





The pruning activity in decade 4 (Figure 3-25) is 63 ha per year when the annual pruning expenditure is constrained to be $\leq \$131\,745$. As the limit on annual expenditure increases to $\$249\,397$ and then to $\$334\,506$, pruning activity rises to 121 ha and 184 ha, respectively. When the annual pruning expenditure is unconstrained (and rises to an average expenditure of $\$526\,984$), pruning activity in decade 4 increases to 496 ha.

Figure 3-26
Pruning and reduction
in timber supply

Figure 3-26 shows the impact on the forecast harvest of maximizing the harvest of pruned timber and allowing the harvest levels to decline from their maximum (S04) levels to the harvest level achieved with select stock only (S02), and 75% of the S02 level. When the harvest is allowed to drop to 75% of the S02 level in the mid term, it recovers to exceed S02 level in the long term.

Figure 3-27
Solid-clear wood harvest

With the harvest reduced to S02 levels, the solid-clear wood component of the harvest from pruned stands (Figure 3-27) is seven times the production of solid clear achieved without relaxing timber harvest levels (265 000 versus 37 000 m³ per year, on average over decades 11-20.) Note that the further relaxation of harvesting to 75% of S02 levels results in little benefit to the production of solid-clear wood.

Figure 3-28
Area pruned

Figure 3-28 shows the pruning activity required to achieve the production of solid-clear wood plotted in Figure 3-27. Note that the pruning activity levels shown in the columns are cumulative, e.g., in decade 4, if the harvest level is reduced to $\geq 75\%$ of the S02 harvest level (S09g), then the area pruned is 2870 ha. However, the increment attributable to relaxing the cut from S09e to S09g is only 10 ha and is not discernable on the figure.

Average pruning costs in decades 1-15 are $\$1\,334\,000$ per year for S09g (relaxed harvest levels), versus $\$527\,000\,000$ for S09a (harvest constrained to maximum S04 levels).

Areas pruned in decades 16-20 may be atypical of the program level required to obtain the production levels plotted in Figure 3-27. Stands pruned in these decades may not be harvested before the end of planning horizon, and so may not contribute to the objective of maximizing the harvest of solid-clear wood. Hence the model will prune fewer stands as it approaches decade 20.

3.4 Management for Timber Quality – Dimension

S06:
Max large logs

Volume is traded-off
for piece size

This scenario was implemented by maximizing the harvest of stems of DBH ≥ 65 cm, i.e., the model maximized the volume produced from a yield table that was compiled with utilization limits of 65+ cm DBH. The harvest schedule was constrained to be greater than or equal to the first decade harvest and all incremental silviculture activities (except pruning) were allowed. The rationale for this relaxation of volume production requirements is that the harvest of 65+ cm volume showed very little increase unless the harvest flow constraint was relaxed.

Figure 3-29

Figure 3-29 shows the composition of the harvest by dimension. The harvest schedule maintains the initial cut for the entire planning horizon.

Figure 3-26. Impact on forecast harvest of maximizing the volume of solid-clear wood produced by pruning (S09).

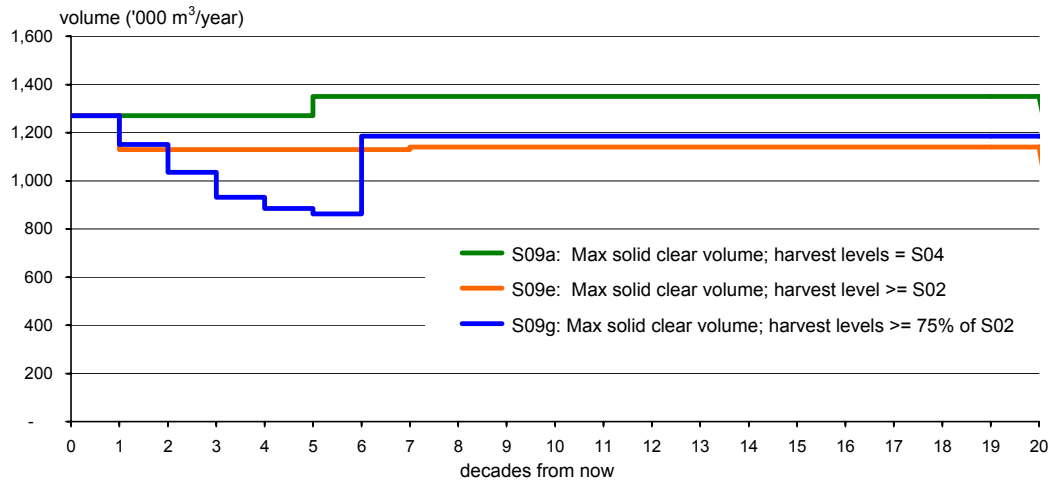


Figure 3-27. Forecast harvest of solid-clear wood with reduction in harvest levels (S09).

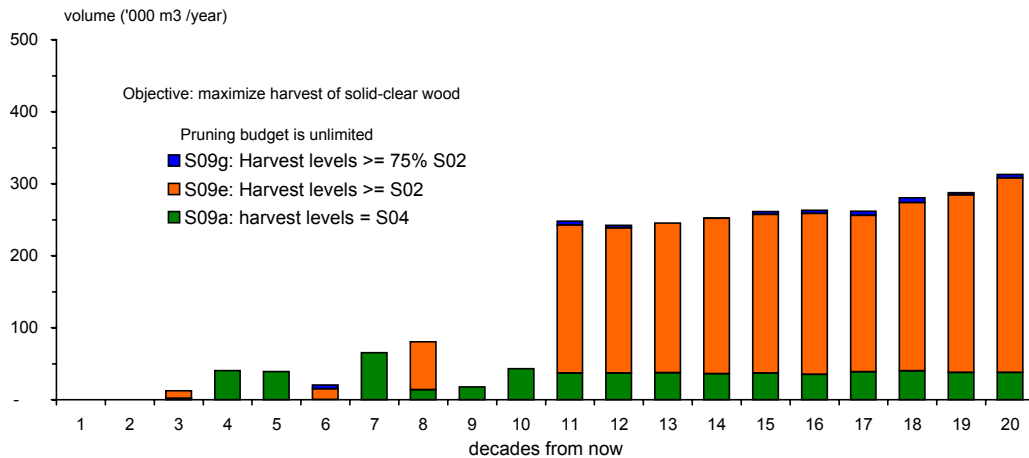
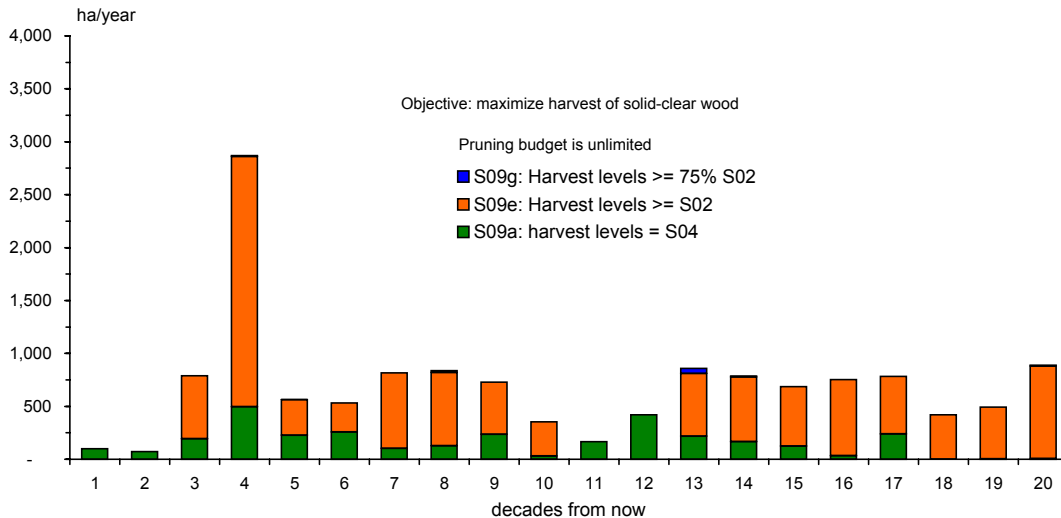


Figure 3-28. Area pruned with reduction in harvest levels (S09).





S06 Increases
harvest of 65+cm
stems by 214 000 m³
per year

Comparing Figure 3-29 to Figure 3-15 — the composition of the harvest by dimension for scenario S04 (maximize volume production)—the average (per decade) harvest volume of 65+ cm stems has increased from 4 1 760 m³ (S04) to 255 868 m³ (S06) while the harvest of 45-64.9 cm stems has nearly doubled from 785 856 (S04) to 1 606 757.

Opportunity cost is
6% of long-term cut

Note that this sixfold increase in harvest of stems with DBH > 65 cm was achieved at the cost of lowering the long-term annual harvest level from 1 371 034 m³ to 1 288 420 m³.

Figure 3-31, 3-32
Age at harvest
increases

The reason why long-term harvest volume is reduced under S06 is apparent from Figure 3-31 and Figure 3-32. The age-class distribution of the harvested stands has shifted to older age classes. Figure 3-32 compares the long-term average age-class distribution of the harvested stands when the management objective changes from maximizing volume harvest to maximizing piece size.

Figure 3-30, 3-33
Shift to higher
grades

Figures 3-30 and 3-33 show that a similar shift has occurred in the distribution of grades in the harvested stands in the long term, with a shift out of U and J grades and into the H and I grades.

3.5 Preferred Management Scenario

After consideration of the results presented in sections 3.1-3.4, District staff and the regional project coordinator specified a “preferred management scenario”.

The scenario is driven by the management objective of maximizing priority-structured harvest volume (see Appendix D), compiled to TSR utilization standards. Select stock is planted, and spacing, fertilization and commercial thinning activities are available to the model. The harvest flow is constrained not drop below the base case (S01b) harvest level, but can increase at a rate of 10% per decade. The total harvest volume must include at least 2% volume from clear wood, and at least 1.5% volume compiled at a utilization level of 65 cm dbh. Finally, the incremental silviculture costs must not exceed 1.6 million dollars per year.

Figure 3-34
Harvest

The preferred management scenario results in a reduction of harvest in the mid-term, allowing the managed stands to be harvested on longer rotations and yield the larger logs and solid-clears required by the scenario. However, at the end of the transition (decades 13-15), the harvest rises to exceed the S04 level and maintains this annual harvest (1.59 million m³) until the end of the forecasting period. It is unlikely that this accelerated harvest level could be sustained as the operable inventory (not shown) drops by 50% between decade 15 and 20.

Figure 3-35
Treatment area

After low levels of spacing in decades 1-2, the scenario spaces an average of 629 ha annually over decades 3-20, prunes 133 ha (quite variable), and initiates fertilization on 622 ha. Repeat fertilization adds another 2533 ha (average) of fertilization annually.

Figure 3-36
Treatment cost

Note that the total expenditure for spacing, pruning and fertilization does not exceed 1.6 million dollars annually, as specified by the scenario.

Figure 3-29. Composition by dimension of forecast harvest of managed stands, maximum dimension scenario (S06).

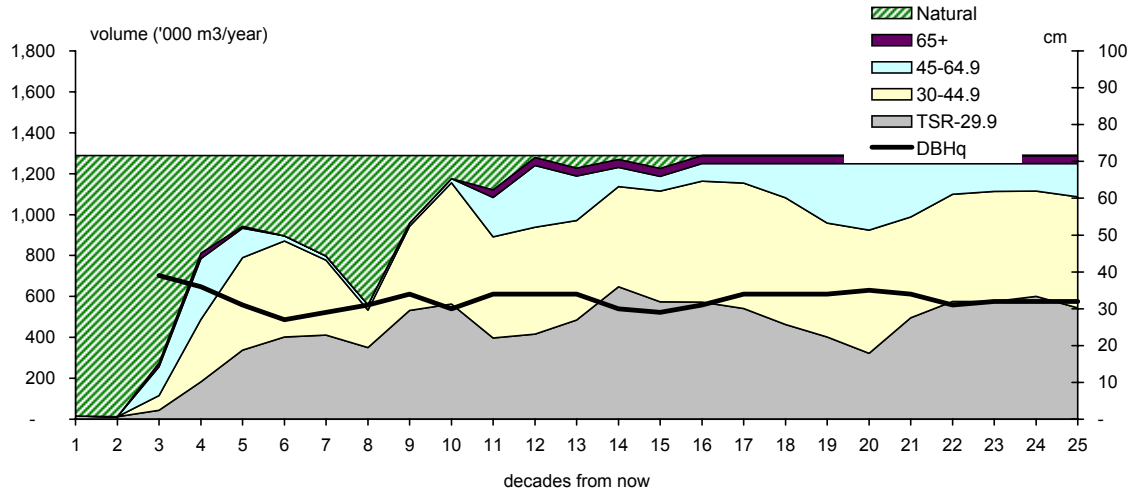


Figure 3-30. Composition by grade of forecast harvest of managed stands, maximum dimension scenario (S06).

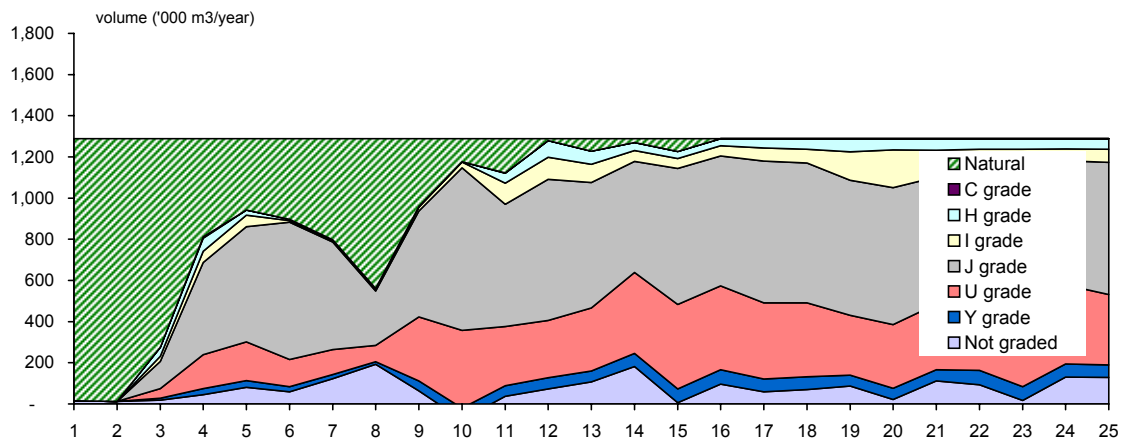


Figure 3-31. Composition by stand age of forecast harvest of managed stands, maximum dimension scenario (S06).

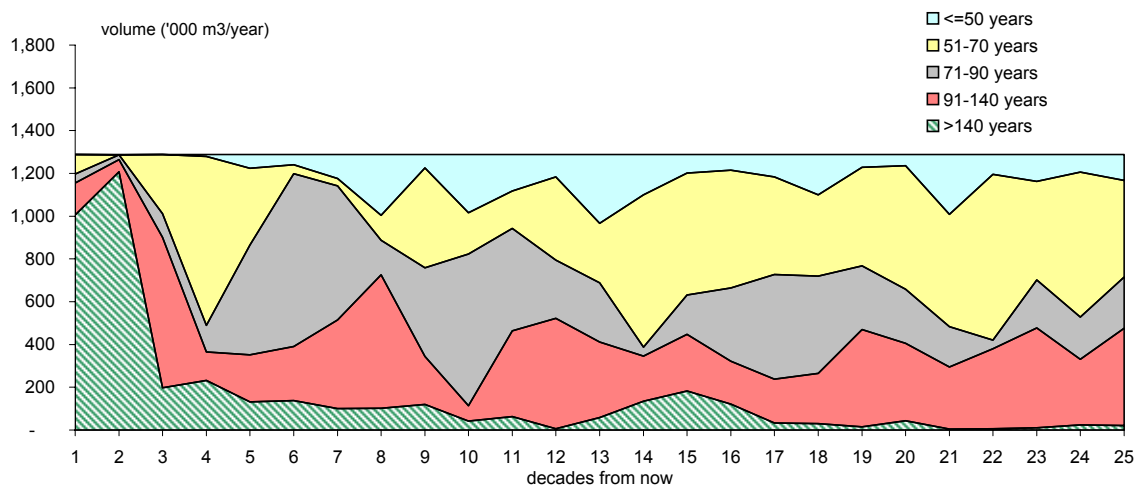


Figure 3-32: Age class distribution of stands harvested in the long term, maximum dimension scenario (S06).

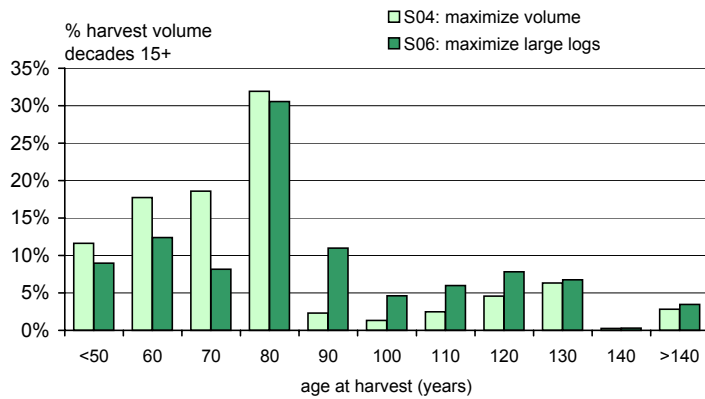


Figure 3-33. Grade distribution of stands harvested in the long term, maximum dimension scenario (S06).

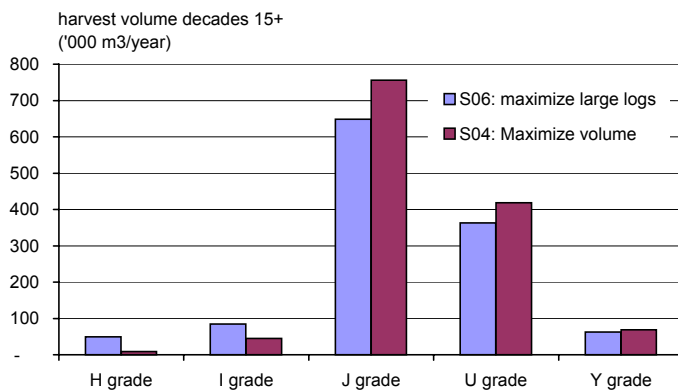


Figure 3-34. Total harvest and harvest of solid-clear logs and large dimension logs, preferred management scenario (S10).

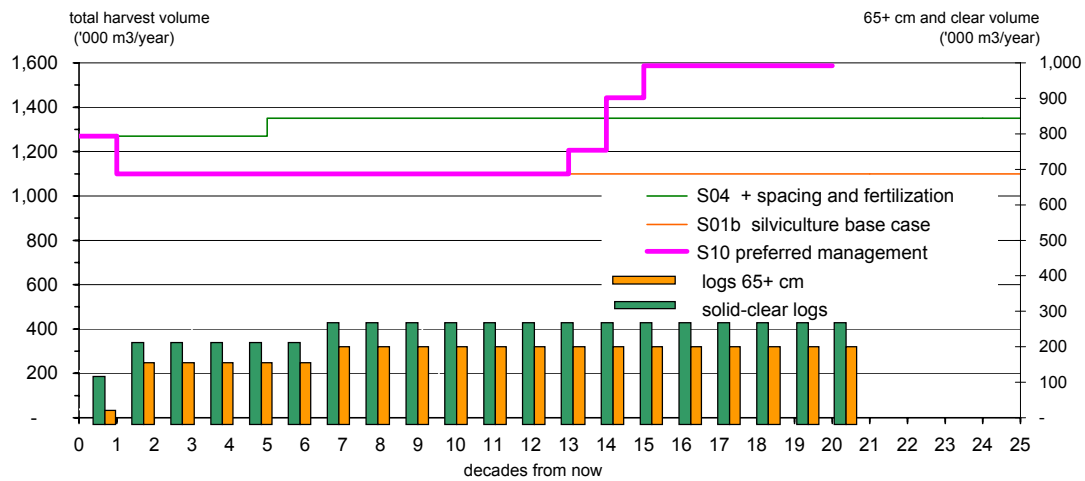


Figure 3-35. Treatment area forecast, preferred management scenario (S10).

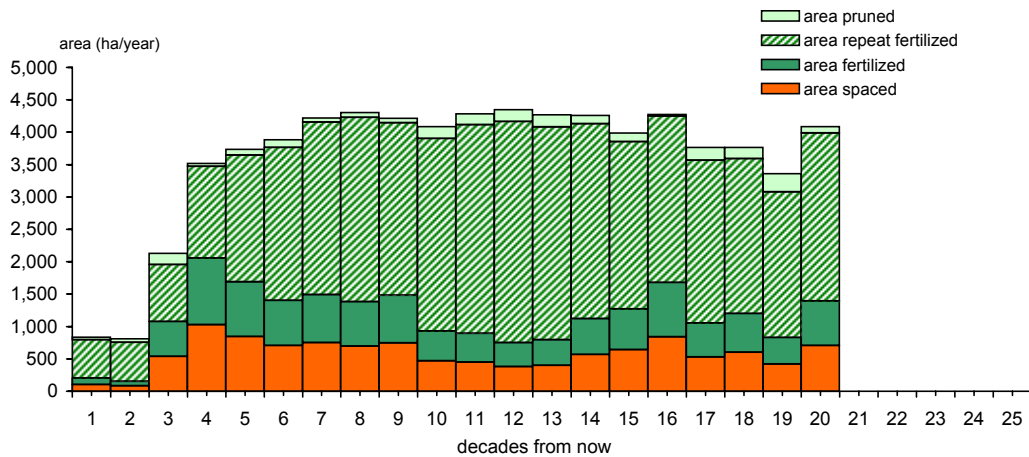
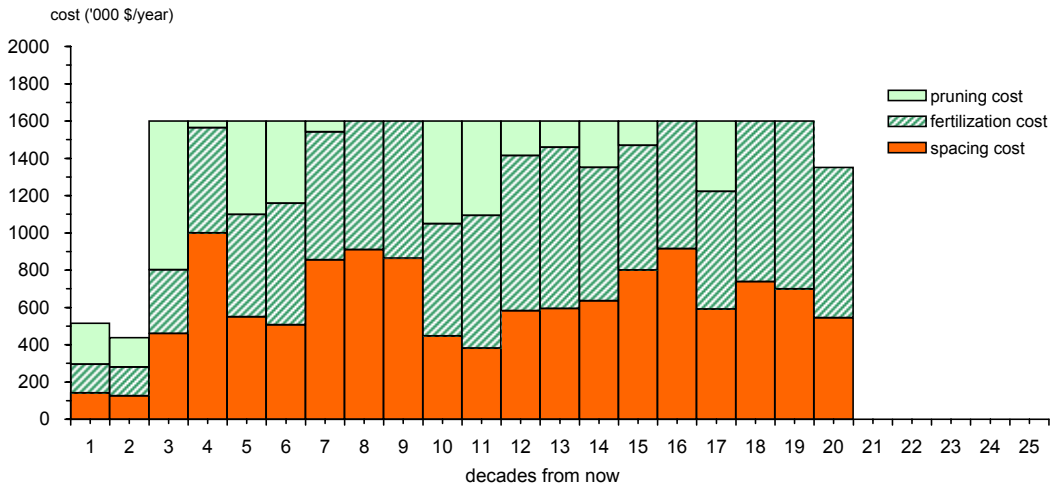


Figure 3-36. Treatment cost forecast, preferred management scenario (S10).





4.0 Silviculture Strategy

The previous section (3.0) reported the potential productive capacity of the Fraser TSA under various management objectives, and also described the impact of intensified management on indicators of the state of the forest. This section (4) reports the silviculture strategies developed by the model to meet the four management objectives embodied by scenarios S04, S06 and S09e, S10, i.e.,

- S04 – Maximize harvest volume, volume complied to TSR utilization standards, employing select stock, spacing, fertilization and commercial thinning
- S06 – Maximize the harvest volume compiled at a utilization level of 65 cm dbh. The harvest flow (compiled at TSR2 utilization levels) is constrained such that it cannot drop below the minimum level (mid-term trough) experienced in S04.
- S09e – Maximize the harvest from pruned stands. The harvest flow (compiled at TSR2 utilization levels) is constrained to the harvest flow achieved in S01 so loss of timber is avoided.
- S10 – Preferred management scenario. Maximize harvest volume, (complied to TSR utilization standards), employing select stock, spacing, fertilization and commercial thinning. The total harvest volume must be comprised of $\geq 2\%$ volume from clear wood, and $\geq 1.5\%$ volume compiled at a utilization level of 65 cm dbh. The incremental silviculture costs must be ≤ 1.6 million dollars per year.

Strategic and Tactical Plans

The silviculture strategy has two parts—the strategic plan that schedules silviculture (including harvesting) out to the 25 decade planning horizon and the tactical plan that implements the strategic plan in the first decade. The strategic plan identifies the regimes selected by the model as contributing maximally to the management objectives, while the tactical plan applies these optimal regimes to the silvicultural opportunities available in the first decade.

4.1 Strategic Plan

For each silvicultural analysis unit, the model has selected regimes that best meet the management objectives that drive the scenario. For SAU01, SAU02, and SAU03 the dominant incremental silviculture regimes, i.e., the regimes that are applied to most of the regenerated land are diagramed in this section to aid comprehension of the regimes selected by the model.



SAU01
Fd ITG=1-31, SI=31

Figure 4-1 diagrams the dominant regimes for SAU01. The silvicultural activities are coded as:

- Plt nnn – plant nnn stems per hectare
- Js nnn – juvenile space to nnn stems per hectare
- Fe 10 – fertilize on a 10-year cycle until harvest
- CT – commercial thin
- CC – clearcut

If the management objective is to maximize volume production (S04) without regard to wood quality and incremental silviculture costs, then the dominant regime employed on SAU01 is to plant to 1600 sph and subsequently space those stands that are operationally feasible to 725 sph, commercial thin and fertilize on a 10 year cycle until harvest. Under this management objective, 83% of the regenerated area is managed by this regime.

When the objective is to maximize log dimension (S06), the dominant regime employed is the same as S04—plant 1600 sph, space to 725 sph, CT, and fertilize (54% of the area regenerated). Some of the regenerated area (24%) shifts to another regime: plant 1200 sph, space to 750 sph, fertilize on a 10-year cycle, and commercial thin.

However, if the objective includes pruned wood (S09), then pruning regimes with fertilization become dominant. The regime utilized most often is to plant 1600 sph, space to 725 sph, prune, and fertilize on a 10-year cycle until harvest (61%). Note that 30% of the regenerated area has shifted to regimes with the lowest planting density: plant 800 sph and prune (16%), and plant 800 sph, prune and fertilize on a 10 year cycle until harvest (14%).

Under the preferred management scenario (S10) the regime most often implemented is the same as S04 and S06 (42%), however the management of the remaining regenerated area is spread more evenly across regimes with lower planting densities and pruning.

Across all management objectives, incremental silviculture regimes were implemented on 89%-96% of the regenerated area of SAU01.

SAU02
Fd ITG=1-31, SI=27

Figure 4-2 diagrams the dominant regimes for SAU02.

If the management objective is to maximize volume production (S04) without regard to wood quality and incremental silviculture costs, then the dominant regime employed on SAU02 is to plant to 1600 sph and subsequently space those stands that are operationally feasible to 550 sph, and fertilize on a 10-year cycle until harvest (78%).

When the management objective is to maximize the harvest volume compiled at a utilization level of 65 cm dbh, the dominant regime is the same as S04 - plant to 1600 sph, space to 550 sph, and fertilize (59%). However, more of the regenerated



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Figure 4-1. Incremental silviculture regimes implemented for SAU01 (Fd, ITG 1-8, SI=31)

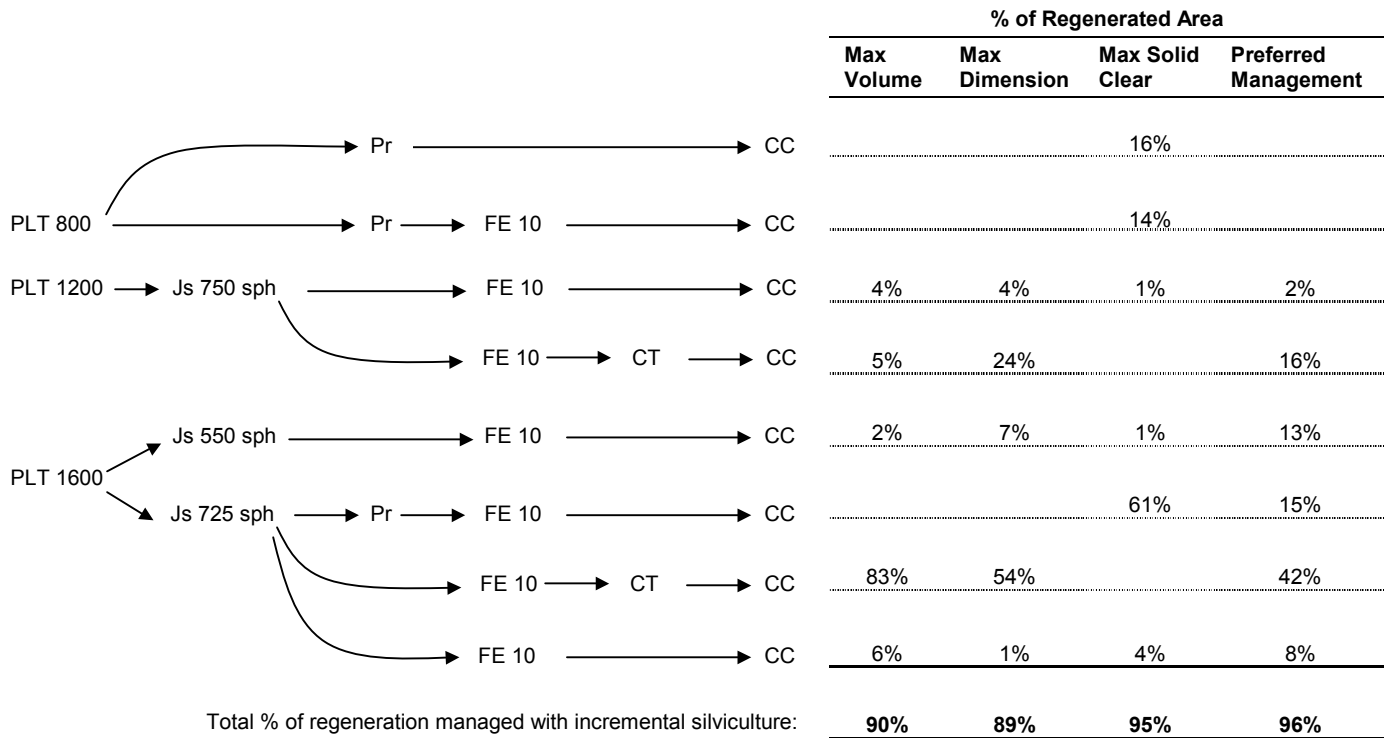
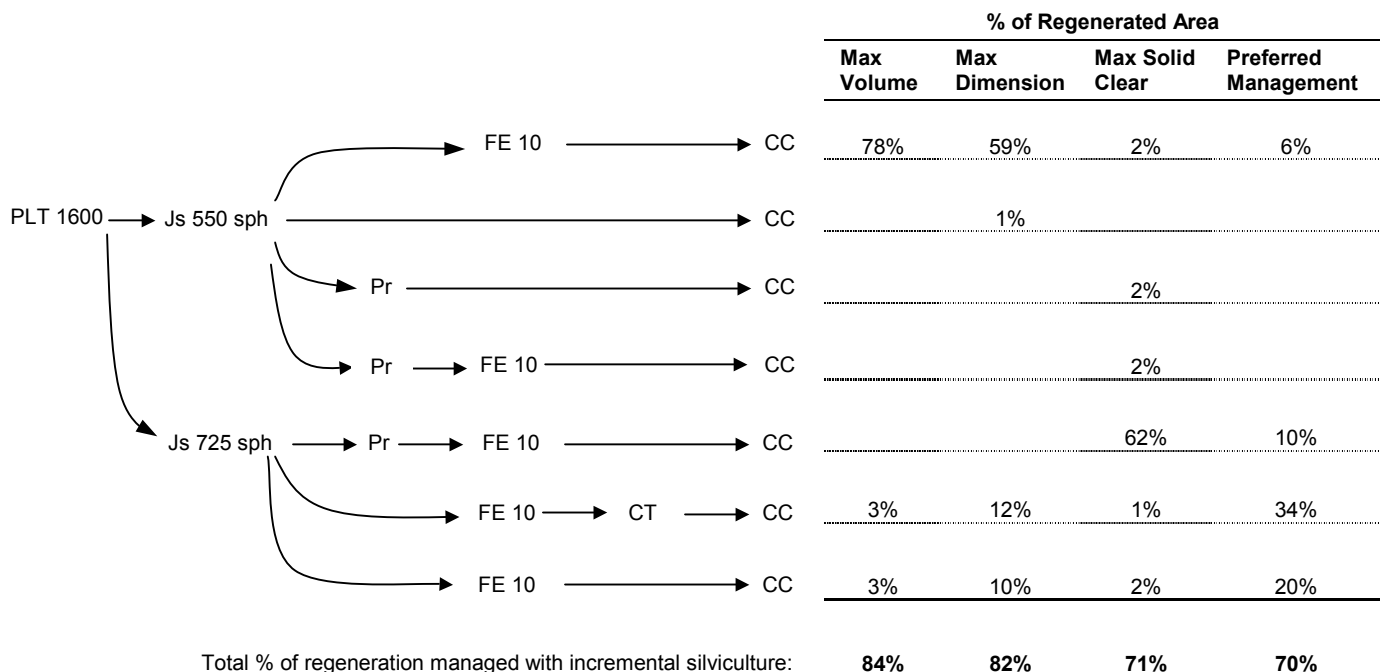


Figure 4-2. Incremental silviculture regimes implemented for SAU02 (Fd, ITG 1-8, SI=27)





area is spaced to the higher residual density (725 sph) and subsequently fertilized (22%) and commercially thinned (10%).

When the objective is to maximize wood from pruned stands the regime most often implemented is plant to 1600 sph, space to 725 sph, prune, and fertilize (62%).

The preferred management scenario (S10) follows the activities implemented in S04 and S06 except that management has shifted to regimes with higher residual spacing densities (64%), commercial thinning (34%) and pruning (10%).

In aggregate, incremental silviculture regimes were implemented on 84% of the regenerated area of SAU02 when the objective was to maximize volume production, but only 70% was managed with incremental silviculture regimes under the preferred management regime.

SAU03

Fd ITG=1-31, SI=23

Figure 4-3 diagrams the dominant regimes for SAU03.

If the management objective is to maximize volume production without regard to wood quality and incremental silviculture costs, then the dominant regime employed on SAU03 is to plant to 1600 sph and subsequently space those stands that are operationally feasible to 750 sph, and fertilize on a 10 year cycle until harvest (72%); 40% of the fertilized stands are commercially thinned when operationally feasible.

The regimes implemented for volume production are also used when the objective is to maximize large dimension wood. The percent of the stands regenerated planted to 1600 sph, spaced to 750 sph, and fertilized is 60%, with only 14% being commercially thinned.

If the objective is to maximize wood from pruned stands the regime most often implemented is plant to 1600 sph, space to 750 sph, prune, and fertilize (52%).

If the scenario is preferred management, only 14% of the regenerated stands are managed with incremental silviculture. Fertilization is scheduled for all of the incremental silviculture regimes implemented.

SAU04

Fd ITG=1-31, SI=19

If the management objective is to maximize volume production, maximize large dimension wood, or maximize pruned wood then the regime implemented is plant 1600 sph (5000 sph with ingress) and space to 800 sph (11%, 12%, and 23% of the regenerated area, respectively).

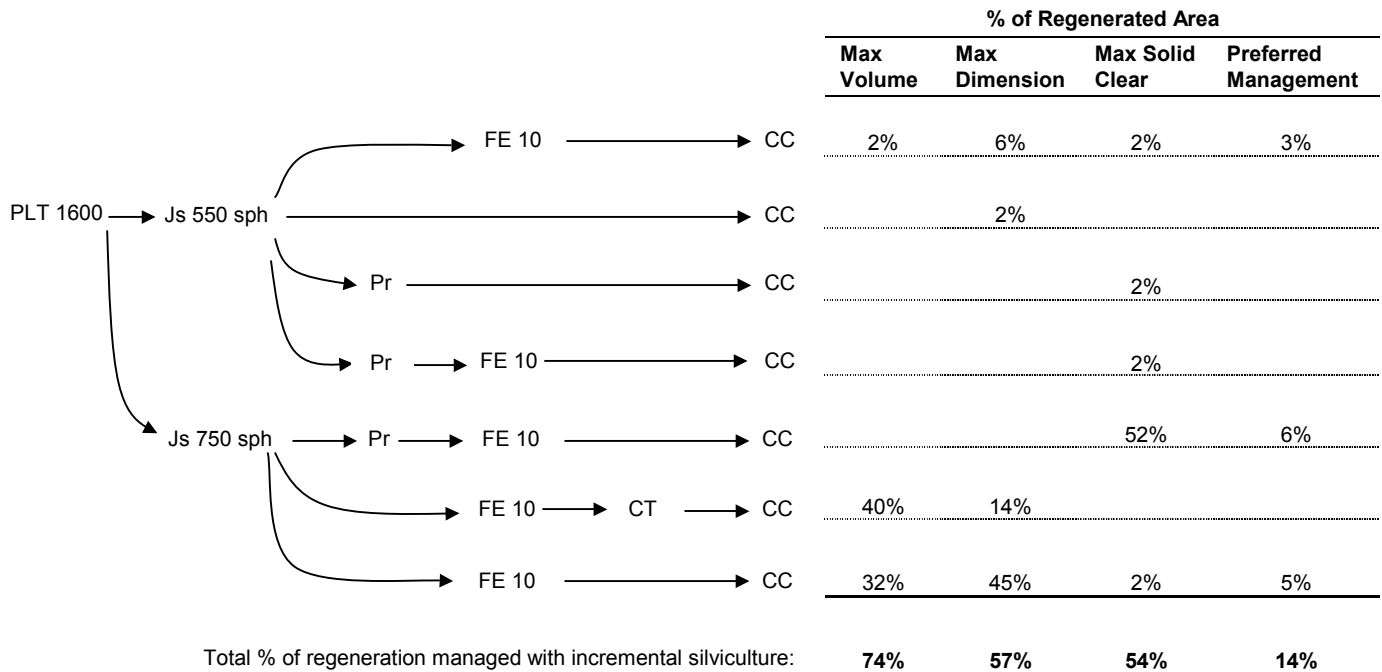
No incremental silviculture activities are implemented under the preferred management scenario.



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Figure 4-3. Incremental silviculture regimes implemented for SAU03 (Fd, ITG 1-8, SI=23)



SAU05 Fd SI=16
SAU08 Cw SI=22
SAU09 Cw SI=15
SAU10 SsPI SI=14
SAU11 HwBa SI=11
SAU12 Decid SI=15

The only development options provided for these analysis units are planting to 1200 sph. The model addresses all three management objectives with the same regime: plant 1200 sph, and hold until clearcut

One exception to the above is SAU12, which has 75% of the managed area planted to SAU01, and 25% of the managed area planted back to natural deciduous species.

SAU06
HwBa ITG=12-20,
SI=27

With this analysis unit, regardless of the objective, the regime most often implemented is plant 1600 sph (3000 sph with ingress), space to 800, and fertilize (10-year cycle). The percent of the area regenerated that is managed with this regime is highest when the management objective is volume production (97%), followed by the large dimension objective (86%), the pruned wood objective (53%), and the preferred management (55%).

SAU07
HwBa ITG=12-20,
SI=19

When the management objective is to maximize volume production, large dimension wood, and pruned wood then the regime implemented is plant 1600 sph (5000 sph with ingress) and space to 800 sph (92%, 83%, and 70% respectively). If the objective is preferred management, no incremental silviculture activities are implemented.



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Table 4-1a,b
Harvest from managed
and natural stands.

The percent of the total harvest volume obtained from each silvicultural state utilized by the model in maximizing volume harvested (S04), in the short-, medium-, and long-term is listed in Table 4-1a (managed states) and Table 4-1b (natural states). Note that 40% of the mid-term harvest and 70% of the long-term harvest from managed states come from 6 regimes applied to 4 SAUs.

SAU01 Plt Fd 1200 sph, RF, clearcut
Plt Fd 1200 sph, JS to 750 sph, RF, clearcut
Plt Fd 1600 sph, JS to 725 sph, CT, RF, clearcut

SAU02 Plt Fd 1600 sph, JS to 550 sph RF, clearcut

SAU06 Plt HwBa 1600 sph, ingress + 1400 sph, JS to 800 sph, RF clearcut

SAU07 Plt HwBa 1600 sph, ingress + 3400 sph, JS to 800 sph, clearcut

Strategy - Summary

With the management objective maximizing volume harvested (S04), the model puts the highest priority on maximizing harvest levels in decade 2, then in the mid term (decades 3-15), and finally in the long term (decades 16-25). Therefore the model implements commercial thinning to bring timber forward in the harvest queue in order to reduce falldown in decade 2 and fill the mid-term trough. Fertilization and genetic gain produce timber quantity benefits in the late mid term and early long term which are conveyed forward in the harvest queue by commercial thinning.

Under the S06 scenario the objective of maximizing piece size is met in the main by increasing age at harvest. Lengthening the rotation age past culmination age reduces the productivity of the TSA, a fact reflected by the 11% drop in the long-term harvest level obtained for scenario S06. In addition to longer rotations, there is a shift in some analysis units (SAU01, SAU02, SAU05, and SAU07) to spacing to lower densities.

Managing for solid-clear harvest volume (S09) is achieved by implementing pruning options of regimes already selected in S04 (maximize volume) in analysis units SAU01, SAU02, and SAU03.

Managing for mixed objectives (the preferred management scenario, S10) results in the implementation each of the strategies described above, in proportions that maximize volume production, satisfy as closely as possible the solid clear wood and large dimension production goals, but also meet the constraint on total silviculture budget.

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Table 4.1a Contributions of management regimes to forest-level timber supply objectives, Fraser TSA

Source of Harvest: SAU/Silv. State Silviculture Code Description			Contribution to Forest-Level Objectives:		
			Timber Supply - % Total Volume		
			Short 1-2	Mid 3-10	Long 11-25
1	P8	SAU01 Fdc SI > 27, Planted to 800 sph	-	0.1	0.0
1	P8-L	SAU01 Fdc SI > 27, Planted to 800 sph, pruned	-	-	-
1	P8-LC	SAU01 Fdc SI > 27, Planted to 800 sph, pruned, commercially thinned	-	-	-
1	P8-LCF	SAU01 Fdc SI > 27, Planted to 800 sph, pruned, commercially thinned, fertilized	-	-	-
1	P8-LF	SAU01 Fdc SI > 27, Planted to 800 sph, pruned, pruned, fertilized	-	-	-
1	P12	SAU01 Fdc SI > 27, Planted to 1200 sph	-	0.0	-
1	P12-C	SAU01 Fdc SI > 27, Planted to 1200 sph, commercially thinned	0.1	0.0	0.0
1	P12F	SAU01 Fdc SI > 27, Planted to 1200 sph, fertilized	0.8	3.6	0.0
1	P12-L	SAU01 Fdc SI > 27, Planted to 1200 sph, pruned	-	-	-
1	P12-LC	SAU01 Fdc SI > 27, Planted to 1200 sph, pruned, commercially thinned	-	-	-
1	P12-LCF	SAU01 Fdc SI > 27, Planted to 1200 sph, pruned, commercially thinned, fertilized	-	-	-
1	P12-LF	SAU01 Fdc SI > 27, Planted to 1200 sph, pruned, fertilized	-	-	-
1	P12S750	SAU01 Fdc SI > 27, Planted to 1200 sph, PCT to 750 sph	-	-	0.0
1	P12S750-C	SAU01 Fdc SI > 27, Planted to 1200 sph, PCT to 750 sph, commercially thinned	-	-	0.0
1	P12S750-CF	SAU01 Fdc SI > 27, Planted to 1200 sph, PCT to 750 sph, commercially thinned, fertilized	-	1.5	0.6
1	P12S750F	SAU01 Fdc SI > 27, Planted to 1200 sph, PCT to 750 sph, fertilized	0.0	3.2	0.5
1	P12S750L	SAU01 Fdc SI > 27, Planted to 1200 sph, PCT to 750 sph, pruned	-	-	-
1	P12S750LC	SAU01 Fdc SI > 27, Planted to 1200 sph, PCT to 750 sph, pruned, commercially thinned	-	-	-
1	P12S750LCF	SAU01 Fdc SI > 27, Planted to 1200 sph, PCT to 750 sph, pruned, commercially thinned, fertilized	-	-	-
1	P12S750LF	SAU01 Fdc SI > 27, Planted to 1200 sph, PCT to 750 sph, pruned, fertilized	-	-	-
1	P16	SAU01 Fdc SI > 27, Planted to 1600 sph	-	0.0	-
1	P16S550	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 550 sph	-	-	-
1	P16S550F	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 550 sph, fertilized	-	-	0.0
1	P16S550L	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 550 sph, pruned	-	-	-
1	P16S550LF	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 550 sph, pruned, fertilized	-	-	-
1	P16S725	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 725 sph	0.2	1.0	-
1	P16S725-C	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 725 sph, commercially thinned	-	0.8	0.0
1	P16S725-CF	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 725 sph, commercially thinned, fertilized	-	5.7	15.5
1	P16S725F	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 725 sph, fertilized	-	0.0	0.0
1	P16S725L	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 725 sph, pruned	-	0.3	-
1	P16S725LC	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 725 sph, pruned, commercially thinned	-	0.2	-
1	P16S725LCF	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 725 sph, pruned, commercially thinned, fertilized	-	0.2	-
1	P16S725LF	SAU01 Fdc SI > 27, Planted to 1600 sph, PCT to 725 sph, pruned, fertilized	0.0	1.1	-
1	CTVOLUME	SAU01 Fdc SI > 27 Commerical thinning volume	0.9	4.7	7.2
2	P12	SAU02 Fdc 25 < SI <= 27, Planted to 1200 sph	-	3.6	0.0
2	P12F	SAU02 Fdc 25 < SI <= 27, Planted to 1200 sph, fertilized	-	1.0	-
2	P16	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph	-	0.6	0.0
2	P16x	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, no further treatment	-	0.2	0.0
2	P16S550	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 550 sph	-	-	0.0
2	P16S550F	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 550 sph, fertilized	-	2.8	14.4
2	P16S550L	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 550 sph, pruned	0	0	0
2	P16S550LF	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 550 sph, pruned, fertilized	-	-	-
2	P16S725	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 725 sph	-	0.4	0.0
2	P16S725-C	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 725 sph, commercially thinned	-	0.2	0.0
2	P16S725-CF	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 725 sph, commercially thinned, fertilized	-	0.7	0.4
2	P16S725F	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 725 sph, fertilized	-	0.7	0.0
2	P16S725L	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 725 sph, pruned	-	0.0	-
2	P16S725LC	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 725 sph, pruned, commercially thinned	-	0.1	-
2	P16S725LCF	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 725 sph, pruned, commercially thinned, fertilized	-	0.0	-
2	P16S725LF	SAU02 Fdc 25 < SI <= 27, Planted to 1600 sph, PCT to 725 sph, pruned, fertilized	-	-	-
2	CTVOLUME	SAU02 Fdc 25 < SI <= 27 Commerical thinning volume	-	0.4	0.1
3	P12	SAU03 Fdc 22 < SI <= 25, Planted to 1200 sph	-	-	0.0
3	P12F	SAU03 Fdc 22 < SI <= 25, Planted to 1200 sph, fertilized	0.6	0.5	-
3	P16	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph	-	-	-
3	P16x	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, no further treatment	-	0.2	0.7
3	P16S550	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 550 sph	-	-	0.0
3	P16S550F	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 550 sph, fertilized	-	-	0.0
3	P16S550L	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 550 sph, pruned	-	-	-
3	P16S550LF	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 550 sph, pruned, fertilized	-	-	-
3	P16S750	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 750 sph	-	-	0.0
3	P16S750-C	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 750 sph, commercially thinned	-	-	0.0
3	P16S750-CF	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 750 sph, commercially thinned, fertilized	-	0.9	1.9
3	P16S750F	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 750 sph, commercially thinned, fertilized	-	0.5	1.3
3	P16S750L	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 750 sph, pruned	-	0.2	-
3	P16S750LC	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 750 sph, pruned, commercially thinned	-	0.0	0.0
3	P16S750LCF	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 750 sph, pruned, commercially thinned, fertilized	-	-	-
3	P16S750LF	SAU03 Fdc 22 < SI <= 25, Planted to 1600 sph, PCT to 750 sph, pruned, fertilized	-	-	-
3	CTVOLUME	SAU03 Fdc 22 < SI <= 25, Commercial thinning volume	0.0	0.8	0.7
4	P12	SAU04 Fdc 17 < SI <= 22, Planted to 1200 sph	-	-	6.8
4	P50	SAU04 Fdc 17 < SI <= 22, Planted to 5000 sph	-	-	0.2
4	P50x	SAU04 Fdc 17 < SI <= 22, Planted to 5000 sph, no further treatment	-	-	0.1
4	P50S800	SAU04 Fdc 17 < SI <= 22, Planted to 5000 sph, PCT to 800 sph	-	-	0.0
5	P12	SAU05 Fdc SI <= 17, Planted to 1200 sph	-	-	-
6	P12	SAU06 HwBa SI > 23, Planted to 1200 sph	-	-	0.0
6	P30	SAU06 HwBa SI > 23, Planted to 3000 sph	-	0.6	0.0
6	P30S675	SAU06 HwBa SI > 23, Planted to 3000 sph, PCT to 675 sph	-	0.0	0.0
6	P30S800	SAU06 HwBa SI > 23, Planted to 3000 sph, PCT to 800 sph	-	2.2	0.0
6	P30S800F	SAU06 HwBa SI > 23, Planted to 3000 sph, PCT to 800 sph, fertilized	-	4.4	10.2
7	P12	SAU07 HwBa 14 < SI <= 23, Planted to 1200 sph	-	-	0.0
7	P50	SAU07 HwBa 14 < SI <= 23, Planted to 5000 sph	-	0.1	0.0
7	P50S800	SAU07 HwBa 14 < SI <= 23, Planted to 5000 sph, PCT to 800 sph	-	20.0	29.7
8	P12	SAU08 Cw SI > 18 Planted, Planted to 1200 sph	-	0.7	2.7
9	P12	SAU09 Cw SI <= 18 Planted, Planted to 1200 sph	-	-	1.7
10	P12	SAU10 Ss, Pl All Planted, Planted to 1200 sph	-	0.0	3.0
11	P12	SAU11 HwBa SI < 14, Planted to 1200 sph	-	-	0.2
Total volume harvested:			25,768,494	107,205,210	205,655,855
Total % Volume Harvested from Managed Stands			2.6	64.2	97.8

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Table 4.1b Contributions of unmanaged stands to forest-level objectives, Fraser TSA.

Source of Harvest: SAU Silv. State		Silviculture Code Description	Contribution to Forest-Level Objectives:		
			Timber Supply - % Total Volume		
			Short 1-2	Mid 3-10	Long 11-25
1	N	SAU01 Fdc SI > 27	10.5	0.6	0.0
2	N	SAU02 Fdc 25 < SI <= 27	6.1	1.8	0.0
3	N	SAU03 Fdc 22 < SI <= 25	5.9	2.3	0.0
4	N	SAU04 Fdc 17 < SI <= 22	8.4	7.3	0.2
5	N	SAU05 Fdc SI <= 17	0.8	0.8	0.1
6	N	SAU06 HwBa SI > 23	2.2	1.1	-
7	N	SAU07 HwBa 14 < SI <= 23	21.3	11.5	0.7
8	N	SAU08 Cw SI > 18 Planted	3.1	1.3	0.0
9	N	SAU09 Cw SI <= 18 Planted	6.1	0.8	0.0
10	N	SAU10 Ss, PI All Planted	3.6	1.4	0.8
11	N	SAU11 HwBa SI < 14	24.0	5.8	0.2
12	N	Deciduous, ITG Group 37-39, all SI	5.5	1.0	0.1
Total volume harvested:			25,768,494	107,205,210	205,655,855
Total % Volume Harvested from Managed Stands			97.4	35.8	2.2



4.2 Tactical Plan

The tactical plan is reported in Table 4-2.

The strategic plan identifies the regimes that maximally contribute to the management objectives specified for the TSA. However, in the first decade the opportunity to implement those regimes is constrained by the operational realities of the harvesting queue and the inventory of existing managed timber. The identification of stand types to be treated in decade 1 under each management objective constitutes the tactical plan.

The planting activities reported in Table 4-2 are generated by the harvesting activities undertaken in the first decade and the planting of NSR and timber lease reversions.

Incremental silviculture

In decade 1, juvenile spacing is scheduled for SAU02 (Fd leading, SI=27), followed by an initial fertilization, under all management objectives. For the clear wood objective and preferred management scenario, these stands are also pruned.

Juvenile spacing is also indicated for the hemlock/balsam analysis units. Under the preferred management scenario, SAU06 with pre-spacing densities of 3000 sph are thinned to 675 sph. SAU07 with densities of at 5000 sph are thinned to 800 sph for all management objectives except the preferred management scenario.

The results of the analysis with respect to juvenile spacing of the hemlock/balsam analysis units were queried in reviews of earlier drafts of this report.² In particular, the response of low site hemlock/balsam ($14 < SI \leq 23$) to juvenile spacing appears anomalous, and the response of the higher site hemlock/balsam ($SI > 23$) to fertilization is not substantiated in the literature.

The yield curve for the juvenile-spaced low site hemlock/balsam was corrected prior to analyzing the Preferred Management Scenario (S10). As noted above, no SAU07 (medium site hemlock/balsam) was juvenile spaced under S10.

The correction of the yield curve and subsequent elimination of juvenile spacing of SAU07 reduced the total area of incremental silviculture from 19,350 ha per decade (S04, unlimited funding) to 1,514 ha per decade (S10). Examination of the regime diagrams (Appendix A) revealed that too few silvicultural opportunities had been specified for existing managed stands.³

Commercial thinning

Commercial thinning activities occur for SAU01 and under the management objectives of maximizing volume production and maximizing large dimensions logs.

² Craig Wickland. Comments on second draft. April 30, 2002

³ Subsequent to the completion of this report, further analysis was undertaken with a more complete set of silviculture opportunities specified for the existing managed stands. These results will be reported in a future addendum.

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Table 4-2 Tactical Plan - area treated by silviculture activity for each management objective in decade 1.

Silvicultural Activity	Decade 1			
	S04 ha	S06 ha	S09e ha	S10 ha
SAU01: Fd, ITG=1-8, WSI=31				
Plant 1200 sph	-	-	6	-
Plant 1600 sph	1,639	1,635	1,631	1,635
CT (Existing managed, Plant 1200 sph, JS to 750 sph, Fe) ^{1,2}	116	290	-	1,468
CT (Existing managed, Plant 1200 sph, JS to 750 sph)	542	645	1	-
SAU02: Fd, ITG=1-8, WSI=26.8				
Plant 1200 sph	-	-	-	-
Plant 1600 sph	1,222	1,293	1,294	1,315
JS (Plant 1600 sph) to 725 sph, Fe	1,009	1,009	1	
JS (Plant 1600 sph) to 725 sph, Pr, Fe	-	-	1,007	1,009
SAU03: Fd, ITG=1-8, WSI=23.4				
Plant 1200 sph	-	1	-	-
Plant 1600 sph	1,448	1,354	1,355	1,331
CT (Existing managed, Plant 1600 sph, JS to 750 sph, Pr)	10	10	-	-
SAU04: Fd, ITG=1-8, WSI=18.9				
Plant 1200 sph	241	474	166	487
Plant 5000 sph	246	13	322	-
SAU05: Fd, ITG=1-8, WSI=15.7				
Plant 1200 sph	67	67	67	67
SAU06: HwBa, ITG 12-20, WSI=27.4				
Plant 3000 sph	866	866	886	1,064
JS (Plant 3000 sph) to 675	5	-	-	505
SAU07: HwBa, ITG 12-20, WSI=18.9				
Plant 1200 sph	-	246	547	7
Plant 5000 sph	13,215	12,968	12,684	13,208
JS (Plant 5000 sph) to 800 sph	18,335	18,333	18,308	-
SAU08: Cw, ITG 9-11, WSI=22.8				
Plant 1200 sph	960	944	1,227	907
SAU09: Cw, ITG 9-11, WSI=15.3				
Plant 1200 sph	2,636	2,663	2,331	2,722
SAU10: SPI, ITG 21-32, WSI=14.49				
Plant 1200 sph	137	137	157	137
SAU11: HwBa, ITG 12-20, WSI=11.63				
Plant 1200 sph	14,691	14,685	14,708	14,685
SAU12: Deciduous, ITG 37-39, All SI				
Plant to SAU01 1200 sph	488	487	1,333	16
Plant to natural existing	163	162	444	5
Total area planted	38,019	37,995	39,158	37,583
Total area incremental silviculture	19,350	19,342	19,316	1,514
Total area commercially thinned	667	945	1	1,468

Notes:

- 1 The activity "CT (Existing managed, Plant 1200 sph, JS to 750 sph, Fe)" means "commercially thin stands which are presently existing on the land base, and are managed stands, i.e., were planted to 1200 sph, juvenile spaced to 750 sph, and fertilized according to a specified schedule." The regime specified for this
- 2 The commercial thinning regime specifies fertilization 1 year following the cut. Therefore, the commercial thinning activity specified implies that 147 ha per year will be commercially thinned and, one year subsequent, fertilized during the first decade.



4.3 Ranking Silvicultural Activities

The previous sections (4.1 and 4.2) described the regimes and first decade silvicultural activities selected by the model to address alternative management objectives. In this section, silvicultural activities are ranked with respect their contribution to the management objective of maximizing volume production (scenario S04) in decade 1, and over the entire planning horizon (decades 1-25).

Table 4-3
1st decade treatments

Table 4-3 lists the analysis units to be treated, their assumed silvicultural state, the silvicultural treatment, and the area treated. The table is divided into two sections. The top part of the table describes activities scheduled for decade 1, and the bottom section describes the activities undertaken out to the planning horizon, i.e., decades 1-25.

1st decade treatment opportunities are limited

While the activities and areas treated are selected based on the forest-level management objective, the opportunities areas that are feasible for treatment are limited in the first decade by the current silvicultural state of the TSA, which in turn is determined by harvesting and silvicultural history.

Shadow prices of silvicultural opportunities

Table 4-3 also lists shadow prices for each activity with respect to four timber supply objectives: timber supply (quantity) in the short, mid and long term, and supply compiled to >65cm.

Shadow prices are calculated specific to a schedule of harvesting and silvicultural treatment; in Table 4-3 they are determined for the optimum harvest and silviculture schedule determined for the S04 scenario (maximize harvest volume).

The shadow prices are calculated assuming that the optimal schedule of silviculture developed in the S04 scenario will be applied in decades 2-25, but no spacing, fertilization or commercial thinning is allowed in decade 1. The shadow prices are interpreted as the change in the objective if this constraint is relaxed and one hectare is treated. For example, in decade 1, juvenile spacing to 800 sph of one additional hectare of existing managed SAU07 would increase mid-term supply by 81 m3 and long-term supply by 143 m3.

Only scarce silviculture opportunities have shadow prices

Shadow prices quantify the value of scarce resources to the forest-level management objectives. This implies that in decade 1 SAU07 in a state feasible for spacing to 800 sph is scarce, i.e., fully consumed by the JS activity at the optimum schedule determined for the S04 scenario. Conversely, at the optimum S04 schedule, SAU04 spacing opportunity (to 800 sph) has a shadow price of 0 in all decades (1-25) and is not scarce— there is a surplus of this opportunity and the model has consumed the optimum amount, and does not want to treat additional hectares of SAU04.

Shadow prices associated with the objective of maximizing supply compiled to >65cm (large piece size) are all zero, consistent with the observation earlier in this section that this objective was achieved by lengthening rotation ages rather than through silvicultural actions. Shadow prices calculated at the optimal activity levels for decade 1, rather than at zero (not shown), show negative values for commercial thinning— increasing the level of commercial thinning will negatively impact the objective of maximizing large piece size.



Note that there are no shadow prices associated with re-fertilization as the structure of the model precluded calculation of these values. When the model implements an initial fertilization action, it is required to maintain the schedule of re-fertilization until harvest.

Shadow prices rank silviculture opportunities	The shadow prices are used to rank the importance of silvicultural treatments to forest-level management objectives in Table 4-3. The shadow prices are assigned ranks in ascending order, and are specific to the management objective. The ranks cannot be compared between management objectives.
Commercial thinning and fertilization are highest priority	Across the three management objectives with useful shadow prices (timber supply in the short, mid and long term), commercial thinning and initial fertilization activities rank the highest. Although ranks are not available for re-fertilization activities, the high rankings of the initial fertilization activities infer that re-fertilization should also be a high priority.
Juvenile spacing is a lower priority	In general, spacing activities that are followed by a fertilization activity have large shadow prices and are highly ranked; spacing activities not intrinsic to fertilization or commercial thinning regimes have smaller shadow prices.
SAU07 (HwBa, SI=19) spacing doubles mid-term harvest opportunity	<p>An exception is the spacing in decade 1 of SAU07 from 5000 sph to 800 sph. A possible explanation of this is that spacing reduces the minimum harvest age of dense (5000 sph) hemlock-balsam stands from 80 to 50 years. The reduced minimum harvest age would allow stands spaced in decade 1 to be harvested twice within the mid-term period (decades 3-15). If the same stand was not spaced in decade 1, it would not be available for harvest until decade 8, and could not be harvested again until decade 16. A similar argument can be constructed for the long term; with 50-year rotations, two harvests can be obtained in decades 16-25.⁴</p> <p>In determining an operational short-term silviculture program, apparent opportunities such as spacing of dense SAU07 should be examined to determine if they are anomalies of the modelling process or reflect useful information about the structure and productivity of the TSA.</p>

⁴ Although the logic of this explanation is correct, the result was based on an incorrect yield table. As explained in section 4.2, spacing of low site hemlock-balsam stands was not scheduled by the model after the yield table was corrected.

Fraser TSA Silviculture Strategy Analysis

Section 4 — Silviculture Strategy

Table 4.3 Prescribed silvicultural treatment, activity levels, and impacts on management objectives (S04 scenario).

				Prescribed	Activity ¹	Shadow price (m3/ha treated) ²				Rank by Management Objective ⁶			
SAU	LS	SI	Silvicultural State	Treatment	(ha)	ST ³	MT ³	ST ³	>65 cm ⁴	ST	MT	LT	>65 cm
Decade 1 only													
SAU01	Fd	31	Existing managed, Plt Fd, 1600 sph, JS to 725, Pr, Fe	Commercial Thin	<1	<1	<1	-	<0	2	2	2	<0
SAU01	Fd	31	Existing managed, Plt Fd, 1200 sph, JS to 750, Fe	Commercial Thin	116	<1	<1	-	<0	2	2	2	<0
SAU01	Fd	31	Existing managed, Plt Fd, 1600 sph, JS to 750	Commercial Thin	542	<1	<1	-	<0	2	2	2	<0
SAU03	Fd	23	Existing managed, Plt Fd, 1600 sph, JS to 750, Pr	Commercial Thin	10	5	13	-	<0	1	1	-	<0
SAU02	Fd	27	Existing managed, Plt Fd, 1600 sph	JS to 725 sph, Fe	1,009	25	85	141	-	1	1	2	1
SAU06	HB	27	Existing managed, Plt HB, 3000 sph	JS to 675 sph	5	ng ⁵	ng	ng	-	ng	ng	ng	1
SAU07	HB	19	Existing managed, Plt HB, 5000 sph	JS to 800 sph	18,335	21	81	143	-	2	2	1	1
Decade 1-25													
SAU01	Fd	31	Existing managed, Plt Fd, 1200 sph	Commercial Thin	2	2	11	29	<0	1	1	1	<0
SAU01	Fd	31	Existing managed, Plt Fd, 1200 sph, JS to 750 sph, Fe	Commercial Thin	116	2	11	29	<0	1	1	1	<0
SAU01	Fd	31	Existing managed, Plt Fd, 1600 sph, JS to 725	Commercial Thin	1,458	2	11	29	<0	1	1	1	<0
SAU01	Fd	31	Existing managed, Plt Fd, 1600 sph, JS to 725, Pr	Commercial Thin	435	2	11	29	<0	1	1	1	<0
SAU01	Fd	31	Existing managed, Plt Fd, 1600 sph, JS to 725, Pr, Fe	Commercial Thin	528	2	11	29	<0	1	1	1	<0
SAU02	Fd	27	Existing managed, Plt Fd, 1600 sph, JS to 725	Commercial Thin	552	1	4	9	<0	2	3	3	<0
SAU02	Fd	27	Existing managed, Plt Fd, 1600 sph, JS to 725, Fe	Commercial Thin	733	1	4	9	<0	2	3	3	<0
SAU02	Fd	27	Existing managed, Plt Fd, 1600 sph, JS to 725, Fe, Pr	Commercial Thin	45	1	4	9	<0	2	3	3	<0
SAU02	Fd	27	Existing managed, Plt Fd, 1600 sph, JS to 725, Pr	Commercial Thin	313	1	4	9	<0	2	3	3	<0
SAU03	Fd	23	Existing managed, Plt Fd, 1600 sph, JS to 750, Pr	Commercial Thin	10	2	8	17	<0	1	2	2	<0
SAU01	Fd	31	Plt Fd 1200 sph, JS to 750, Fe	Commercial Thin	4,428	2	11	29	-	1	1	1	<0
SAU01	Fd	31	Plt Fd 1600 sph, JS to 725, Fe	Commercial Thin	75,063	2	11	29	-	1	1	1	<0
SAU02	Fd	27	Plt Fd, 1600 sph, JS to 725, Fe	Commercial Thin	2,479	1	4	9	-	2	3	3	<0
SAU03	Fd	23	Plt Fd, 1600 sph, JS to 750,F	Commercial Thin	13,073	2	8	17	-	1	2	2	<0
SAU01	Fd	31	Plt Fd 1600 sph	JS to 550 sph, Fe	1,559	13	60	135	-	3	2	2	1
SAU01	Fd	31	Plt Fd 1600 sph	JS to 725 sph, Fe	80,359	14	60	123	-	2	2	3	1
SAU01	Fd	31	Plt Fd 1200 sph	JS to 750 sph, Fe	8,409	22	87	161	-	1	1	1	1
SAU02	Fd	27	Plt Fd 1600 sph	JS to 550 sph, Fe	63,133	11	50	112	-	4	3	4	1
SAU02	Fd	27	Plt Fd 1600 sph	JS to 725 sph, Fe	3,084	7	32	77	-	6	5	6	1
SAU02	Fd	27	Existing managed plt Fd 1600 sph	JS to 725 sph, Fe	1,736	7	32	77	-	6	5	6	1
SAU03	Fd	23	Plt Fd 1600 sph	JS to 550 sph, Fe	730	7	31	69	-	6	6	7	1
SAU03	Fd	23	Plt Fd 1600 sph	JS to 750 sph, Fe	23,772	8	33	75	-	5	4	5	1
SAU04	Fd	19	Plt Fd 5000 sph	JS to 800 sph	7,436	0	0	0	-	7	8	9	1
SAU06	HwBa	27	Existing managed, plt HB, 3000 sph	JS to 675 sph	10	ng	ng	ng	-	ng	ng	ng	ng
SAU06	HwBa	27	Plt HB 3000 sph	JS to 800 sph, Fe	40,021	ng	ng	ng	-	ng	ng	ng	ng
SAU07	HwBa	19	Plt HB 5000 sph	JS to 800 sph	209,213	<1	2	3	-	7	7	8	1
SAU07	HwBa	19	Existing managed, Plt HB, 5000 sph	JS to 800 sph	33,310	<1	2	3	-	7	7	8	1

Notes:

¹ Activity is the area treated as scheduled by the S04 scenario at its optima.

² The shadow price can be interpreted as the increase in the management objective for an additional hectare treated. These shadow prices were calculated at the S04 optimum activity levels, constrained in 1st decade to zero.

³ ST, MT and LT are the short-, mid- and long-term components of the timber supply.

⁴ >65 cm is the volume harvested complied to >65 cm.

⁵ ng means "no guidance".

⁶ Ranks are only meaningful within objectives.



5.0 Limitations of the Study

This study is a descriptive analysis. It quantifies the changes in productive capacity of the Fraser TSA that result from modifying:

- management objective
- level of expenditure
- intensity of management

This study is not prescriptive: it makes no recommendations concerning the appropriate management objectives and does not specify a desirable level of expenditure and intensity of management.

Prescriptive studies should follow confirmation of the descriptive model

The critical components of the physical production model (yield tables, silviculture history, and regime diagrams) should be confirmed before addressing the question of the appropriate level of silviculture investment.

1. Accuracy of the Yield Tables

All of the biology in the modelling process is contained in the yield curves. The remainder of the model is an accounting system that selects yield tables and moves hectares through feasible sequences (regimes) of activities. Therefore the accuracy of the forest-level yield forecasts of the model is largely associated with the accuracy of the yield tables, specifically the managed-stand yield tables developed with TASS.

TASS-TIPSY issues

In the execution of this project, it became apparent that a top-height adjustment was required in the development of the TASS tables to make them consistent with TIPSY managed stand yield tables. The inclusion of this adjustment necessitated the development of “work-around” procedures to simulate the application of juvenile spacing, pruning and commercial thinning to fertilized stands and stands grown from select stock (incorporating genetic gain). The yield tables developed for this study (Appendix E) – and in particular, the “work-arounds” devised to deal with the TIPSY-TASS differences – should be reviewed for plausibility, and, subsequently, the forest-level productivity forecasts reported in this document should be considered in light of this review.

TASS is central to silviculture strategies

The accuracy and scope of TASS is central to the development of meaningful silviculture strategies and forest-level plans. The strengthening of TASS should be encouraged and its proper application in studies such as this should be clarified and documented.

2. Representation of Silvicultural History

The accurate assignment of existing managed stands to silvicultural states is essential if the model is to develop a plausible schedule of management actions in



the initial decades. The assignment of the existing managed stands to the inventory data set used in this study (Appendix A) was accomplished with an *ad hoc* procedure that is unlikely to be accurate. The representation of silviculture history in the model should be reviewed in conjunction with consideration of the short-term silviculture program (section 4.2).

Ultimately the silvicultural history records should be spatially integrated with the inventory database.

3. Modelling of Regimes

Just as the biology in the modelling process is contained in the yield curves, the alternative development pathways that a stand may take as the result of management actions are embodied in the regime diagrams. The diagrams must be accurate with respect to the transitions that occur when a stand is treated, and must be of appropriate scope—i.e., include sufficient management actions and development pathways to account for the current and future management of the stands.

Operability issues

Of special concern are limitations on management actions that are related to operability factors not included in the silvicultural state of the model. For example, according to a regime diagram, a stand may be operable for commercial thinning if certain target volume and residual tree requirements are met. However, the silviculturalists may know that only 30% of the terrain is appropriate for commercial thinning, regardless of whether the stand meets the target volume and residual tree criteria. These operability constraints must be implemented in the model in order to obtain reasonable results.



Fraser TSA Silviculture Strategy Analysis



Appendix A– The Current Silvicultural State

Assignment of existing managed stands to a silvicultural state

The accurate assignment of existing managed stands to silvicultural states is essential if the model is to develop a plausible schedule of management actions in the initial decades.

The silviculture state of a stand records the information that the manager needs in order to determine what silviculture activities are immediately feasible (not including operational considerations such as harvesting restrictions, accessibility, terrain, or markets). For example, the species mix, age, density, basal area, crown closure may be the variables that the silviculturalist considers when deciding the treatment of a stand. These state variables change over time with the development of the stand (growth, competition, mortality) and with silviculture actions (e.g., juvenile spacing).

Describing the silviculture state at this level of detail is appropriate for tactical, program-level planning, but is too detailed for strategic planning with a forest-level model. For the purposes of this project, the silviculture state of (aggregations of) forest stands will be described by the list of treatments already applied. The possible silviculture states for the Fraser TSA are listed in Table B-1 (Appendix B).

Method

The assignment of the existing managed stands to the inventory data set used in this study was accomplished with an *ad hoc* procedure. From ISIS, a table was constructed that listed for each analysis unit and age class combination the total area recorded as planted, juvenile spaced, pruned and fertilized.

Each of these records (analysis unit x age class) was subdivided into additional records according to a set of rules based on logical silviculture practices:

1. The priority for areas to be fertilized will be, first, areas pruned, second, areas spaced but not pruned, and third, areas planted but not subsequently spaced or pruned.
2. The priority for areas to be pruned will be, first, areas spaced, and second, areas planted but not subsequently spaced.
3. The priority for areas to be spaced will be areas that have been previously planted.
4. If the area fertilized or pruned or spaced exceeds the area planted, then it is assumed that the treatments were applied to natural stands, and the same hierarchy of treatment priorities applies.

While it is unlikely that applying these rules to the ISIS data has resulted in the exact silviculture state of the TSA, the procedure is unambiguous and results in a unique set of silviculture states for each age class of each analysis unit. Table A-1 summarizes the relevant silvicultural history for the Fraser TSA as obtained from ISIS. In Table A-2 this history is allocated across the inventory as existing managed stands.

Table A-1. Silviculture history of the Fraser TSA.

Year	Juvenile Spacing (ha)	Pruning (ha)	Fertilization (ha)
1973	6		
1974	239		
1975	559		
1976	237		
1977	516		
1978	864		
1979	1,515		610
1980	1,231		
1981	1,576		789
1982	1,579		
1983	1,321		
1984	143		
1985	485		
1986	888	24	
1987	913		224
1988	931	7	1,980
1989	1,238	20	831
1990	824	23	983
1991	1,357	402	1,048
1992	1,395	409	1,446
1993	1,400	577	1,263
1994	1,557	652	943
1995	1,902	411	1,434
1996	864	146	1,441
	23,539	2,670	12,993
Average 1990-96	1328	374	1223

Source: ISIS

Table A-2. Initial silvicultural state of the Fraser TSA

State Code	Silviculture State	Fd 31 SAU01	Fd 26 SAU02	Fd 23 SAU03	Fd 18 SAU04	Fd 15 SAU05	HwBa 27 SAU06	HwBa 18 SAU07	Cw 22 SAU08	Cw 15 SAU09	SsPl 14 SAU10	HwBa 11 SAU11	Decid 14 SAU12	Total
N	Natural	5,559	8,171	8,671	28,900	4,898	3,069	53,860	5,011	5,794	11,756	31,409	8,974	176,071
NSR	Natural - timber lease		3				445	8,463			137	777		9,825
TLR	non-sufficient regeneration	15	28	121	487	67	11	1,028	147	428		775		3,107
eP12	Existing managed, planted to 1200 sph	114	9,972		8,886	728			243	62	2,449	989		23,443
eP12-C	Existing managed, planted to 1200 sph, commercially thinned	147												147
eP12F	Existing managed, planted to 1200 sph, fertilized	3,880	1,257	1,196										6,333
eP12S750F	Existing managed, planted to 1200 sph, JS to 750 sph, fertilized	2,129												2,129
eP30	Existing managed, planted to 3000 sph						1,281							1,281
eP30S800	Existing managed, planted to 3000 sph, JS to 800 sph						5,632							5,632
eP30S800F	Existing managed, planted to 3000 sph, JS to 800 sph, fertilized						1,173							1,173
eP50	Existing managed, planted to 5000 sph				1,220			33,489						34,709
eP50S800	Existing managed, planted to 5000 sph, JS to 800 sph							3,225						3,225
eP50x	Existing managed, planted to 5000 sph, no further treatment				473									473
eP8	Existing managed, planted to 800 sph	132												132
eP16	Existing managed, planted to 1600 sph	61	3,384											3,446
eP16S725	Existing managed, planted to 1600 sph, JS to 725 sph	3,272	1,665											4,937
eP16S725L	Existing managed, planted to 1600 sph, JS to 725 sph, pruned	974	313											1,287
eP16S725LF	Existing managed, planted to 1600 sph, JS to 725 sph, pruned, fertilized	1,586	45											1,631
eP16S750L	Existing managed, planted to 1600 sph, JS to 750 sph, pruned			527										527
eP16x	Existing managed, planted to 1600 sph, no further treatment		494											494
Grand Total		17,870	25,332	10,515	39,966	5,692	11,610	100,065	5,402	6,283	14,342	33,950	8,974	280,000

Note: The existing managed stands of SAU02 are evenly distributed across decades 1-3 and represent potential management opportunities.



Fraser TSA Silviculture Strategy Analysis



Appendix B— Regimes Diagrams

Regime diagrams are the “blueprint” for the construction of the silviculture modules of the forest-level model.

The silviculture regime specifies a sequence of management actions that may be applied to the stands of the silviculture analysis unit for which the regime was designed. Each of these actions causes a change in the silvicultural state of the stand and so alternative regimes result in alternative development pathways that a silviculture analysis unit may follow.

A series of alternative regimes was specified for each the 12 silviculture analysis units defined for the Fraser TSA, and the alternative development pathways were plotted (Figures B-1 to B-12). The arcs of these diagrams correspond to silviculture actions and the nodes represent the silviculture state of the stand. Tables B-1 and B-2 explain the codes used in the diagrams and Table B-3 lists the treatment specification for each feasible regime. Note that clearcut harvesting (clc_m) may occur from any treatment state (including planting and ingress only), but the activity arcs that would lead back to regenerating (R) are not shown in the regime diagrams in order to maintain legibility. Also, forest stands are not required to progress along a pathway — a stand may remain in any state indefinitely.

Table B-1. State codes

Code	Treatment state
N	Natural
Existing managed stands	
eP12	Existing managed, plant to 1200
eP12--C	Existing managed, plant to 1200, commercial thin
eP12F	Existing managed, plant to 1200, fertilize
eP12S750F	Existing managed, plant to 1200, space to 750, fertilize
eP12S750-CF	Existing managed, plant to 1200, space to 750, commercial thin, fertilize
eP16	Existing managed, plant to 1600
eP16S725	Existing managed, plant to 1600, space to 725
eP16S725L	Existing managed, plant to 1600, space to 725, prune
eP16S725LF	Existing managed, plant to 1600, space to 725, prune, fertilize
eP16S750L	Existing managed, plant to 1600, space to 750, prune
eP30	Existing managed, plant to 3000
eP30S800	Existing managed, plant to 3000, space to 800
eP30S800F	Existing managed, plant to 3000, space to 800, fertilize
eP50	Existing managed, plant to 5000
eP50S800	Existing managed, plant to 5000, space to 800
eP8	Existing managed, plant to 800



Fraser TSA Silviculture Strategy Analysis

Appendix B—Regimes Diagrams

Table B-1. State codes *(continued)*

Code	Treatment state
Existing managed stands created by future management actions on existing states	
eP16S550	Existing managed, plant to 1600, space to 550
eP16S550F	Existing managed, plant to 1600, space to 550, fertilize
eP16S550L	Existing managed, plant to 1600, space to 550, prune
eP16S550LF	Existing managed, plant to 1600, space to 550, prune, fertilize
eP16S725-C	Existing managed, plant to 1600, space to 725, commercial thin
eP16S725-CF	Existing managed, plant to 1600, space to 725, commercial thin, fertilize
eP16S725F	Existing managed, plant to 1600, space to 725, fertilize
eP16S725LC	Existing managed, plant to 1600, space to 725, prune, commercial thin
eP16S725LCF	Existing managed, plant to 1600, space to 725, prune, commercial thin, fertilize
eP16S750LC	Existing managed, plant to 1600, space to 750, prune, commercial thin
eP16S750-C	Existing managed, plant to 1600, space to 750, commercial thin
eP16S750-CF	Existing managed, plant to 1600, space to 750, commercial thin, fertilize
eP30S675	Existing managed, plant to 3000, space to 675
Future managed states	
P12	Plant 1200
P12--C	Plant 1200, commercial thin
P12--CF	Plant 1200, commercial thin, fertilize
P12-L	Plant 1200, prune
P12-LC	Plant 1200, prune, commercial thin
P12-LCF	Plant 1200, prune, commercial thin, fertilize
P12-LF	Plant 1200, prune, fertilize
P12S750	Plant 1200, space 750
P12S750-C	Plant 1200, space 750, commercial thin
P12S750-CF	Plant 1200, space 750, commercial thin, fertilize
P12S750F	Plant 1200, space 750, fertilize
P12S750L	Plant 1200, space 750, prune
P12S750LC	Plant 1200, space 750, prune, commercial thin
P12S750LCF	Plant 1200, space 750, prune, commercial thin, fertilize
P12S750LF	Plant 1200, space 750, prune, fertilize
P16	Plant 1600
P16S550	Plant 1600, space 550
P16S550F	Plant 1600, space 550, fertilize
P16S550L	Plant 1600, space 550, prune
P16S550LF	Plant 1600, space 550, prune, fertilize
P16S725	Plant 1600, space 725
P16S725-C	Plant 1600, space 725, commercial thin
P16S725-CF	Plant 1600, space 725, commercial thin, fertilize
P16S725F	Plant 1600, space 725, fertilize
P16S725L	Plant 1600, space 725, prune



Fraser TSA Silviculture Strategy Analysis

Appendix B—Regimes Diagrams

Table B-1. State codes *(continued)*

Code	Treatment state
Future managed states	
P16S725LC	Plant 1600, space 725, prune ,commercial thin
P16S725LCF	Plant 1600, space 725, prune, commercial thin, fertilize
P16S725LF	Plant 1600, space 725, prune, fertilize
P16S750	Plant 1600, space 750
P16S750-C	Plant 1600, space 750, commercial thin
P16S750-CF	Plant 1600, space 750, commercial thin, fertilize
P16S750F	Plant 1600, space 750, fertilize
P16S750L	Plant 1600, space 750, prune
P16S750LC	Plant 1600, space 750, prune, commercial thin
P16S750LCF	Plant 1600, space 750, prune, commercial thin, fertilize
P16S750LF	Plant 1600, space 750, prune, fertilize
P30	Plant 3000
P30S675	Plant 3000, space 675
P30S800	Plant 3000, space 800
P30S800F	Plant 3000, space 800, fertilize
P50	Plant 5000
P50S800	Plant 5000, space 800
P8	Plant 800
P8-L	Plant 800, prune
P8-LC	Plant 800, prune, commercial thin
P8-LCF	Plant 800, prune, commercial thin, fertilize
P8-LF	Plant 800, prune, fertilize

Table B-2. Activity codes.

Code	Activity Description
CLC	Clearcut
Pl nn	Plant nn stems per hectare
Js nn	Juvenile space to nn stems per hectare
Pr	Prune to specifications noted in Table B-3
Fert	Fertilization
CT	Commercial thin to specifications noted in Table B-3



Fraser TSA Silviculture Strategy Analysis

Appendix B–Regimes Diagrams

Table B-3. Specifications for TASS runs to create volume tables for regenerated development types, Fraser TSA

1. Utilization levels

	Dbh min	Stump max	Top dib min
Fdc, HwBg, Cw, Sx	17.5	30	10
Pine/Lx	12.5	30	10
Interior Spruce	12.5	30	10

Note: all figures in centimetres.

2. Operational adjustment factors

OAF 1	15
OAF 2	5

3. Juvenile spacing

- leave well-spaced trees, favouring tallest

4. Commercial thinning

- thin from below: removing shortest, and leaving well-spaced trees, favouring fattest
- CT stems leave takes precedence over volume remove

5. Pruning

- use predominant height
- retain 30% live crown on first lift
- retain 40% live crown on second lift

6. Fertilization regimes

In general, repeat fertilize every 7 years from age 15 until harvest.

if juvenile spacing,

- fertilize 1 year after spacing, but age must be ≥ 15 years
- repeat fertilize every 7 years until harvest or commercial thinning

if pruning,

- fertilize 2 years after 2nd lift, and repeat fertilize every 7 years until harvest or commercial thinning

if commercial thinning,

- repeat fertilize every 7 years from juvenile space or pruning until commercial thinning
- fertilize 1 year after commercial thin, and repeat fertilize every 7 years until harvest

**Figure B-1. Alternate development pathways for future managed stands
SAU01 Fd (1-5,8), SI>=27, WSI = 31, 6% THLB, Fraser TSA**

Arrows represent silvicultural actions
(including harvesting) that move an
existing natural stand into future
managed states

CT Opportunity

P8-L
P12-L
P12
P12S750L
P12S750
P16S725L
P16S725

CTstates

P8-LC
P12-LC
P12-C
P12S750LC
P12S750-C
P16S725LC
P16S725-C

Area_CT_States <= 74% Area_SAU01

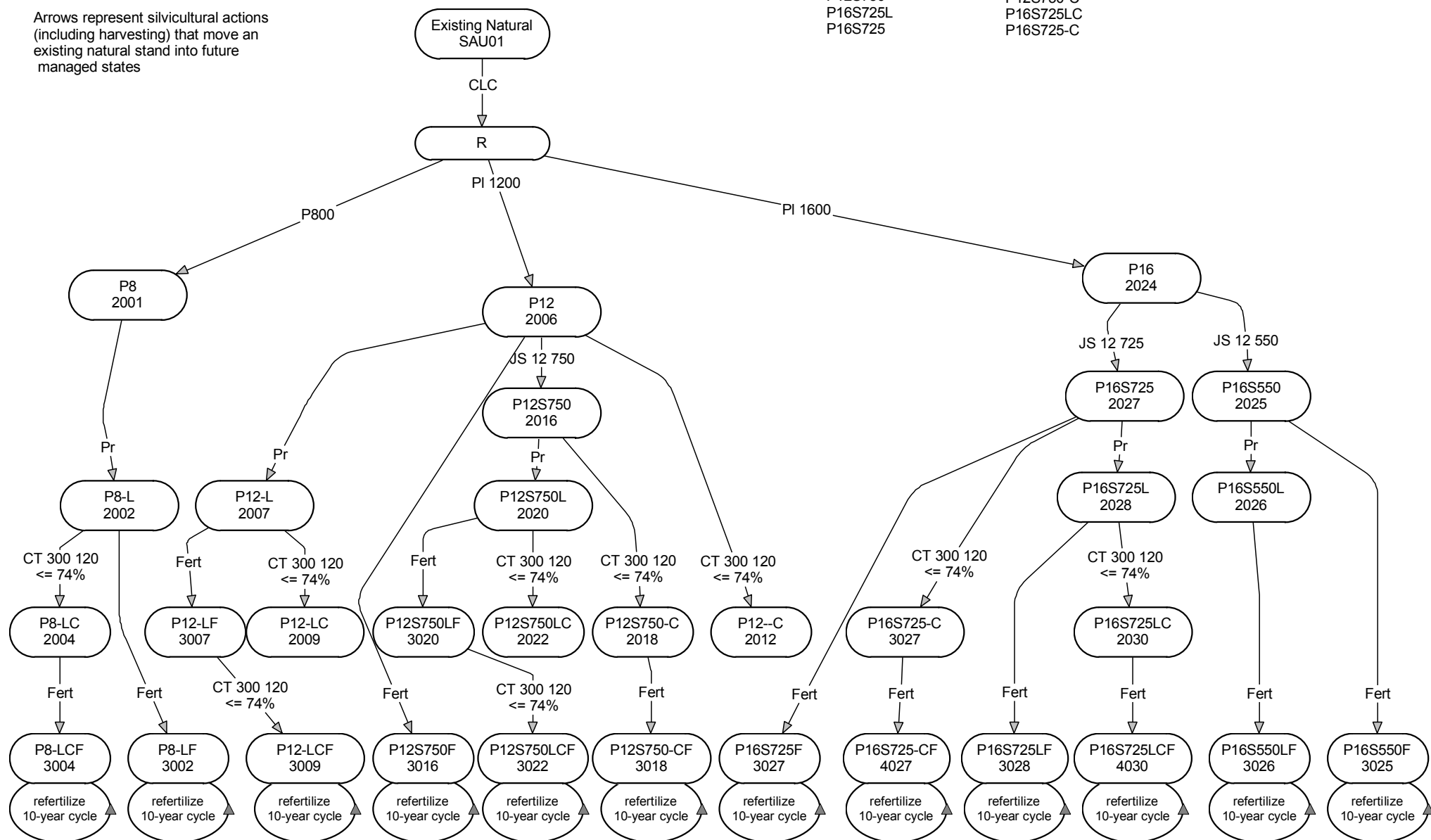


Figure B-2. Alternate development pathways for existing managed stands
SAU01 Fd (1-5,8), SI>=27, WSI = 31, 6% THLB, Fraser TSA

Arrows represent silvicultural actions (including harvesting) that move an existing natural stand into future managed states

CT Opportunity
eP12S750F
eP16S725
eP16S725L
eP16S725LC

CTstates
eP12S750-CF
eP16S725-C
eP16S725LC
eP16S725LCF

Area_CT_States <= 74% Area_SAU01

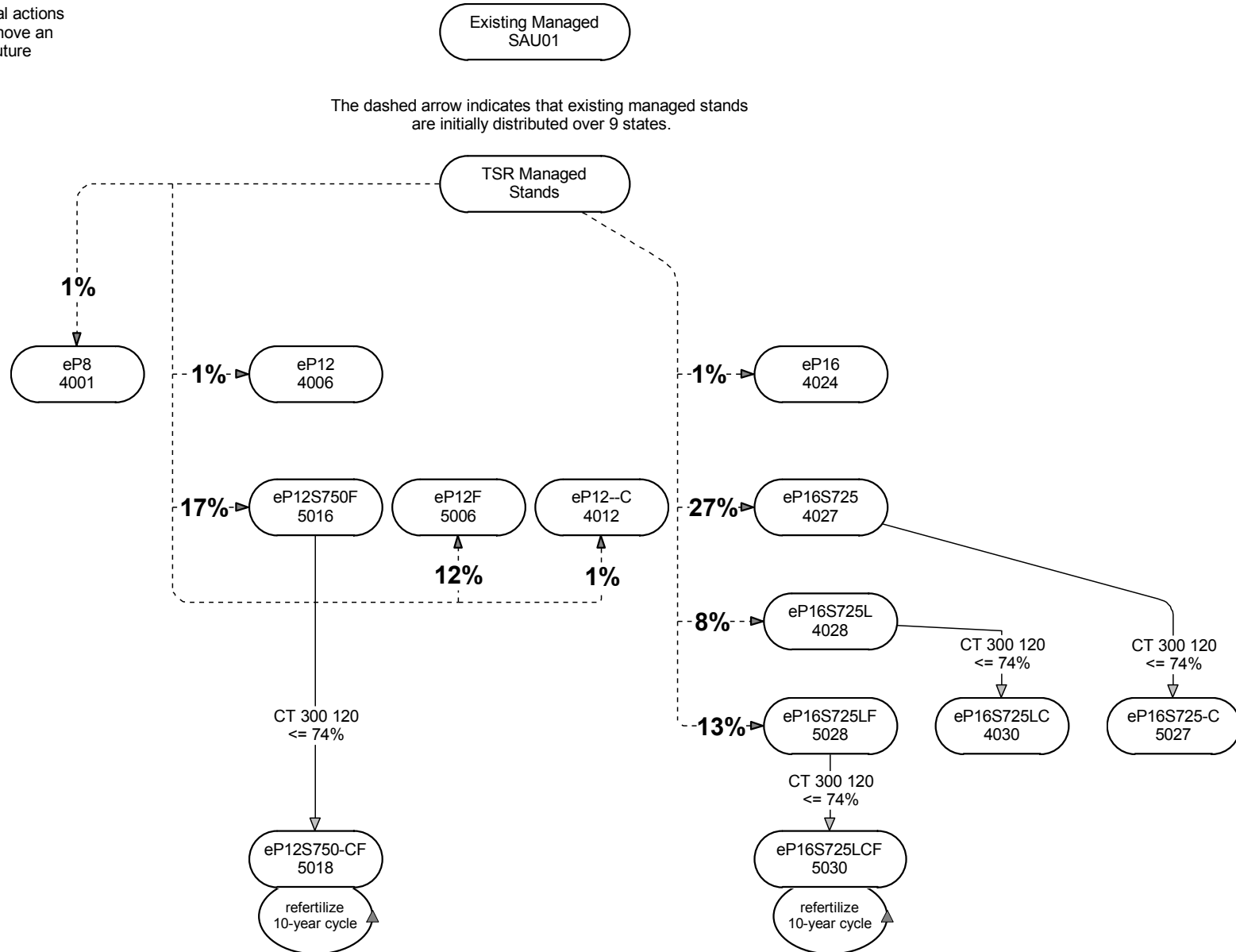


Figure B-3. Alternate development pathways for future managed stands
SAU02 Fd (1-5,8), 25<SI<=27, WSI = 26.8, 9% THLB

CT Opportunity
P16S725
P16S725L

CTstates
P16S725LC
P16S725-C

Area_CT_States <= 50% Area_SAU02

Arrows represent silvicultural actions
(including harvesting) that move an
existing natural stand into future
managed states

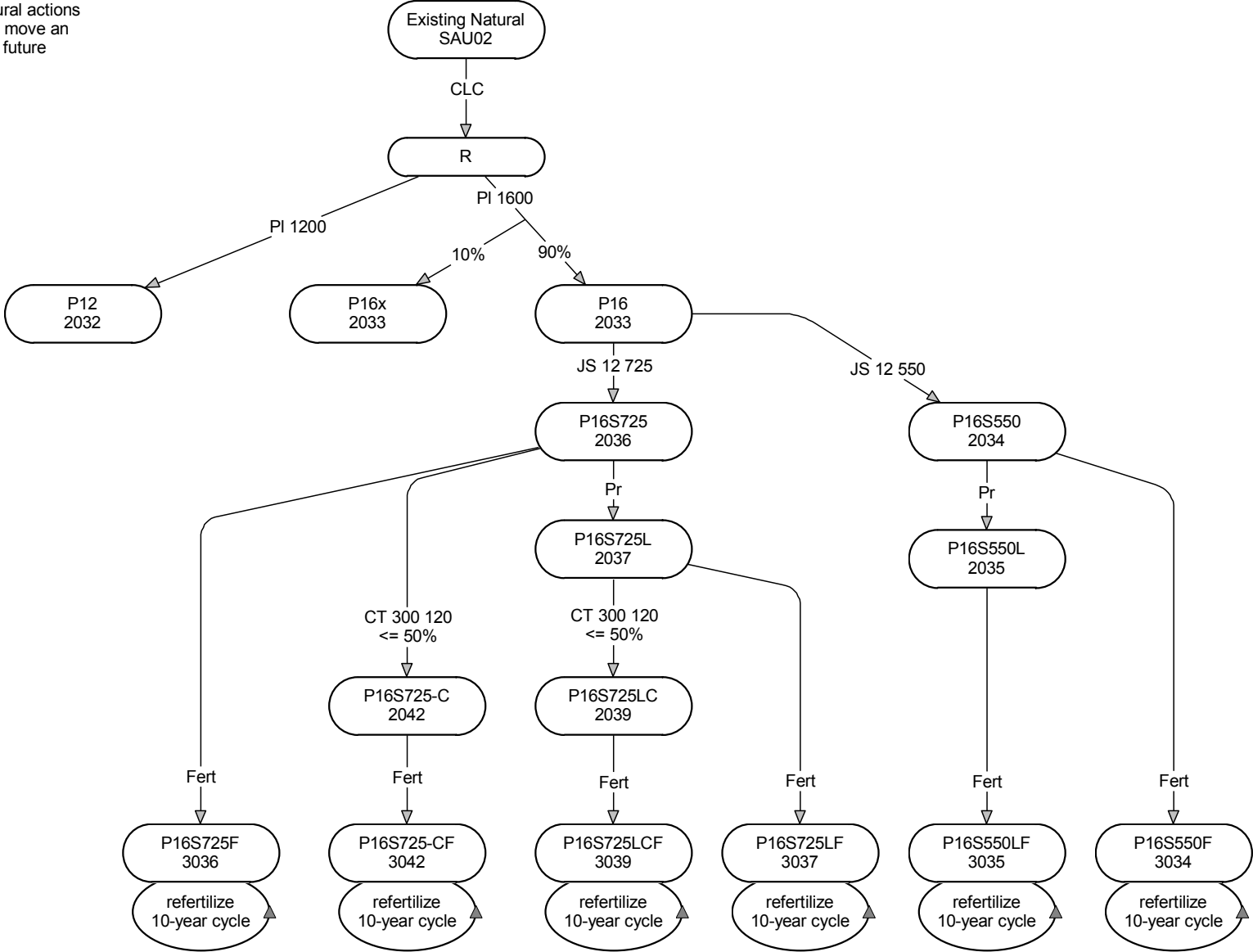


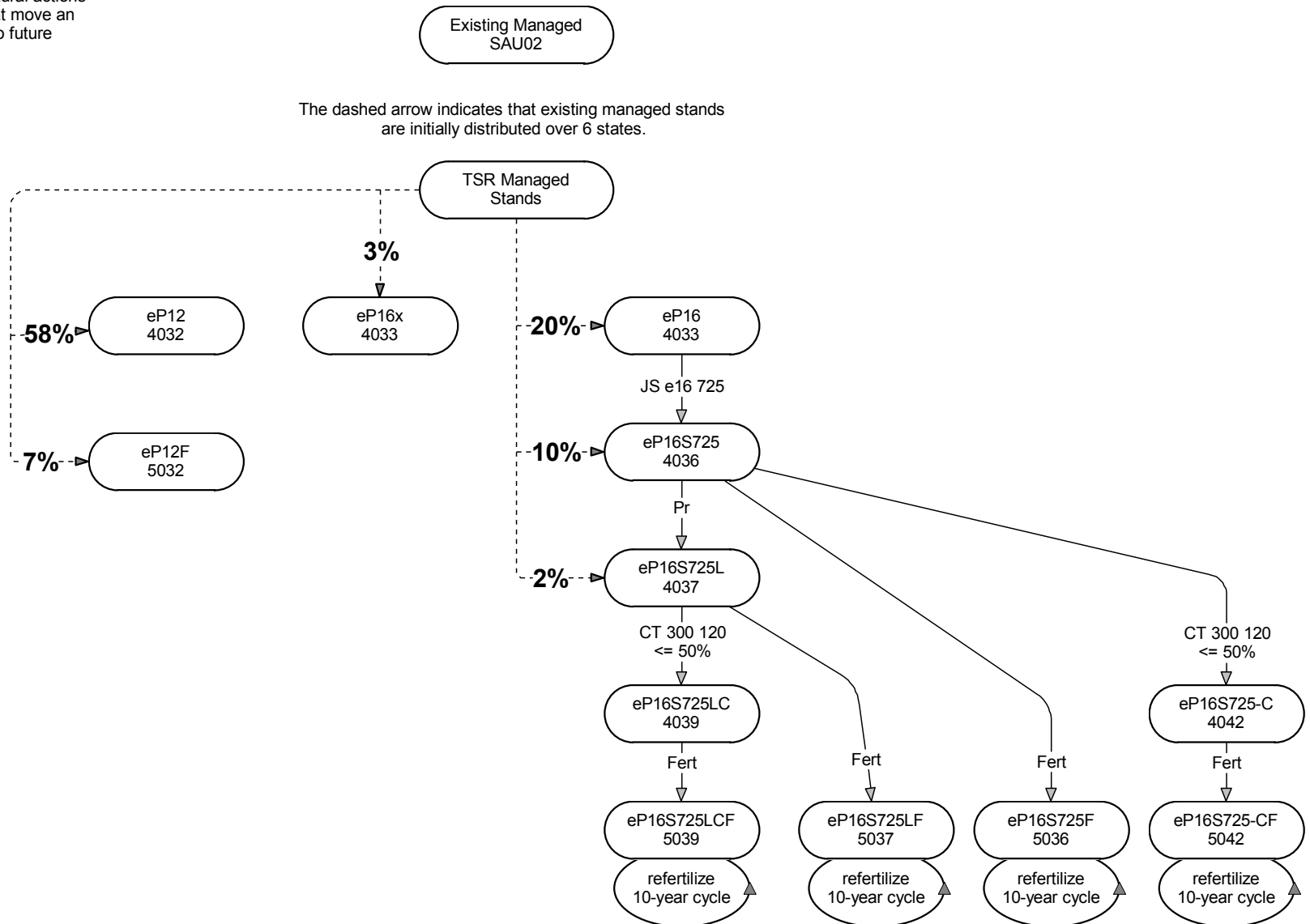
Figure B-4. Alternate development pathways for existing managed stands
SAU02 Fd (1-5,8), 25<SI<=27, WSI = 26.8, 9% THLB

CT Opportunity
eP16S725
eP16S725L

CTstates
eP16S725LC
eP16S725-C

Area_CT_States <= 50% Area_SAU02

Arrows represent silvicultural actions
(including harvesting) that move an
existing natural stand into future
managed states



Arrows represent silvicultural actions (including harvesting) that move an existing natural stand into future managed states

CT States
P16S750LC
P16S750-C

P16S750LC
P16S750-C

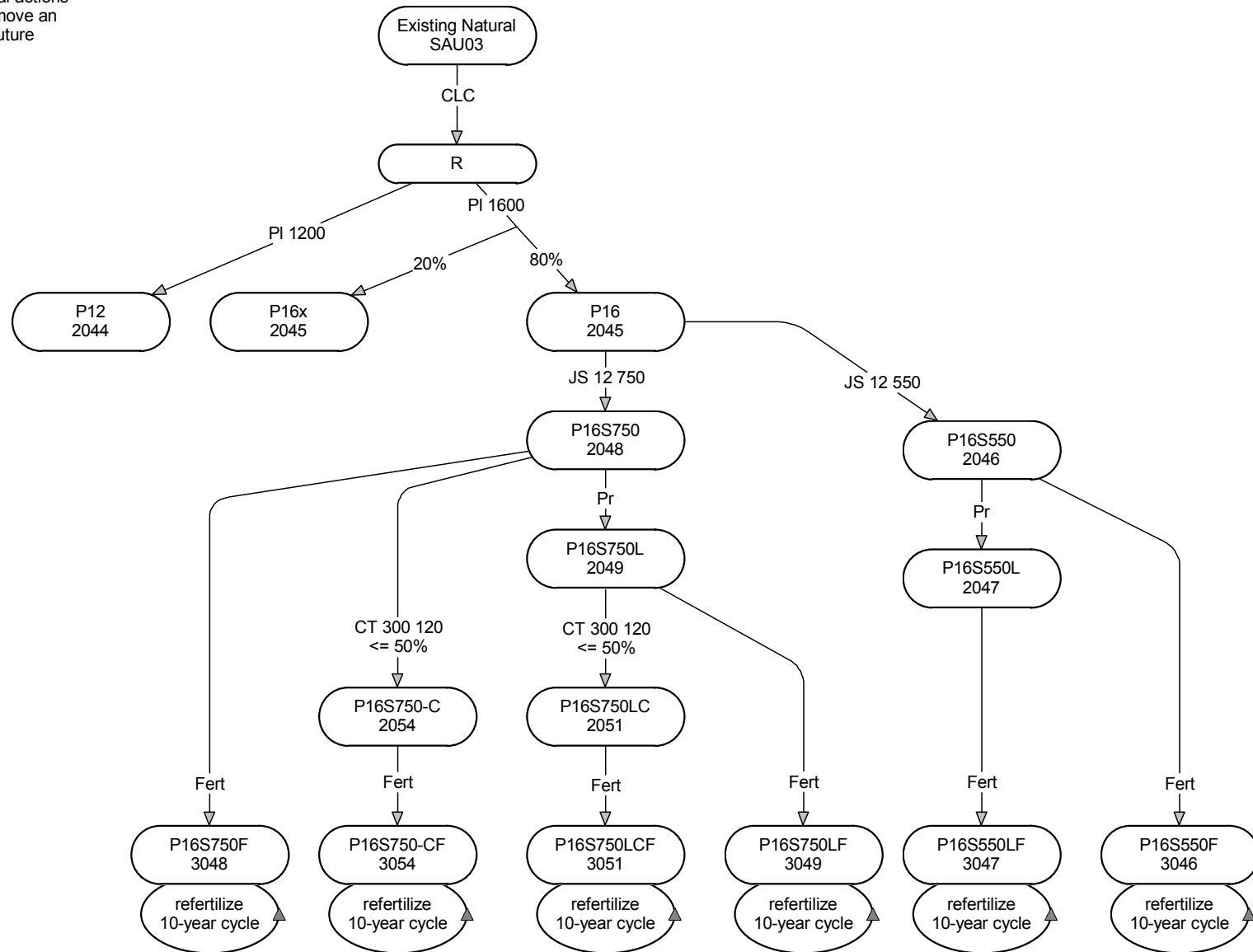


Figure B-6. Alternate development pathways for existing managed stands
SAU03 Fd (1-5,8), 22<SI<=25, WSI = 23.4, 4% THLB

Arrows represent silvicultural actions
(including harvesting) that move an
existing natural stand into future
managed states

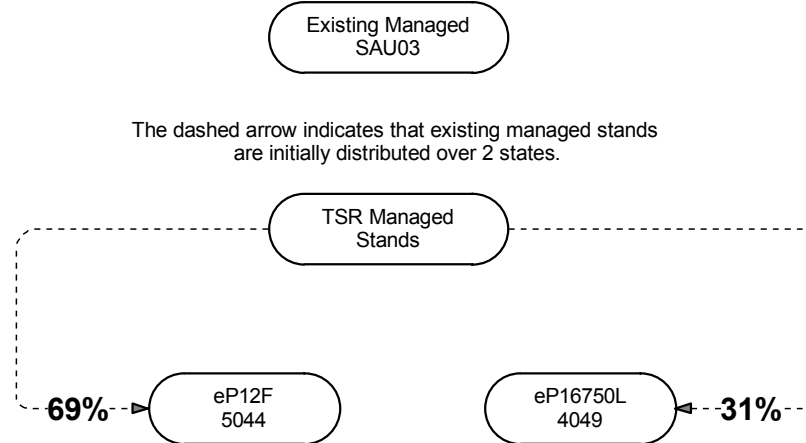


Figure B-7. Alternate development pathways for managed stands, SAU04 Fd (1-5,8), 17<SI<=22, WSI = 18.9, 14% THLB

Arrows represent silvicultural actions (including harvesting) that move an existing natural stand into future managed states

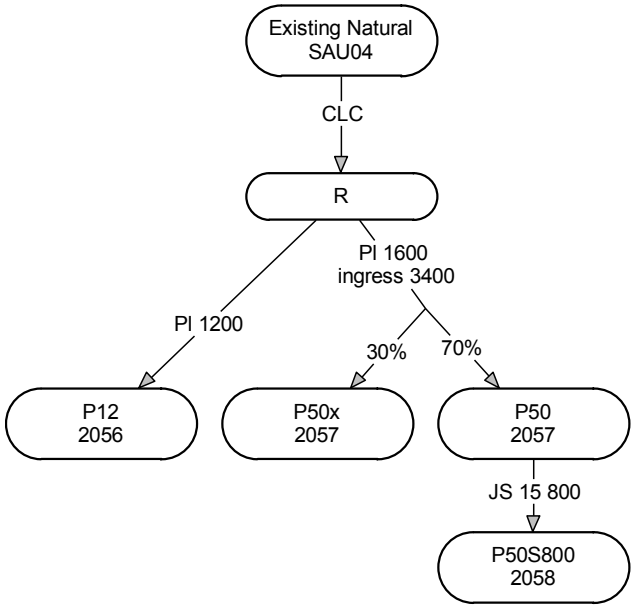
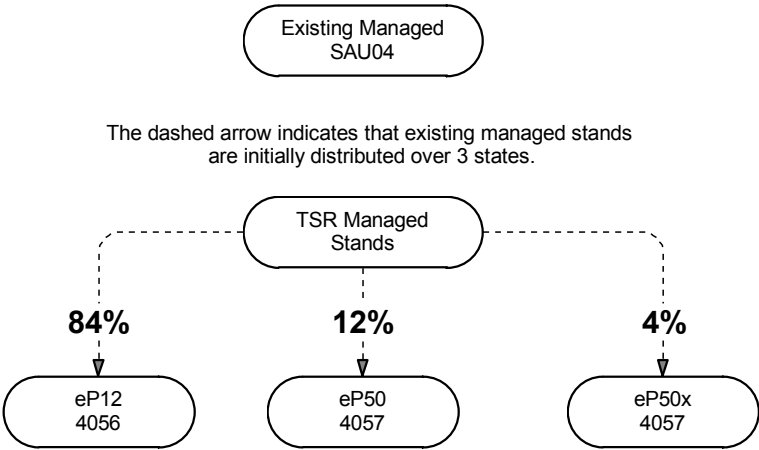


Figure B-8. Alternate development pathways for managed stands
SAU05 Fd (1-5,8), SI<=17, WSI = 15.7, 2% THLB

Arrows represent silvicultural actions
(including harvesting) that move an
existing natural stand into future
managed states

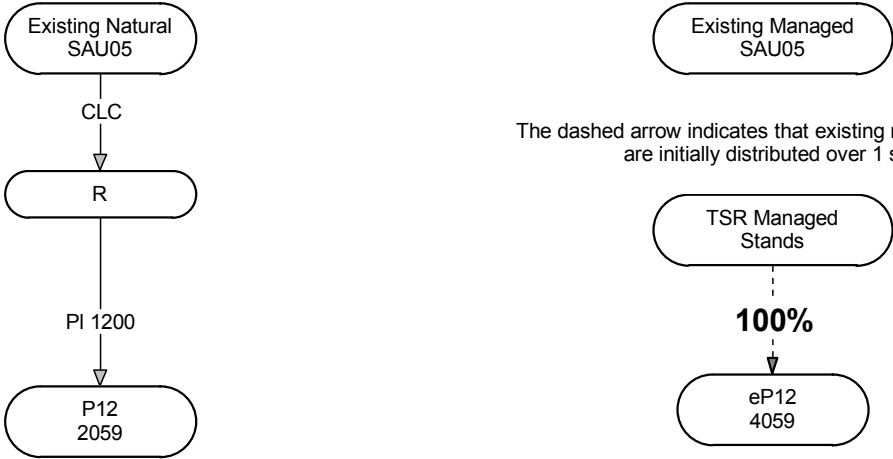


Figure B-9. Alternate development pathways for managed stands
SAU06 HwBa , SI >23, WSI = 27.4, 4% THLB

Arrows represent silvicultural actions
(including harvesting) that move an
existing natural stand into future
managed states

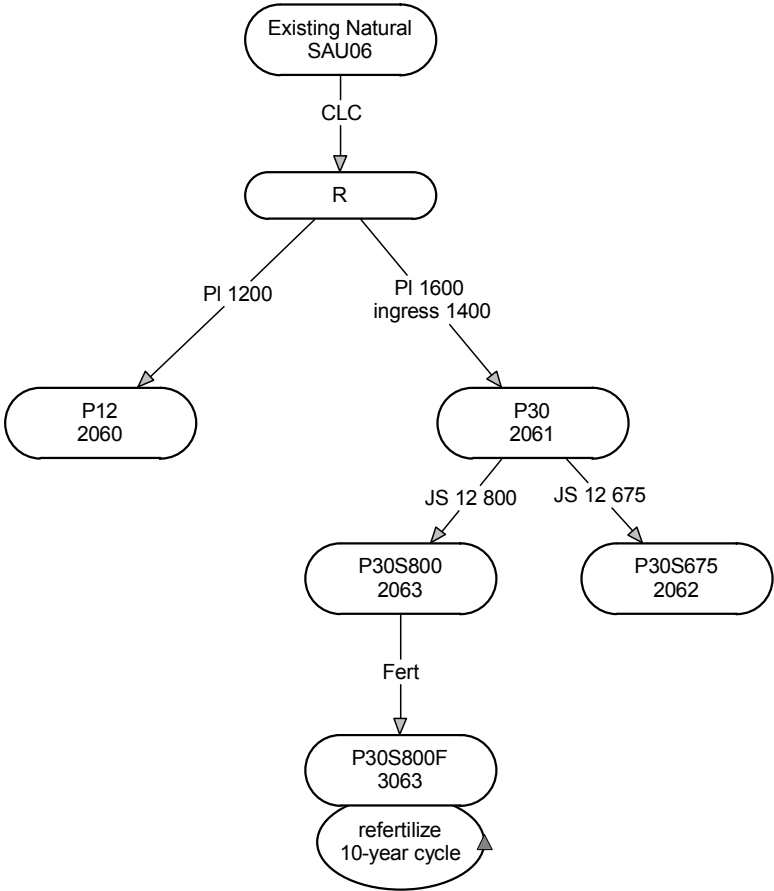
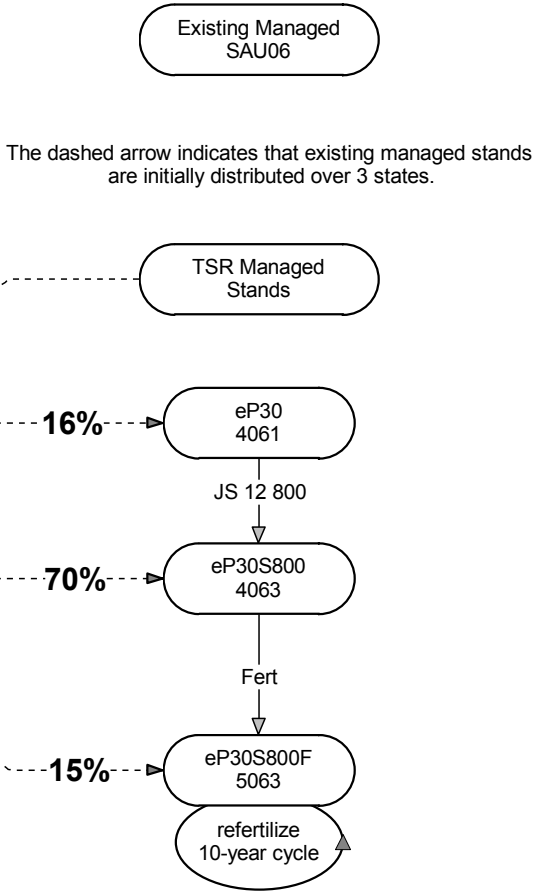


Figure B-10. Alternate development pathways for managed stands
SAU07 HwBa , 14< SI <=23, WSI = 18.9, 36% THLB

Arrows represent silvicultural actions
(including harvesting) that move an
existing natural stand into future
managed states

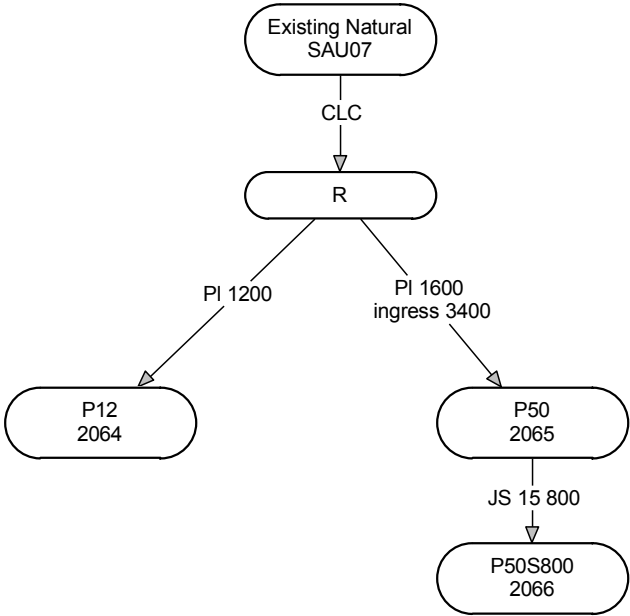
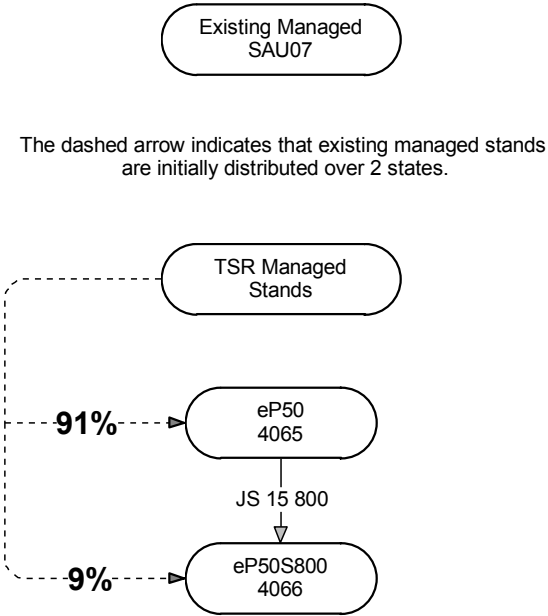


Figure B-11. Alternate development pathways for managed stands

- SAU08 Cw , SI > 18, WSI = 22.8, 1.9% THLB
- SAU09 Cw, SI <= 18, WSI = 15.33, 2.2% THLB
- SAU10 SsPI, All, WSI = 14.49, 5.1% THLB
- SAU11 HwBa, SI < 14, WSI = 11.63, 12.1% THLB

Arrows represent silvicultural actions (including harvesting) that move an existing natural stand into future managed states

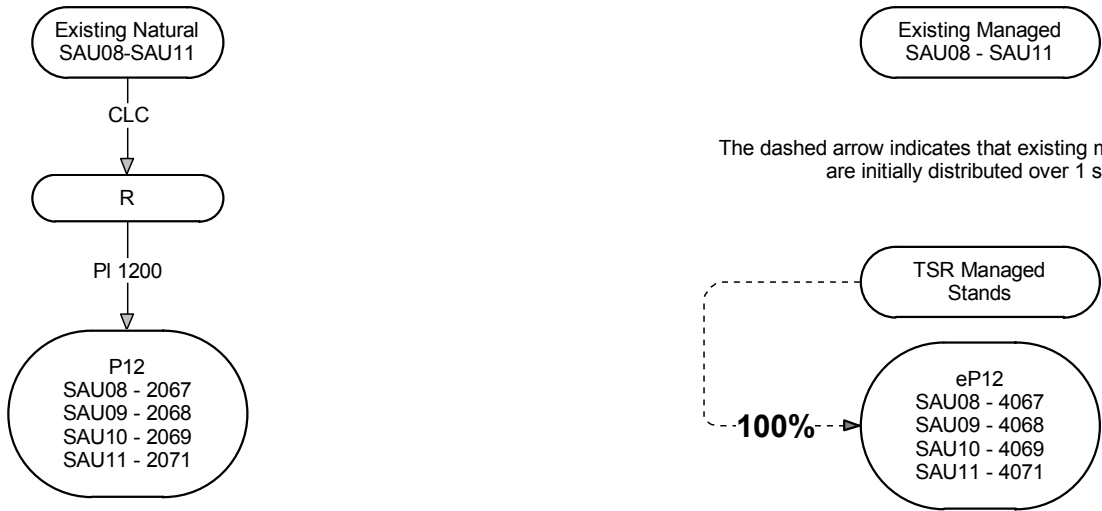
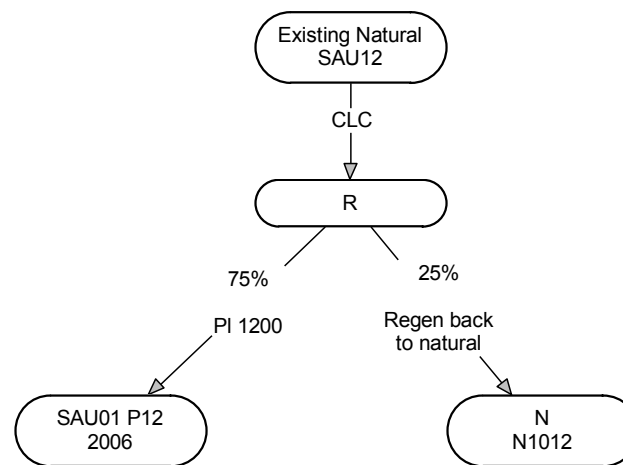


**Figure B-12. Alternate development pathways for managed stands
SAU12 Decid, All, 3.2% THLB**

Arrows represent silvicultural actions
(including harvesting) that move an
existing natural stand into future
managed states





Appendix C — Genetic Gain

The seed zones and elevation breaks (Table C-1) and the forecast gain in volume from improved seed (Table C-2) for the Fraser TSA were obtained from the Forest Genetics Council. The gain forecast for 2007–2008 was assumed to be applicable out to the planning horizon of this study (25 decades) and was prorated over the planting mixes identified by the district and the proportion of the TSA in each elevation.

Table C-1. Class "A" Seed Zones related to each TSA by species, Fraser TSA.

Fd	Class "A" Seed Zones by species					
	Hw	Cw	Ba	Yc	SxSs	Ss
M,SM	M	M,SM	M,SM	M	M,SM	M

65% of the Fraser TSA = M

35% of the Fraser TSA = SM

Source: FGC, Ron Planden

Table C-2. Forecast gain in volume from improved seed, Fraser TSA.

Species & Seed Zone	Elevation (m)	Gain from Improved Seed (%)		
		99-00	04-05	07-08
Fd M Low	<700	8.0	12.2	14.0
Fd M High	>700	2.0	5.0	5.0
Fd SM	200-1000	2.0	4.0	4.0
Hw M Low	<700	15.0	15.0	15.0
Hw M High	>700	2.0	2.0	2.0
Cw M Low	<700	2.5	11.6	11.6
Cw M High	>700	no genetic gain information available		
Cw SM	200-1000	no genetic gain information available		
Ba M SM Low	<700	2.0	2.0	2.0
Bg M Low	<700	2.0	2.0	2.0
Ss M Low	<700	3.0	4.0	4.9
SxSs SM/NST	all	2.0	2.0	2.0
Yc M	400-1200	5.1	10.5	20

Source: FGC



Appendix D – Analysis Method

The key component of the analysis method the development a silvicultural planning model that is consistent with the TSR model and base case for the Fraser TSA, and also fully represents the additional forest-level objectives and silvicultural activities required for silvicultural planning in a multiple resource planning context. The model will then emulate the TSR base case if incremental silviculture activities are turned off (i.e., the silviculture budget is constrained to \$0). As the budget is increased, the model will select silviculture activities that maximize its objectives. In essence, the model devises a silvicultural strategy that is consistent with the analyst's objectives for the TSA from the silviculture treatments specified for each SAU.

The silviculture model is constructed with Woodstock/LP

3.1 Develop a LP Model of the TSR Base Case

One of the major differences between this analysis and the TSR is the choice of the forest estate model. While the TSR uses FSSIM, a forest-level simulator, this analysis casts the silviculture planning problem as an linear model, solvable by linear programming (LP). Woodstock™ (Remsoft, 1997) was used to create the LP model and two optimization codes (C-Whiz™ and XA™) were used to solve it.¹

The first step in the analysis is to develop an LP model formulation of the TSR base case. An LP model represents the forest and its management as a series of linear equations, which can be arranged in a matrix. One equation, the objective function, expresses the forest-level objective (e.g., maximize volume production). Other equations represent the forest management rules such as limits on harvest fluctuation and forest cover constraints. The LP solution software finds the set of management activities (e.g., harvesting) that best meet the objective.

Regime diagrams are the “blueprint” for the model

3.2 Implement Silviculture Activities in the Forest-Level Model

The regime diagrams (Appendix B) are implemented in the silviculture planning model as activities, transitions, inputs and outputs.

Actions are defined in the model to represent each silvicultural activity listed or implied in the regime diagram for each SAU. Transitions map the flow of land between states. For example, a spacing action moves land from a regenerated state to a spaced state and a pruning action moves spaced land to a post-first-lift state.

¹ C-WHIZ Linear Programming Optimizer, Ketron Management Science, July 1994
XA/LP, Sunset Software Technology, San Marino, CA



Costs are incurred and outputs generated with each transition initiated by an action. Costs are summed by regime, by strategy, and in total, and are constrained by budget. Other outputs, such as employment, volume harvested, quality and value measures, are summed to the appropriate objective functions in the model.

Multiple objectives
guide the analysis

3.3 Implement Forest Level Objectives

Each forest-level objective must be implemented in the silviculture planning. The current version of the ASPM has six objectives implemented:

- maximize short-term timber harvest (decades 1-2)
- maximize mid-term timber harvest (decades 3-14)
- maximize long term timber supply (decades 15-20)
- maximize a priority-structured timber supply
- maximize volume harvested with dbh $\geq$ 65cm
- maximize volume harvested from pruned stands

The priority-structured objective maximizes the harvest over the entire 25-year planning horizon but puts the highest priority on maximizing harvest levels in decade 2, the second priority in the mid term (decades 3-14), and the lowest priority in the long term (decades 15-25).

Only one of the forest-level objectives can be active at a time and the other rows are described as non-constraining. These non-constraining rows calculate the contribution of harvesting and silvicultural activities to each forest level objective and are referred to as objective tracking rows.

Forest cover
constraints

Harvest-flow
guidelines

3.4 Implement Management Rules as LP Constraints

Forest cover constraints, as specified in TSR1, are represented explicitly in the LP model of the base case.

TSR harvest forecasts are shaped in part by harvest-flow guidelines. When using a simulation model such as FSSIM, harvest-flow guidelines are implemented by the modeller during the search for the best harvest schedule. However, with an LP model, the harvest flow guidelines must be implemented explicitly in the model as constraints.

To model the TSR1 base case, the following constraints were added to the model.

- decade 1: annual harvest = the current AAC (1996) of 393 073 m³
- decade 2: annual harvest $\leq$ annual harvest decade 1
- decade 3-5: annual harvest $\geq$ 88% of annual harvest previous decade



decade 6 –25: annual harvest $\geq$ annual harvest of previous decade

Disturbance constraints	Constraints on the area disturbed (not “greened up”) are specified for each of the eight management zones recognized in the TSR.
Sustainable target forest	Other forest management rules may be added as constraints. In order to ensure that the long-term harvest is sustainable in decades 26 and beyond, the growing stock (total inventory volume) in decade 25 is constrained equal or exceed 17,288,000 m ³ . This growing stock level was identified through experimentation with the base case model.
Harvest profile	The first-decade harvest profile (Section 2.4) for clear cutting and commercial thinning are implemented in the LP model as constraints.

3.5 Analyze Scenarios

The silvicultural planning problem expands the timber supply problem by adding silvicultural activities, constraints on silviculture expenditures, and the objective function rows required to calculate contributions to forest-level objectives.

Silviculture scenarios are constructed in a manner that the benefits from specific silvicultural practices can be identified in terms of the models objectives, e.g., the impact (benefit) of fertilization on mid-term timber supply.

The LP solver finds both the harvest area and the level of silvicultural activity for each of the time periods represented in the model. Silvicultural expenditures are constrained and shadow prices (sensitivity coefficients) associated with each constraint are calculated as part of the solution process.

The scenarios developed for this analysis are:

- S01. TSR1 Base Case – This scenario reproduces the TSR2 base case in order to validate the data and model. The management objective is to maximize priority-structured timber supply.
- S02. TSR1 Base Case plus Planting Select Stock – This scenario assumes that select stock will be planted for species for which it is available, with genetic gains as described in Appendix C. The management objective is to maximize priority-structured timber supply.
- S03. TSR1 Base Case plus Commercial Thinning and Select Stock – This scenario demonstrates the changes in the harvest forecast attributable to commercial thinning. The management objective is to maximize priority-structured timber supply.
- S04. Optimal Management Scenario – This scenario demonstrates the combined effects of all of the silviculture activities implied by the regimes defined for the TSA. It assumes an unlimited silviculture budget.



The management objective is to maximize priority-structured timber supply.

- S05. Optimal Management Scenario at Various Budget Levels – This scenario demonstrates the effects on harvest levels of setting the incremental silviculture budget to various levels between 0% and 100% of the total silviculture expenditure of the unlimited optima (S04). The management objective is to maximize priority-structured timber supply.
- S06. Optimal Management Scenario (Quality/Dimension) – This scenario is identical to S04 except that the objective is to maximize the harvest volume compiled at a utilization level of 65 cm dbh. The harvest flow (compiled at TSR2 utilization levels) is constrained such that it cannot drop below the minimum level (mid-term trough) experienced in S04.
- S07. Optimal Management Scenario at Recent Historical Levels – This scenario is identical to S04 except that the incremental silviculture activities in the first decade are constrained to recent historical levels. The management objective is to maximize priority-structured timber supply. The purpose of this scenario is to calculate the shadow prices of the incremental silviculture activities constrained in the first decade.
- S08. Not used in this analysis.
- S09. Optimal Management Scenario (Quality/Clear) – This scenario is identical to S04 except that the objective is to maximize volume harvested from pruned stands. The harvest flow (compiled at TSR2 utilization levels) is constrained to the harvest flow achieved in S04 so loss of timber supply is avoided. The annual expenditure on pruning is constrained at five different levels.



Fraser TSA Silviculture Strategy Analysis



Appendix F– MoF Guidelines for Deviating from the Silviculture Strategy

Ministry of Forests

File: 22130-20/SILV STRATEGY

Date: October 24, 2001

Occasionally, it will be necessary to deviate from the set of silviculture activities recommended in the Silviculture Strategy. In most Management Units in the province, the current Silviculture Strategy is the most comprehensive and rigorous evaluation of silviculture options ever conducted. Nevertheless, no Silviculture Strategy is perfect; each will always require fine-tuning. For the following reasons, it may be necessary to deviate from the plan:

1. Objectives

The complex, multiple objectives of real-world silviculture programs are imperfectly represented in the Silviculture Strategy analysis. Objectives and policies may change quickly from those assumed during the development of this Silviculture Strategy. If the objectives assumed in the Silviculture Strategy do not match the current objectives, it may be necessary to deviate from the plan.

2. Inventory and yield predictions

The inventory and yield predictions used in this analysis may contain errors. If over time, new information comes to light identifying deficiencies in the yield and landbase assumptions, it may be necessary to deviate from the plan.

3. Budgets

Budget levels, delivery mechanisms, and estimates of the impact of treatments on stand value change over time. These changes may necessitate deviations from the plan.

Thus, though this Silviculture Strategy represents a major step forward in silviculture planning, deviations from this plan may be required. When deviation is required, it is important that the rationale for the deviation be formally documented and attached to the current Silviculture Strategy. Considerable resources have been invested in the development of this strategy, so deviations from this plan should not be undertaken lightly. A proposed deviation from the plan should be substantiated with rigorous analysis and justification.



Fraser TSA Silviculture Strategy Analysis



Appendix G – Revisions to Management Regimes and Financial Analysis

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Appendix G – Revisions to Management Regimes and Financial Analysis

This Appendix reports analysis activities undertaken subsequent to the completion of the Fraser TSA Silviculture Strategy (Type 2).¹ The final scenario analyzed and reported in that study was designed by the Chilliwack Forest District (the “Preferred Management Scenario”) and upon reviewing the results of that scenario, the District suggested revisions to the set of incremental silviculture regimes available to the model. This Addendum reports the results from the re-analysis of the Preferred Management Scenario using the revised management regimes.

The analysis was extended to include a financial efficiency objective and the calculation of financial gain attributable to incremental silviculture. This Addendum also describes the results of this analysis.

Despite the fact that the forest asset is owned by the Crown, the analysis is described here as “financial” rather than “economic” because the evaluation is driven with a profit-maximizing objective (profit to the forest enterprise), as opposed to a social welfare function. The costs and benefits considered in this analysis derive directly from markets; no adjustments are made for indirect market and non-market transactions.

1.0 Revisions to Management Regimes

The revisions specified by the District modified the incremental silviculture regimes for silviculture area units SAU01, SAU02, SAU06 and SAU07, described in Table 1.

Table 1. Silviculture analysis units with revised management regimes.

Silviculture Analysis Unit	Leading Species	Site Index Range
SAU01	Fd	SI > 27
SAU02	Fd	25 < SI ≤ 27
SAU06	HwBa	SI > 23
SAU07	HwBa	14 < SI ≤ 23

SAU01 and SAU02

For SAU01 and SAU02 the following management regimes for natural stands were added:

- natural ingress to 2000, space to 750 (NS750)
- natural ingress to 2000, space to 750, prune (NS750L)
- natural ingress to 2000, space to 750, prune, fertilize (NS750LF)

¹ Cortex Consultants Inc., 2002. Fraser TSA Silviculture Strategy (Type 2). Report prepared for Vancouver Forest Region. 44 pages + appendices



- natural ingress to 2000, space to 750, fertilize (NS750F)
- natural ingress to 2000, fertilize (N---F)

Natural stands are operable for spacing and or pruning when less than 20 years of age and may be fertilized if less than 60 years of age.²

SAU02

For SAU02, a plant and fertilize management regime was added for future and existing manage stands:

- plant to 1200 sph, fertilize (P12---F)

SAU06

Fertilization was eliminated from the incremental silviculture regimes allowed for SAU06 (hemlock-balsam, SI > 23) leaving only two alternative regimes:

- plant to 1200 sph – no further treatment (P12)
- plant to 1600 sph, natural ingress to 3400 sph, space to 750 (P30S750)

SAU07

For SAU07 (hemlock-balsam, 14 < SI ≤ 23) only the following regimes are available:

- plant to 1200 sph – no further treatment (P12)
- plant to 1600 sph, natural ingress to 3400 sph, space to 800 (P50S800)

2.0 Re-analysis of the Preferred Management Scenario

The Preferred Management Scenario (S10), as described in the original strategy document, is driven by the management objective of maximizing priority-structured harvest volume, compiled to TSR utilization standards.³ Select stock is planted, and spacing, fertilization, pruning and commercial thinning activities are available to the model. The harvest flow is constrained to not drop below the base case (S01b) harvest level, but can increase at a rate of 10% per decade. The total harvest volume must include at least 2% volume from clear wood, and at least 1.5% volume compiled at a utilization level of 65 cm dbh. Finally, the incremental silviculture costs must not exceed 1.6 million dollars per year.

The Preferred Management Scenario was re-analyzed with the updated management regimes and labeled S10 Max Vol.

² As per instruction of Craig Wickland, Chilliwack Forest District. Note that the natural stand regimes were incorrectly specified in the model, but subsequent analysis demonstrated that potential impacts of these errors on the results reported in this Addendum were inconsequential.

³ For a definition of maximizing priority-structured harvest volume see the original strategy document Appendix D.



The scenario (with updated management regimes) was also re-analyzed with the objective of maximizing net present value (NPV) calculated with a discount rate of 4%. A constraint was added to prevent the harvest from dropping below the base case level (S01b). This version of the scenario was labeled S10 Max NPV.

Figure 1.
S10 – Volume and
NPV objectives

Figure 1 compares the harvest schedules obtained for S10 Max Vol and S10 Max NPV. The S10 Max Vol scenario traces the base case harvest level until period 12 when future managed stands reach merchantable limits, and then increases rapidly. The S10 Max NPV scenario obtained higher harvest levels than the base case from period 2 to the end of the planning horizon.

Maximizing NPV with the updated regimes and harvest flow rules allows the model to harvest previously rationed timber in the short- and mid-term. The additional fertilization regimes specified for SAU01 and SAU02 allow the young natural and managed stands to reach harvesting size earlier, and allow the harvesting in the early mid term of presently mature stands that would be otherwise be rationed until later in the planning period.

The LTHL for S10 Max NPV scenario is lower than the S10 Max Volume scenario because the model can now emphasize harvest in the short and mid-term. The S10 – Max Volume scenario was forced to ration existing stands for future harvest, and could not increase harvest levels until future managed stands come on-line in the long-term.

Under a financial efficiency objective such as maximizing NPV, the model will always accelerate the harvest in order to minimize the loss in future value due to the discount rate, resulting in shorter rotations.

Figure 2.
Age distribution of the
harvest

This effect is evident in Figure 2 where stands are harvested at ages of 50 years or less, beginning immediately (decade 1) and becoming a significant portion of the cut by decade 6.

Figure 3.
Dimension distribution of
the harvest

The quadratic mean diameter of managed stands fluctuates around 30 cm over the planning period. Note that the dimensions are not available for the harvest of natural stands, due to the limitations of the yield curves (VDYP).

Figure 1. Harvest forecasts for S10 determined with maximize volume and maximize NPV objectives.

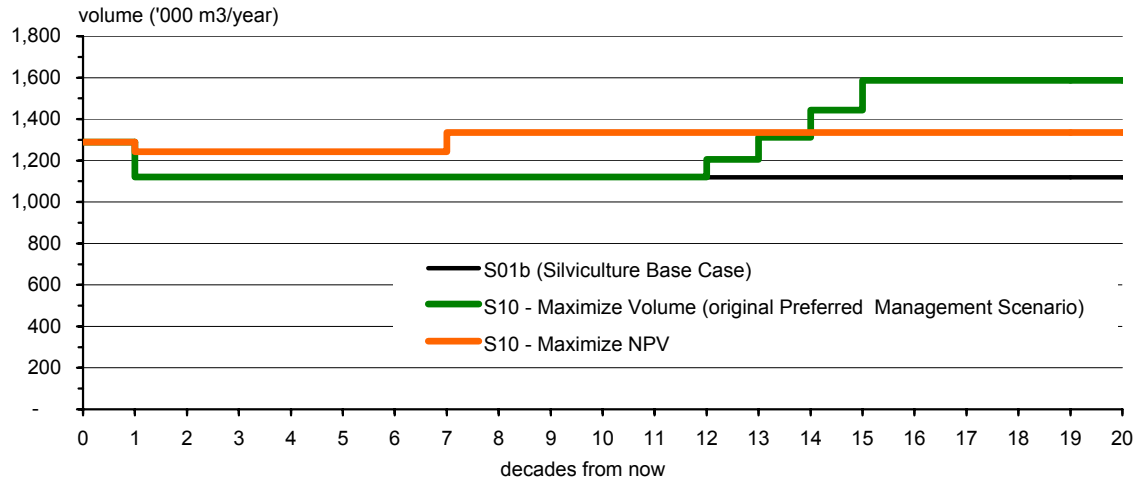


Figure 2. Composition by stand age of forecast harvest of managed stands, maximum NPV scenario (S10).

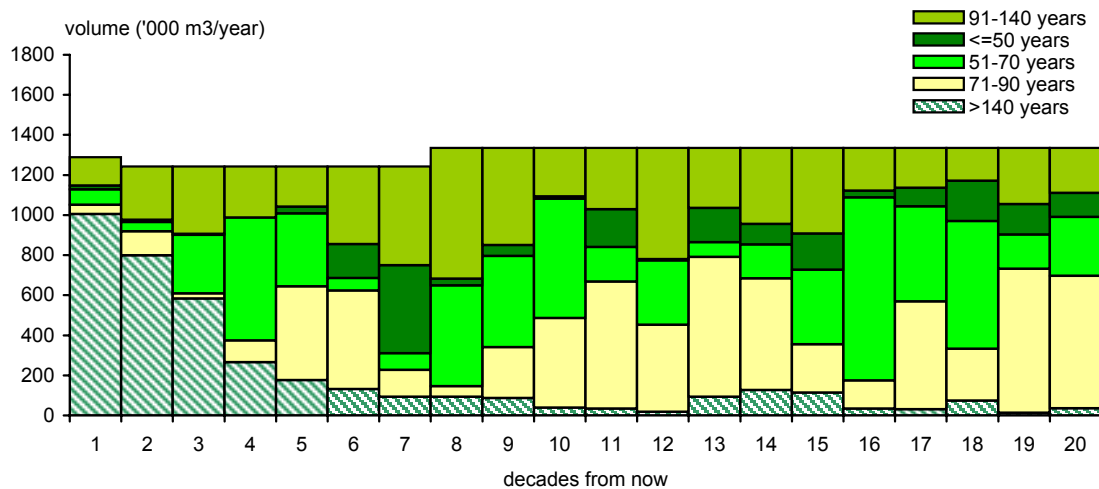


Figure 3. Composition by dimension of forecast harvest of managed stands, maximum NPV scenario (S10).

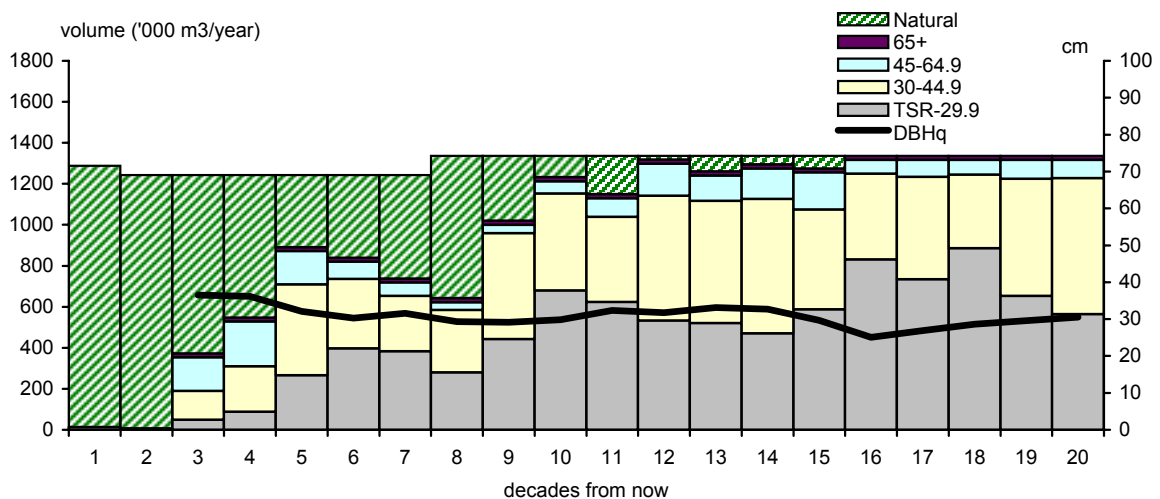




Figure 4.
Area treated

The area juvenile spaced in decades 1-2 is about 1250 ha each year. Note that this is roughly twice the area (650 ha) reported in the silviculture strategy for the Preferred Management Scenario, attributable to the additional management regimes supplied in this Addendum for SAU01 and SAU02. Subsequent to decade 2, the area spaced averages 735 ha per year, exceeding the area reported in the silviculture strategy (637 ha). No spacing is undertaken in decades 18-20 as the model chooses not to incur the spacing cost given that there is insufficient decades left in the planning period to grow the spaced stands to a harvestable age.

The area fertilized in decades 1-2 averages about 600 ha per year, greatly exceeding the area reported in the silviculture strategy (85 ha per year). The rationale for this increase is the same as for spacing: the additional opportunities provided in the addendum analysis to space and fertilize natural SAU01 and SAU02 stands.

The area fertilized increases steadily through decades 1-4 as an inventory of spaced stands is developed, and re-fertilization opportunities increase. From decade 5-18, the average rate of fertilization is 2967 ha per year. This is 12% less than the rate reported in the silviculture strategy (3355 ha per year).

Pruning levels fluctuate according to the availability of candidate stands, averaging 114 ha per year over decades 1-17, versus 140 ha per year reported in the silviculture strategy. No pruning is undertaken in decades 17-20 for the same reason that spacing is eliminated in decades 18-20 – the model chooses not to incur the pruning cost given that there is insufficient decades left in the planning period to grow the pruned stands to a harvestable age.

Note that repeat-fertilization does occur until the final decade, as the model can harvest the fertilized stand in the same decade.

Figure 5.
Treatment cost

Total treatment costs remain constant at the maximum budget level of \$1.6 million over decades 1-18 and the costs per treatment reflect the activity levels displayed in Figure 4.

Figure 4. Treatment area forecast, maximum NPV scenario (S10).

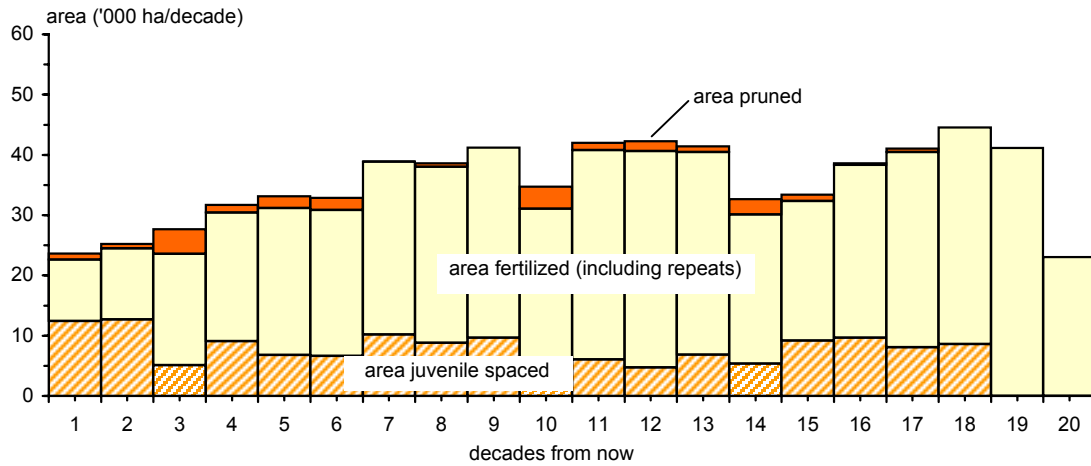


Figure 5. Treatment cost forecast, maximum NPV scenario (S10).

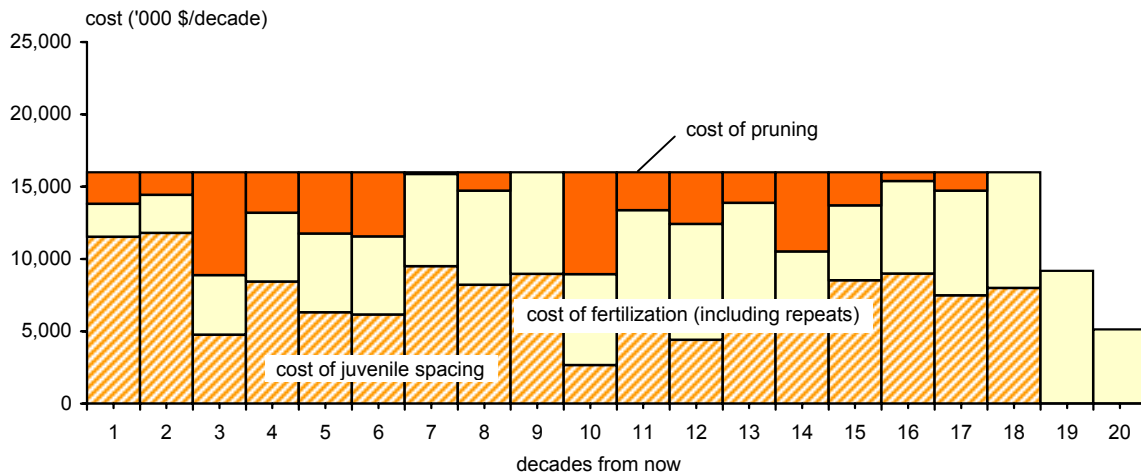
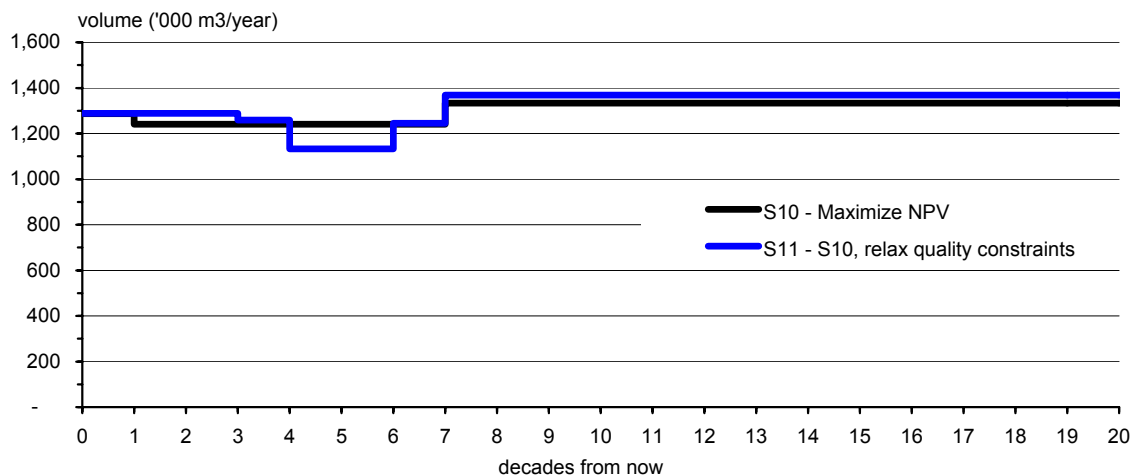


Figure 6. Effect on harvest level of the relaxation of the S10 quality constraints (S11).





3.0 Financial Efficiency of Incremental Silviculture

Limitations of the NPV calculation

Calculation of the net present value (NPV) of a forest estate requires summing the discounted flow of costs and revenues attributable to the management and harvesting of the forest over the planning period. In this analysis, the revenue from timber harvest was supplied by the District for natural stands and from TASS for managed stands. The only cost included in the calculation of NPV is the cost incremental silviculture; the costs of log production (delivered wood cost—stump to mill) are not included. Therefore the harvest and management schedule determined in this analysis to maximize NPV does not reflect log production costs.

The general practice in timber supply modeling in British Columbia has been to determine a timber harvesting land base (THLB) upon which all stands are operable, and then to model harvesting within that land base. In effect this approach assumes that all stands on the THLB are harvestable at the same cost and that the cost is less than the revenue that will be generated from the conversion of the stand to logs. This assumption is carried into the present analysis and limits the utility of the analysis with respect to issues of financial efficiency. Some of these limitations will be identified in subsequent sections.

Figure 6. Relaxation of quality constraints (S11)

Scenario S11 is identical to S10 Max NPV, except that the quality requirements (at least 2% clear wood, 1.5% >65 cm dbh) have been eliminated. Figure 6 compares the harvest schedule determined under scenario S10 Max NPV, with scenario S11. The relaxation of the quality constraints allows the initial harvest level to be maintained for 2 more decades before dropping in decade 4. The S11 cut exceeds the S10 Max NPV cut by 3.6%, 3.6% and 1.2 % for decades 2, 3 and 4, respectively. In decades 5-6, the S11 cut drops below the S10 Max NPV level, but for decade 8-18 it exceeds it by 2.5%.

Pruning is eliminated

Pruning is eliminated by the model for S11, implying that the NPV can be maximized by allocating the incremental silviculture budget to other activities, or simply not spending it.

Spacing changes slightly

Comparing S11 and S10 Max NPV, juvenile spacing drops slightly in decades 1-2 (1200 ha/year vs. 1250 ha/year) and increases slightly (780 ha/year vs. 735 ha/year) in decades 3-20.

Fertilization increases

Fertilization increases substantially (43%) in decades 1-2 (860 ha/year vs. 600 ha/year) and by 11% in decades 3-18 (3247 vs. 2967).

The level of commercial thinning is unchanged at about 130,000 m³ per year, but the timing of the harvests differs.

Figure 7. Silviculture budget=0

Scenario S12 is identical to S11, except that the incremental silviculture budget is set to zero for the planning period, i.e., no incremental silviculture activities can be implemented. The harvest forecast for S12 drops below the S11 forecast substantially in decades 3-4 (by 11%), in decade 7 (10%), and decades 11-20 (17%).

Financial gain of spacing and fertilization

Subtracting the NPV achieved in S12 (without incremental silviculture) from the NPV achieved in S11 (with incremental silviculture) yields the net present value of the incremental silviculture program: 121.7 million dollars. This is the financial gain



attributable to the spacing and fertilization program. However, as noted above, it does not include log production cost—it is the present value of the increment of supply attributable to spacing and fertilization, “net” of incremental silviculture costs only. This financial gain is inflated by ignoring log production cost.

Figure 8.
Financial gain vs.
average log cost.

Since the log production costs for each stand (or logical aggregations of stands) are unknown for the Fraser TSA, the financial gain calculated above was corrected for a range of average log production costs. Note that there is positive financial gain attributable to the scenario S11 spacing and fertilization program for average log production costs less than about 87 dollars per m³.

Assigning “average” log production costs in a financial analysis can be misleading. Logs are produced at a various costs based on stand condition, topography, access cost and haul distance and the value of a log at the mill is independent of the cost of production and delivery to the mill, i.e., some valuable logs may come from high cost areas and hence be economically inoperable, while some poor quality logs may be obtained at low cost, and hence are operable.

Recommendation

This analysis of the financial gain attributable to the incremental silviculture program should be repeated after log production costs have been assigned to the inventory as a function of stand condition, location, access and topography.

Figure 7. Effect on the harvest forecast of eliminating the silviculture budget (S12).

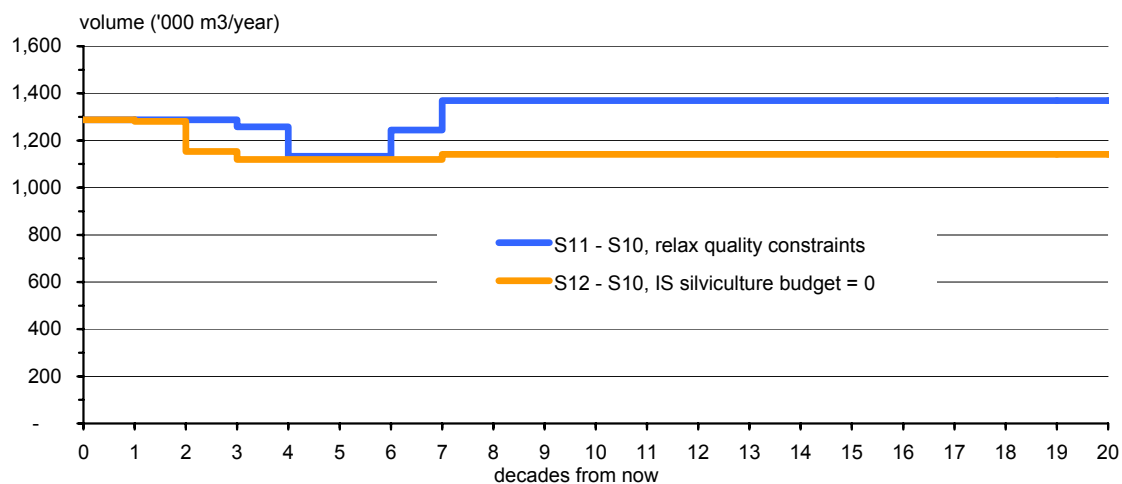
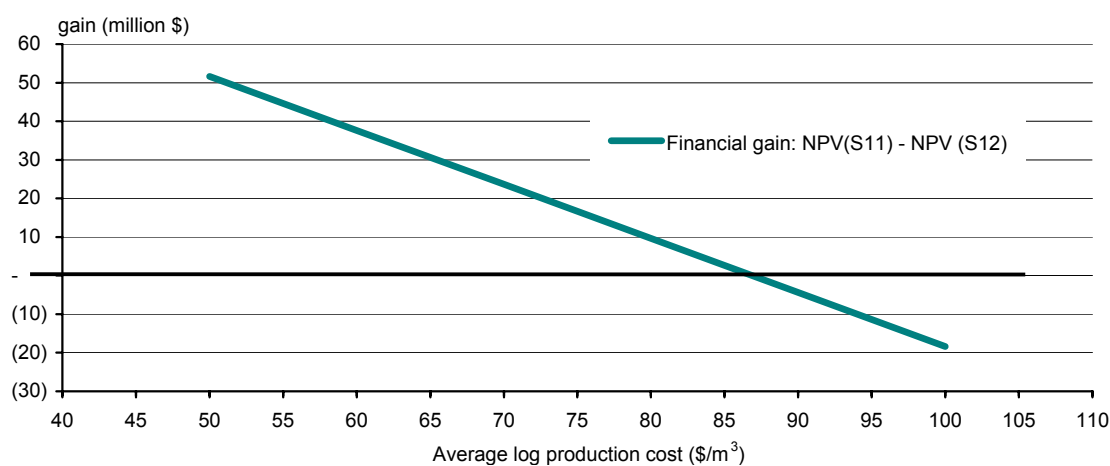


Figure 8. Financial gain attributable to spacing and fertilization, corrected for average log production costs.





4.0 Strategic Plan – Update

This section updates the strategic plan presented in the original silviculture strategy document to reflect the revisions to the management regimes described in section 1, and management for a financial objective, as embodied in the scenario S10 Max NPV.

For each silvicultural analysis unit, the model has selected regimes that best meet the management objectives that drive the scenario. For SAU01, SAU02, and SAU03 the dominant incremental silviculture regimes, i.e., the regimes that are applied to most of the regenerated land are diagrammed in this section to aid comprehension of the regimes selected by the model.

SAU01

Fd ITG=1-31, SI=31

Figure 9 diagrams the dominant regimes for SAU01. The silvicultural activities are coded as:

- Nat nnn – natural origin stands established at nnn stems per hectare
- Plt nnn – plant nnn stems per hectare
- Js nnn – juvenile space to nnn stems per hectare
- Fe 10 – fertilize on a 10-year cycle until harvest
- CT – commercial thin
- CC – clearcut

For planted stands, the area treated by each regime is expressed as a percentage of the total area of the analysis unit regenerated over the 20-decade planning period. For natural stands, the actual area managed is recorded.

If the management objective is to maximize volume production (S04) without regard to wood quality and incremental silviculture costs, then the dominant regime employed on SAU01 is to plant to 1600 sph and subsequently space those stands that are operationally feasible to 725 sph, commercial thin and fertilize on a 10 year cycle until harvest. Under this management objective, 83% of the regenerated area is managed by this regime.

When the objective is to maximize log dimension (S06), the dominant regime employed is the same as S04 – plant 1600 sph, space to 725 sph, CT, and fertilize (54% of the area regenerated). Some of the regenerated area (24%) shifts to another regime: plant 1200 sph, space to 750 sph, fertilize on a 10-year cycle, and commercial thin.

However, if the objective includes pruned wood (S09), then pruning regimes with fertilization become dominant. The regime utilized most often is to plant 1600 sph, space to 725 sph, prune, and fertilize on a 10-year cycle until harvest (61%). Note that 30% of the regenerated area has shifted to regimes with the lowest planting density: plant 800 sph and prune (16%), and plant 800 sph, prune and fertilize on a 10 year cycle until harvest (14%).

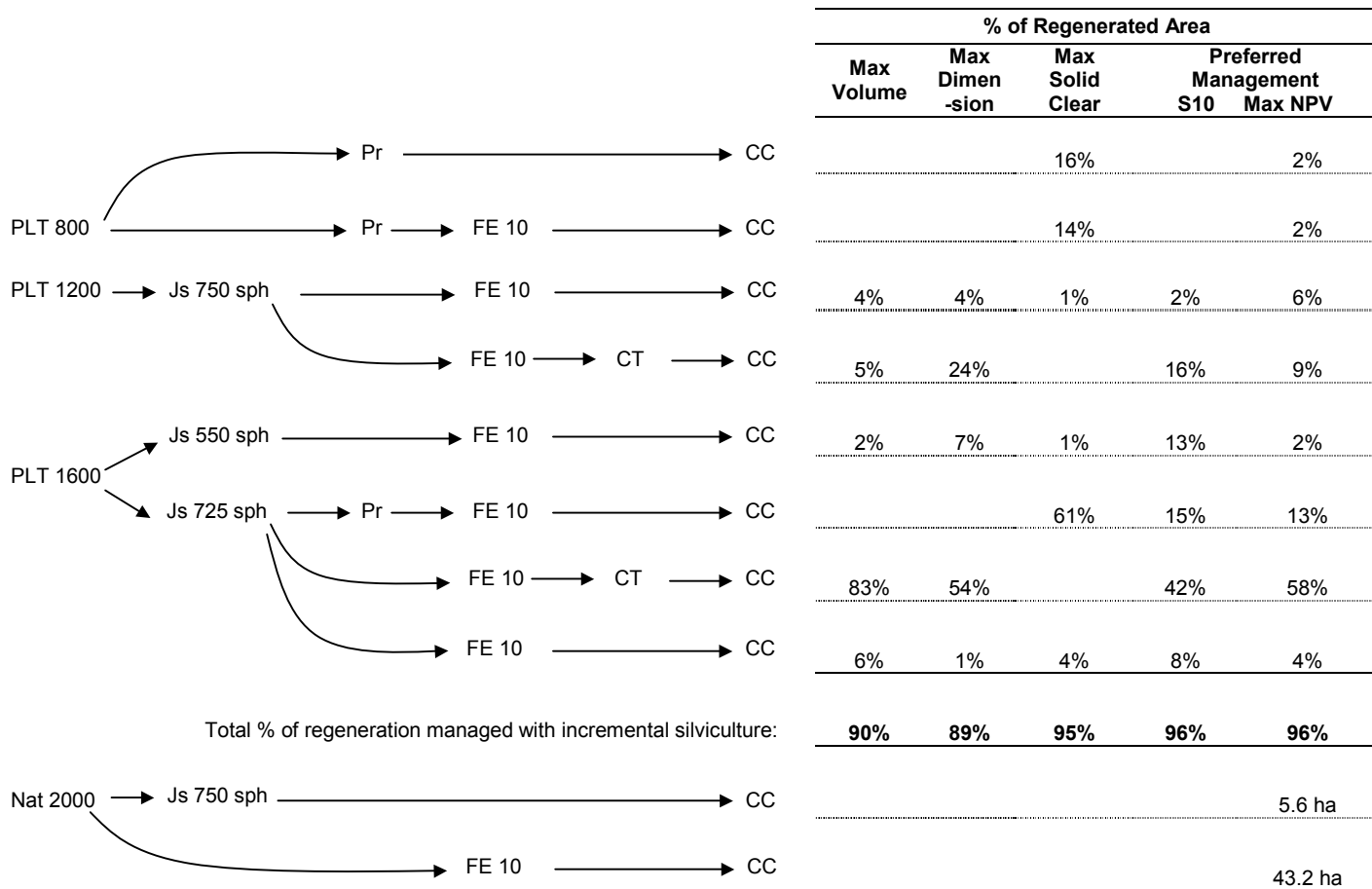
Under the preferred management scenario (S10) the regime most often implemented is the same as S04 and S06 (42%), however the management of the remaining regenerated area is spread more evenly across regimes with lower planting densities and pruning.



After revising the preferred management scenario to consider the new management regimes and changing the objective to maximize NPV (scenario S10 Max NPV), exactly the same area (96% of area regenerated) is managed with incremental silviculture, although the distribution of the area across the regimes has changed to maximize financial efficiency. In addition, some natural stands are spaced and fertilized.

Across all management objectives, incremental silviculture regimes were implemented on 89%-96% of the regenerated area of SAU01.

Figure 9. Incremental silviculture regimes implemented for SAU01 (Fd, ITG 1-8, SI=31)





SAU02

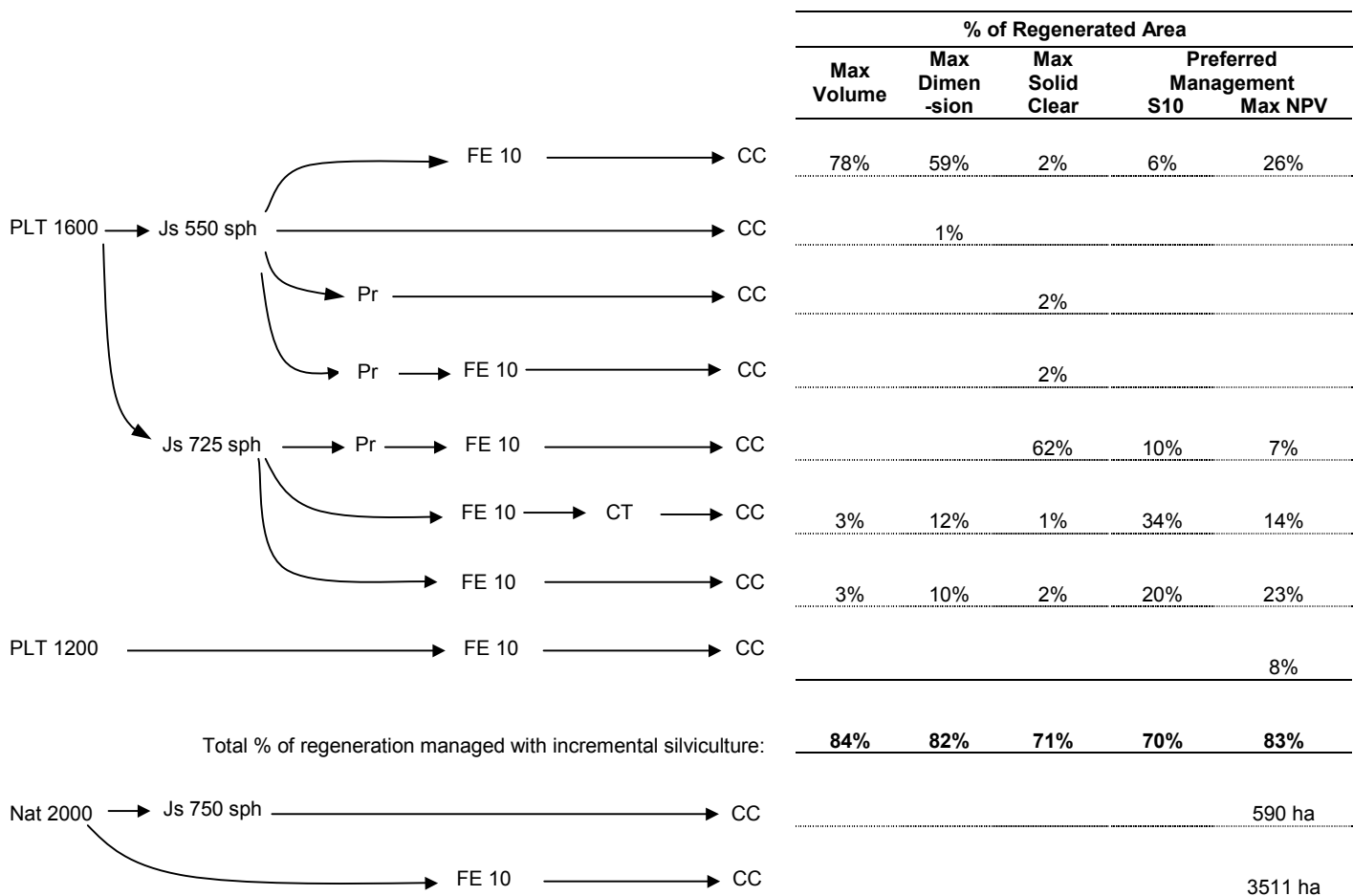
Fd ITG=1-31, SI=27

Figure 10 diagrams the dominant regimes for SAU02.

If the management objective is to maximize volume production (S04) without regard to wood quality and incremental silviculture costs, then the dominant regime employed on SAU02 is to plant to 1600 sph and subsequently space those stands that are operationally feasible to 550 sph, and fertilize on a 10-year cycle until harvest (78%).

When the management objective is to maximize the harvest volume compiled at a utilization level of 65 cm dbh, the dominant regime is the same as S04 - plant to 1600 sph, space to 550 sph, and fertilize (59%). However, more of the regenerated area is spaced to the higher residual density (725 sph) and subsequently fertilized (22%) and commercially thinned (12%).

Figure 10. Incremental silviculture regimes implemented for SAU02 (Fd, ITG 1-8, SI=27)





When the objective is to maximize wood from pruned stands the regime most often implemented is plant to 1600 sph, space to 725 sph, prune, and fertilize (62%).

The preferred management scenario (S10) follows the activities implemented in S04 and S06 except that management has shifted to regimes with higher residual spacing densities (64%), commercial thinning (34%) and pruning (10%).

The revised preferred management scenario (S10 Max NPV), driven by the objective of maximizing net present value, reduces pruning (7%) and commercial thinning (14%), but increases the area of natural stands fertilized as well as the total area managed with incremental silviculture (83%). Of the 3101 ha of natural stands treated, 590 are spaced and held until harvest and 3511 ha (not spaced) are fertilized and held for harvest.

In aggregate, incremental silviculture regimes were implemented on 84% of the regenerated area of SAU02 when the objective was to maximize volume production, but only 70% was managed with incremental silviculture regimes under the preferred management regime.

SAU03

Fd ITG=1-31, SI=23

Figure 11 diagrams the dominant regimes for SAU03.

If the management objective is to maximize volume production without regard to wood quality and incremental silviculture costs, then the dominant regime employed on SAU03 is to plant to 1600 sph and subsequently space those stands that are operationally feasible to 750 sph, and fertilize on a 10 year cycle until harvest (72%); 40% of the fertilized stands are commercially thinned when operationally feasible.

The regimes implemented for volume production are also used when the objective is to maximize large dimension wood. The percent of the stands regenerated planted to 1600 sph, spaced to 750 sph, and fertilized is 59%, with only 14% being commercially thinned.

If the objective is to maximize wood from pruned stands the regime most often implemented is plant to 1600 sph, space to 750 sph, prune, and fertilize (52%).

If the scenario is preferred management, only 14% of the regenerated stands are managed with incremental silviculture. Fertilization is scheduled for all of the incremental silviculture regimes implemented.

Natural stands of SAU03 were not eligible for incremental silviculture treatments.

SAU04

Fd ITG=1-31, SI=19

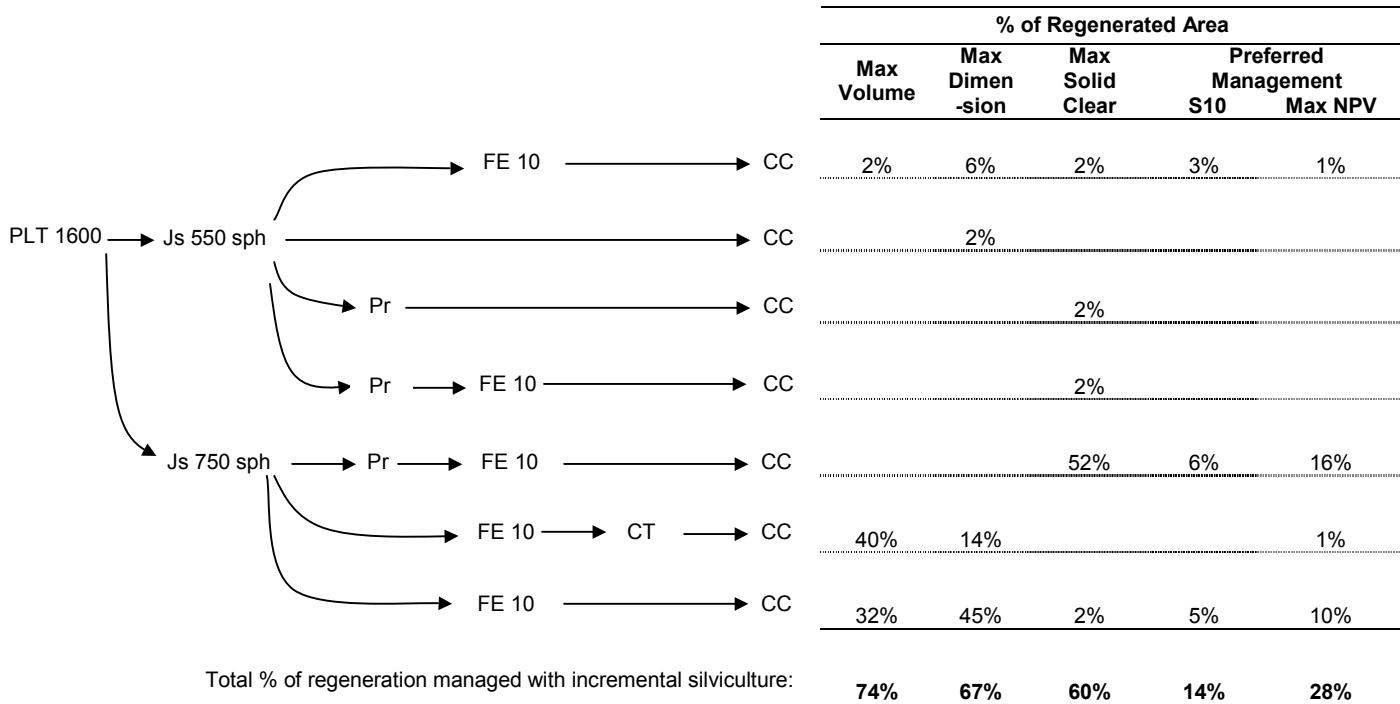
If the management objective is to maximize volume production, maximize large dimension wood, or maximize pruned wood then the regime implemented is plant 1600 sph (5000 sph with ingress) and space to 800 sph (11%, 12%, and 23% of the regenerated area, respectively).

No incremental silviculture activities are implemented under the preferred management scenario (S10) or the revised preferred management scenario (S10 Max NPV).

Natural stands of SAU04 were not eligible for incremental silviculture treatments.



Figure 11. Incremental silviculture regimes implemented for SAU03 (Fd, ITG 1-8, SI=23)



SAU05 Fd SI=16
SAU08 Cw SI=22
SAU09 Cw SI=15
SAU10 SsPI SI=14
SAU11 HwBa SI=11
SAU12 Decid SI=15

The only development options provided for these analysis units are planting to 1200 sph. The model addresses all three management objectives with the same regime: plant 1200 sph, and hold until clearcut.

One exception to the above is SAU12, which has 75% of the managed area planted to SAU01, and 5% of the managed area planted back to natural deciduous species.

SAU06
HwBa ITG=12-20,
SI=27

With this analysis unit, for all of the scenarios except the revised preferred management scenario (S10Max NPV), the regime most often implemented is plant 1600 sph (3000 sph with ingress) and space to 800 sph, and fertilize (10-year cycle). The percent of the area regenerated that is managed with this regime is highest when the management objective is volume production (97%), followed by the large dimension objective (86%) and the pruned wood objective (53%), and the preferred management (55%). Under the revised preferred management scenario (S10 Max NPV), fertilization was eliminated from the candidate regimes and no incremental silviculture was implemented by the model.

SAU07
HwBa ITG=12-20,
SI=19

When the management objective is to maximize volume production, large dimension wood, and pruned wood then the regime implemented is plant 1600 sph (5000 sph with ingress) and space to 800 sph (92%, 83%, and 70% respectively). If the objective is preferred management (S10), no incremental silviculture activities are



implemented. However for the revised preferred management scenario S10 Max NPV, 18% of the regenerated area is spaced to 800 sph with no further treatment.

Strategy - Summary

With the management objective maximizing volume harvested (S04), the model puts the highest priority on maximizing harvest levels in decade 2, then in the mid term (decades 3-15), and finally in the long term (decades 16-25). Therefore the model implements commercial thinning to bring timber forward in the harvest queue in order to reduce falldown in decade 2 and fill the mid-term trough. Fertilization and genetic gain produce timber quantity benefits in the late mid term and early long term which are conveyed forward in the harvest queue by commercial thinning.

Under the S06 scenario the objective of maximizing piece size is met mainly by increasing age at harvest. Lengthening the rotation age past culmination age reduces the productivity of the TSA, a fact reflected by the 11% drop in the long-term harvest level obtained for scenario S06. In addition to longer rotations, there is a shift in some analysis units (SAU01, SAU02, SAU05, and SAU07) to spacing to lower densities.

Managing for solid-clear harvest volume (S09) is achieved by implementing pruning options of regimes already selected in S04 (maximize volume) in analysis units SAU01, SAU02, and SAU03.

Managing for mixed objectives (the preferred management scenario, S10) results in implementing each of the strategies described above, in proportions that maximize volume production, satisfy as closely as possible the solid clear wood and large dimension production goals, but also meet the constraint on total silviculture budget.

The preferred management scenario with the revised management regimes and financial objective implements fertilization and spacing of existing natural stands of medium and high site Fd, spaces dense medium site HwBa, and minimizes pruning to a level and schedule sufficient to meet the regime requirement of 2% clear wood in the long term.

5.0 Tactical Plan – Update

This section updates the tactical plan to reflect the revisions to the management regimes described in section 1 and management for a financial objective (maximizing NPV). The tactical plan is reported in Table 2.

The strategic plan identifies the regimes that maximally contribute to the management objectives specified for the TSA. However, in the first decade the opportunity to implement those regimes is constrained by the operational realities of the harvesting queue and the inventory of existing managed timber. The identification of stand types to be treated in decade 1 under each management objective constitutes the tactical plan.

The planting activities reported in Table 2 are generated by the harvesting activities undertaken in the first decade and the planting of NSR and timber lease reversions.



**Incremental
silviculture**

In decade 1, juvenile spacing is scheduled for SAU02 (Fd leading, SI=27), followed by an initial fertilization, under all management objectives. For the clear wood objective and preferred management scenario, these stands are also pruned.

The revised preferred management scenario, driven by a financial objective (S10 Max NPV), implements the same incremental silviculture activities as S10, but also implements some of the new regimes for managing natural stands described in section 1. Existing natural and managed stands are fertilized, and some natural stands are spaced.

Juvenile spacing is also indicated for the hemlock/balsam analysis units. Under the preferred management scenario, SAU06 with pre-spacing densities of 3000 sph are thinned to 675 sph. SAU07 with densities of at 5000 sph are thinned to 800 sph for all management objectives except the preferred management scenario.

The results of the analysis with respect to juvenile spacing of the hemlock/balsam analysis units were queried in reviews of earlier drafts of this report.⁴ In particular, the response of low site hemlock/balsam ($14 < SI \leq 23$) to juvenile spacing appears anomalous, and the response of the higher site hemlock/balsam ($SI > 23$) to fertilization is not substantiated in the literature.

The yield curve for the juvenile-spaced low site hemlock/balsam was corrected prior to analyzing the Preferred Management Scenario (S10). As noted above, no SAU07 (medium site hemlock/balsam) was juvenile spaced under S10.

The correction of the yield curve and subsequent elimination of juvenile spacing of SAU07 reduced the total area of incremental silviculture from 19,350 ha per decade (S04, unlimited funding) to 1,514 ha per decade (S10).

However, driving the preferred management scenario S10 with a financial objective (S10 Max NPV) brought juvenile spacing of SAU07 back into the decade 1 plan, with 11,090 ha of high density stands (5000 sph) spaced to 800 sph.

**Commercial
thinning**

Commercial thinning activities occur for SAU01 and under the management objectives of maximizing volume production and maximizing large dimensions logs.

⁴ Craig Wickland. Comments on second draft. April 30, 2002

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Table 2. Tactical Plan - area treated by silviculture activity for each management objective in decade 1.

Silvicultural Activity	Decade 1				S10 Max NPV ha
	S04 ha	S06 ha	S09e ha	S10 ha	
SAU01: Fd, ITG=1-8, WSI=31					
Plant 1200 sph	-	-	6	-	
Plant 1600 sph	1,639	1,635	1,631	1,635	1,635
CT (Existing managed, Plant 1200 sph, JS to 750 sph, Fe) ^{1,2}	116	290	-	1,468	597
CT (Existing managed, Plant 1200 sph, JS to 750 sph)	542	645	1	-	
SAU02: Fd, ITG=1-8, WSI=26.8					
Plant 1200 sph	-	-	-	-	
Plant 1600 sph	1,222	1,293	1,294	1,315	1,301
Fe (Existing managed, Plant 1200)					2,936
Fe (natural)					738
JS (Natural) to 750 sph					302
JS (Plant 1600 sph) to 725 sph, Fe	1,009	1,009	1		1
JS (Plant 1600 sph) to 725 sph, Pr, Fe	-	-	1,007	1,009	1,008
SAU03: Fd, ITG=1-8, WSI=23.4					
Plant 1200 sph	-	1	-	-	
Plant 1600 sph	1,448	1,354	1,355	1,331	1,346
CT (Existing managed, Plant 1600 sph, JS to 750 sph, Pr)	10	10	-	-	
SAU04: Fd, ITG=1-8, WSI=18.9					
Plant 1200 sph	241	474	166	487	487
Plant 5000 sph	246	13	322	-	
SAU05: Fd, ITG=1-8, WSI=15.7					
Plant 1200 sph	67	67	67	67	67
SAU06: HwBa, ITG 12-20, WSI=27.4					
Plant 3000 sph	866	866	886	1,064	883
JS (Plant 3000 sph) to 675	5	-	-	505	
SAU07: HwBa, ITG 12-20, WSI=18.9					
Plant 1200 sph	-	246	547	7	
Plant 5000 sph	13,215	12,968	12,684	13,208	13,216
JS (Plant 5000 sph) to 800 sph	18,335	18,333	18,308	-	11,090
SAU08: Cw, ITG 9-11, WSI=22.8					
Plant 1200 sph	960	944	1,227	907	994
SAU09: Cw, ITG 9-11, WSI=15.3					
Plant 1200 sph	2,636	2,663	2,331	2,722	2,662
SAU10: SPI, ITG 21-32, WSI=14.49					
Plant 1200 sph	137	137	157	137	137
SAU11: HwBa, ITG 12-20, WSI=11.63					
Plant 1200 sph	14,691	14,685	14,708	14,685	14,685
SAU12: Deciduous, ITG 37-39, All SI					
Plant to SAU01 1200 sph	488	487	1,333	16	810
Plant to natural existing	163	162	444	5	571
Total area planted	38,019	37,995	39,158	37,583	38,794
Total area incremental silviculture	19,350	19,342	19,316	1,514	12,099
Total area commercially thinned	667	945	1	1,468	597

Notes:

- 1 The activity "CT (Existing managed, Plant 1200 sph, JS to 750 sph, Fe)" means "commercially thin stands which are presently existing on the land base, and are managed stands, i.e., were planted to 1200 sph, juvenile spaced to 750 sph, and fertilized according to a specified schedule."
- 2 The commercial thinning regime specifies fertilization 1 year following the cut. Therefore, the commercial thinning activity specified implies that 147 ha per year will be commercially thinned and, one year subsequent, fertilized during the first decade.

