TFL 3
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 Slocan Forest Products Ltd. (SFP) for implementation on TFL 3. The objective of the project is to provide strategic direction to the SFP planning staff in the design of their silviculture program.

Benefits are evaluated against the MP9 base case

A silvicultural planning model was developed using the Woodstock (Remsoft, 1997) modeling language that is consistent with the current timber supply model and base case for the TFL (Management Plan 9, 1998), 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 the TFL (July 1998), are the basis of the silviculture planning model implemented for this study. Using the MP 9 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.

Forest-level Objectives

Three alternate forest-level management objectives guided the development of the silviculture strategy:

- maximize harvest volume without regard to product mix
- satisfy, as closely as possible, a product mix profile, and maintain the maximum harvest level
- satisfy, as closely as possible, a product mix profile, and reduce the harvest level

17% increase in LTHL

Table S-1 lists the impacts on the long-term harvest level (LTHL) of five scenarios that incorporate increasing intensification of silviculture. These scenarios were driven by the first management objective, maximization of harvest volume. Although the total impact on LTHL of the silvicultural inputs (including treatment of backlog) is 17%, most of the increase is attributable to the genetic gain of select stock. Regimes that include spacing, fertilization and commercial thinning account for less than 1%.

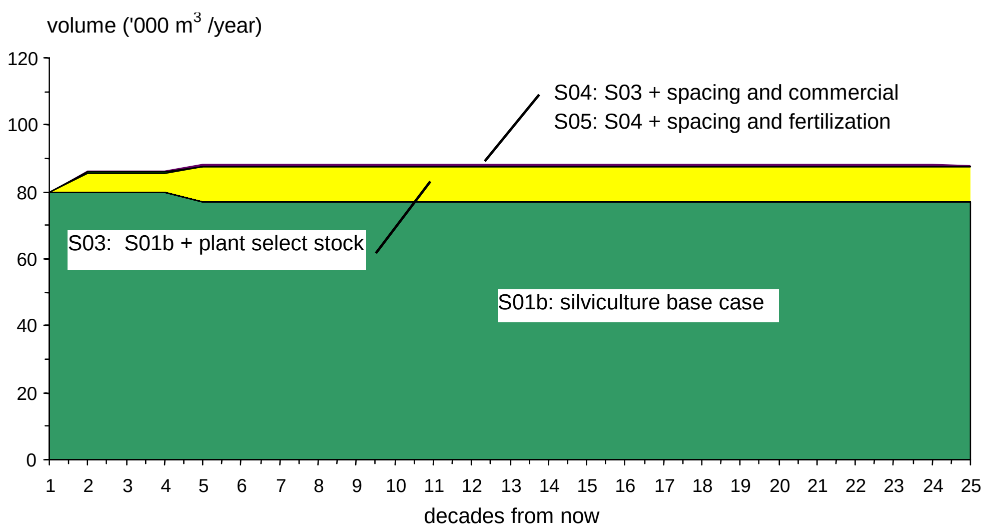
Table S-1. Timber supply (volume) benefit from incremental silviculture.

Scenario	Scenario Description	Benefit (LTHL)[1]
S01b	Silviculture base case	76 951 m^3
S02	S01b + no treatment of backlog	-2.4%
S03	S01b + plant select stock	+13.7%
S04	S03 + commercial thinning	+0.2%
S05	S04 + spacing and fertilization	0.6%
	Total timber supply benefit (LTHL)	17%

[1]All benefits are expressed as percentages of the silvicultural base case LTHL

Figure S-1 shows the impact of intensification of management on the timber supply schedule. Note that the benefits are available as early as decade 2, due to the substitution of managed stands for rationed mature natural stands in the harvest queue, and the release of these mature stands for earlier harvesting.

Figure S-1. Impact of planting select stock, commercial thinning, spacing and fertilization on the forecast harvest, TFL 3.



Regular sawlogs double to 57%

When the scenarios are evaluated with the management objective of satisfying the product mix profile and maintaining the maximum harvest levels, regular sawlogs increase from 28% of the harvest to 57%. Further improvement in the product profile of the harvest can be attained only if the harvest level is reduced, allowing longer rotations.

Table S-2. Product mix achieved with incremental silviculture and reduced harvest levels.

Product	Target	Base Case	Incremental Silviculture	Incremental Silviculture/ Reduced Harvest
LTHL m^3/year		76 951	86 263	47 390
Clear sawlogs %	15	0	2	4
Cedar Poles %	5	3	5	5
Peelers %	10	0	0.1	0.4
White Pine %	5	0	3	5
Regular Sawlogs %	65	28	57	65
Small Logs%	0	69	33	21

Strategy Summary

Under the management objective of maximizing volume production, regimes are selected that allow harvesting of younger stands through spacing, or spacing prior to fertilization. However, when the management objective includes the product mix profile, the emphasis shifts to regimes that include planting Pw; spacing is employed to improve dimension and as part of regimes that include pruning. Fertilization is reduced.

Under the product mix management objective, commercial thinning helps maintain harvest levels while allowing the residual stand to be held long enough to develop the dimensional characteristics of the desired product profile.

Finally, planting rates are highest when the management objective is to maximize volume without regard to product mix and decrease when meeting the product profile is included in the objectives. This is due to the lengthening of rotations in order to attain the dimension and clear wood requirements of the product profile.

In general, the strategy is limited in its ability to meet the timber quantity and product mix objectives by the restricted scope of the silvicultural regimes provided to the analysis, and by the constraints specified on the operability of various silvicultural activities.

Tactical Plan

Planting and spacing activities in the first decade that are consistent with the strategic plan are identified in the report.

Limitations

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.

This study quantifies the change in productive capacity of TFL 3 with intensification of management and alternative management objectives. It does not specify which management objectives should be pursued, and therefore does not prescribe a desirable intensity of forest management.

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.

Table of Contents

Summary......iii
Table of Contents vii
List of Figures viii
List of Tables ix

1.0 Introduction......1

2.0 Data and Management Assumptions 3

2.1 The TSR2 Landbase...... 3
2.2 Silviculture Analysis Units...... 3
2.3 Silvicultural State of the Landbase...... 4
2.4 Management Practices...... 5
2.5 Select Stock and Genetic Gain......6

3.0 Analysis Results......7

3.1 Base Case 7
3.2 Management for Timber Quantity 14
3.3 Management for a Product Profile......20

4.0 Silviculture Strategy......27

4.1 Strategic Plan...... 27
4.2 Tactical Plan 31

5.0 Limitations of the Study 33

Appendix A — Silvicultural State of TFL 3

Appendix B — Regime Diagrams

Appendix C — Genetic Gain

Appendix D — Analysis Method

Appendix E — Yield Tables

List of Figures

Figure 3-1 Base case harvest forecasts. 8
Figure 3-2 Composition by leading species of forecast harvest, silviculture base case 8
Figure 3-3 Composition by existing natural and managed stands of forecast harvest, silviculture base case 8
Figure 3-4 Composition by product of forecast harvest of managed stands, silviculture base case. 10
Figure 3-5 Composition by diameter limit (dbh) of forecast harvest of managed stands, silviculture base case 10
Figure 3-6 Total area and volume per unit area of the forecast harvest, silviculture base case 10
Figure 3-7 Total and operable growing stock forecast, silviculture base case 12
Figure 3-8 Aggregate silvicultural state forecast, silviculture base case 12
Figure 3-9 Forecast age distribution of operable area for total inventory, silviculture base case. 13
Figure 3-10 Contribution of planting select stock, commercial thinning, spacing and fertilization on the forecast harvest. 15
Figure 3-11 Total and operable growing stock forecasts with intensification of management 15
Figure 3-12 Composition of forecast harvest by existing natural and managed stands, maximum harvest volume scenario (S05) 15
Figure 3-13 Total area and volume per unit area of the forecast harvest, maximum harvest volume scenario (S05) 17
Figure 3-14 Composition by diameter limit (dbh) of forecast harvest of managed stands, maximum harvest volume scenario (S05) 17
Figure 3-15 Composition by product of forecast harvest of managed stands, maximum harvest volume scenario (S05) 17
Figure 3-16 Treatment area forecast, maximum harvest volume scenario (S05). 19
Figure 3-17 Treatment cost forecast, maximum harvest volume scenario (S05) 19
Figure 3-18 Silviculture direct employment forecast, maximum harvest volume scenario (S05) 19
Figure 3-19 Harvest forecasts corresponding to product mix targets 22
Figure 3-20 Average age of harvested stands 22
Figure 3-21 Total area and volume per unit area of the forecast harvest, product profile scenario (S08), with harvest levels varied 24
Figure 3-22 Composition by diameter limit (dbh) of forecast harvest, product profile scenario (S08), with harvest levels varied 25
Figure 3-23 Composition by product of forecast harvest, product profile scenario (S08), with harvest levels varied 26

List of Tables

Table 2-1 Timber harvesting land base 3
Table 2-2 Definition of the silvicultural analysis units 4
Table 2-3 Harvest profile (% volume harvested) in first decade 5
Table 2-4 Cost and labour assumptions for silviculture treatments 6
Table 2-5 Genetic gain assumptions for the TFL 3 6
Table 3-1 Distribution of harvest by diameter limit in base case (S01b) and maximum volume scenario (S05) 16
Table 3-2 Components (products and diameter limits) of the harvest achieved at alternative harvest levels 21
Table 4-1 Strategic plan– area managed by each silviculture regime for three management objectives, decades 1-25 .... 28/29
Table 4-2 Tactical plan– area treated by silviculture activity for each management objective in decade 1 29

1.0 Introduction

This report documents a forest-level modeling study that examines the implications of silviculture regime options proposed by the Slocan Forest Products Ltd. (SFP) for implementation on TFL 3. The objective of the project is to provide strategic direction to the SFP planning staff in the design of a silviculture program.

A silvicultural planning model was developed that is consistent with the current TSR[1] model and management plan for the TFL[2]; 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;
- it 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;
- it ensures that the silvicultural planning model is based on the timber supply assumptions for the TFL that the Chief Forester considered (or will consider) in setting the AAC for that TFL[3].

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 Slocan Silviculture Planning Model (SSPM).

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

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[1] Stirling Wood Group Inc., Slocan Forest Products Ltd., TFL 3 Timber Supply Analysis, March 1998.
[2] Slocan Forest Products Ltd. TFL 3 Management Plan 9, May 1998.
[3] Tree Farm Licence 3 (Issued to Slocan Forest Products), Rationale for AAC Determination July 1, 1998.

the long-term silviculture strategy for the TFL-- the regimes selected to achieve the forest-level objectives—and the silvicultural activities that are feasible in the first decade.

The validity of this study depends substantially on the accuracy of the managed-stand yield tables, the representation of TFL's silvicultural history in the modeled landbase, and the specification and modelling of the silvicultural regimes. These limitations 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 for 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 The TSR2 Landbase

The data set provided to the project team by Slocan Forest Products Ltd. comprised of 27 971 ha forested area (Table 2-1). All of this area (including backlog and appraisal NSR) has been categorized as the timber harvesting land base (THLB). THLB areas contribute to old growth and green-up forest cover objectives.

Table 2-1. TFL 3 analysis area.

Classification	MP 9
Current THLB	27 063
NSR	908
Total	27 971

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 SSPM, 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 4.1% from harvested existing stands greater than 40 years.

2.2 Silviculture Analysis Units

The 27 analysis units defined for TSR2 were aggregated by SFP planning staff into 8 silviculture analysis units (SAUs) deemed appropriate for the silviculture regimes contemplated for the TFL (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.

Table 2-2. Definition of the silvicultural analysis units

SAU #[1]	Composition	ITG	SI Breaks	BEC Zone	Elevation	Area (ha)	Weighted SI[4]
1	S, B	18-26	any	ICH	any	2 172	18.4
2	S, B	18-26	any[2]	ESSF	any[3]	5 350	14.8
3	C, H	9-17	>=20	ICH, ESSF	Any	3 097	20.6
4	C, H	9-17	<20	ICH, ESSF	Any	2 586	17
5	Fdi	1-8, 27-34	>20	ICH, ESSF	Any	5 709	22.2
6	Fdi	1-8, 27-34	15<SI<=20	ICH, ESSF	Any	6 366	18
7	Fdi	1-8, 27-34	<=15	ICH, ESSF	Any	690	13.8
8	S, B	18-26	>=16	ESSF	< 1700	2 003	20
	Total					27 971	

Notes
1. SAUs for this study were defined with the assistance of Pat Cutts and Kathy Howard, Slocan Forest Products Ltd.
2. Any SI for Elevation > 1700 m and SI <= 15 for Elevation < 1700 m
3. SI <= 15 Elevation < 1700 m, Elevation > 1700 m
4. Mean site indices are the area-weighted average site indices of the TSR2 analysis units.

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) the forest stands was developed from the Slocan Forest Products Ltd. Phoenix data bases and is described in Appendix A.

2.4 Management Practices

Harvesting operability responds to silviculture

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

In addition to the harvesting methods included in the TSR analysis (clearcutting–conventional), this study explicitly models commercial thinning. The development of stands after 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 SFP. The SFP planning staff also specified three ages of entry.

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 harvest data based on the 1997-2001 forest development plan.

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

SAU	% Total Harvest Volume Harvest profile
1	5
2	24.3
3	20.2
4	5.2
5	28.2
6	7.5
7	0
8	9.6
	100%

Source: TFL 3 MP 9 Information Package, March 1998, p. 53.

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 SFP 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.

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) were modeled utilizing Batch VDYP. The yield tables for each SAU are included in Appendix E. The TFL has defined more than one species groupings for some SAU's. For example SAU3 plants Fd40Lw30Pl10Cw20 (species group 1) to 1200 sph, as well as Fd40Pw30Lw30 (species group 2) to 1200 sph. This report will refer of the various planting regimes by SAU as species group 1 and species group 2.

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	850	2
space	1133	0.28
prune	720	0.16
fert	142	2

Source: Slocan Forest Products Ltd. TFL 3 Silviculture Strategy, March 2000.

2.5 Select Stock and Genetic Gain

The benefits from planting select stock in TFL 3 are evaluated in this study. The genetic gains for TFL 3 species are listed in Table 2.5 and the source and calculation of these gains for each silvicultural analysis unit (SAU) is detailed in Appendix C.

Table 2-5. Genetic gain assumptions for TFL 3.

SAU	Species	Date of availability	Elevation	% Elevation by species	Species % gain
Sx	NE	1995	1000-1500	59	15
Sx	NE	1995	>1500	41	18
Lw	NE	2000	<1300	100	7
Fdi	NE	2003	<1000	100	26
Fdi	NE	2003	>1000	0	22
Pli	NE	2000	<1400	100	7
Pw	NE	2010	no data	no data	no data

Source: Patt Cutts, Slocan Forest Product Ltd.

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 TFL'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. It traces the TSR2 harvest schedule from the initial harvest level (AAC, July 1998), along a even-flow harvest level from decades 1 to 4. In decade 5 the harvest level drops 1.2%. The S01a schedule maintains this level (79 120 m^3 per year) through to the planning horizon.

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 follows the TSR2 schedule through decade 4. The decade 5 harvest level is 3.7% below the TSR2 harvest level. The harvest level of 76 951 m^3 per year is maintained 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 or due to a more accurate representation of current silvicultural practices.

Schedule S01b, based on the silvicultural history landbase, forecasts a harvest level 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. In order to account for current silviculture history records, natural stands are converted to existing managed

Figure 3-1. Base case harvest forecasts.

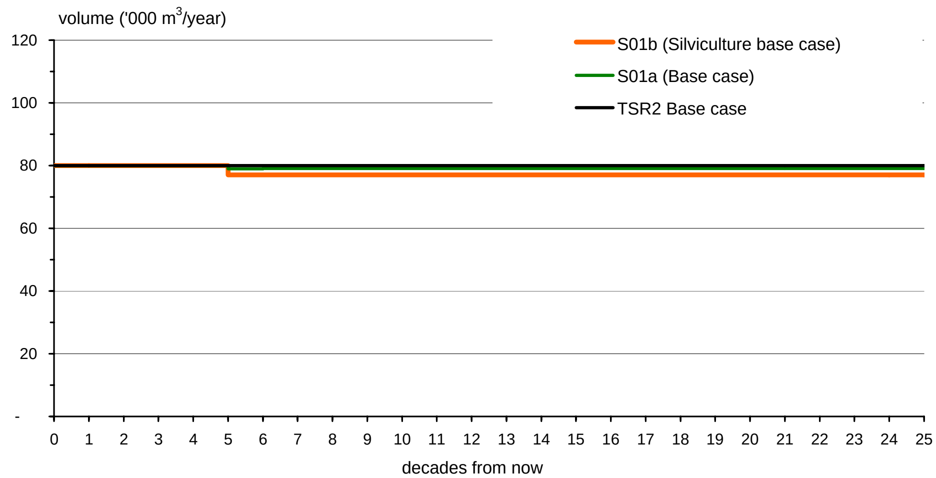


Figure 3-2. Composition by leading species of forecast harvest, silviculture base case (S01b).

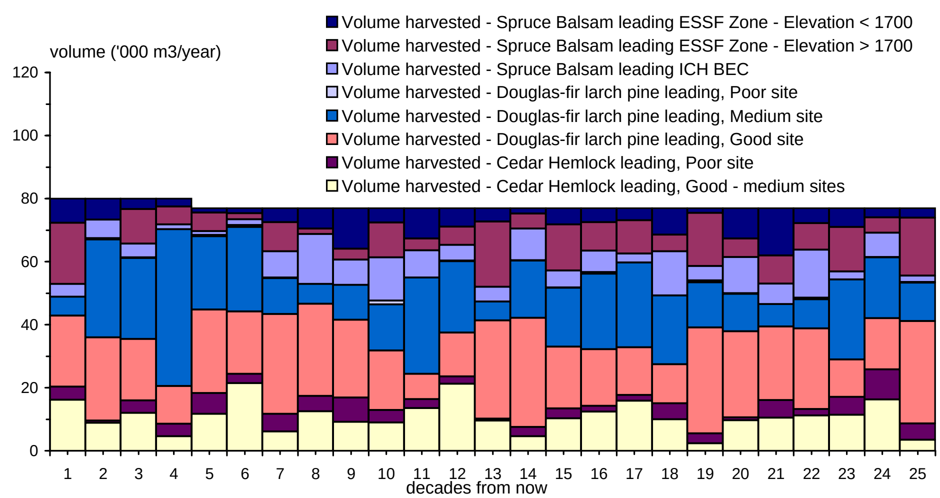
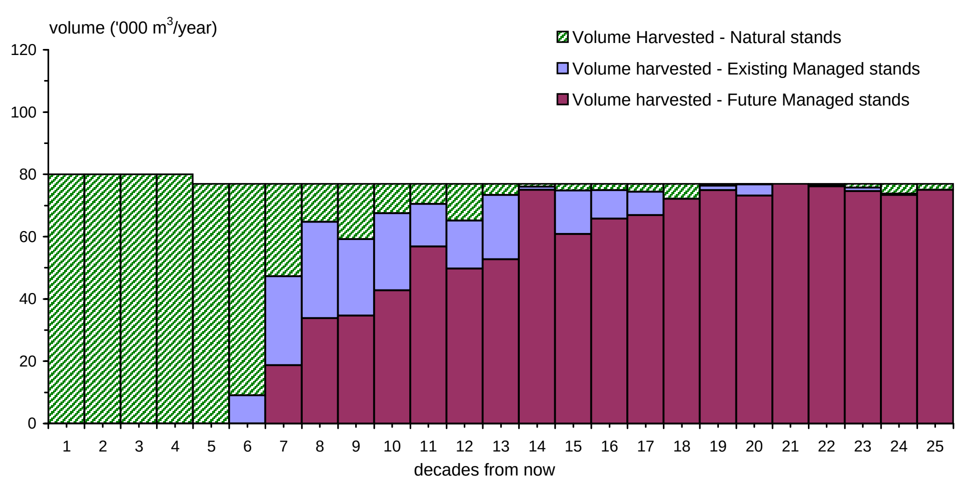


Figure 3-3. Composition by existing natural and managed stands of forecast harvest, silviculture base case (S01b).



stands. The process to allocated the current silviculture records is outlined in Appendix A. The S01b harvest cannot increase in the long-term 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 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

Figure 3-2 shows the composition of the base case harvest by leading species. The mix of species harvested in decade 1 is controlled by the harvest profile specified by MP 9 (section 2.4) but the species mix in subsequent decades is determined by the model.

Figure 3-3

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 entirely of existing stands until decade 6, and the transition to managed stand is not largely complete until decade 14.

Response framework

The end of the transition to managed stands (decade 14) 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 composition of the forecast harvest of managed stands by log category and log diameter limit are plotted in Figures 3-4 and 3-5, respectively. In both figures the harvest from natural stands is not differentiated by category or diameter due to limitations of the yield tables.

In the long term (decades 15-25), the forecast harvest is composed of 67% small logs (17.5-30.0 cm), 27% regular sawlogs (30+ cm), and 3% cedar poles.[4] The remainder of the harvest is logs from natural existing stands.

With respect to diameter limit (dbh), the long term forecast harvest is 22% logs 17.5-22.4 cm, 49% logs 22.5-32.4 cm, 20% logs 32.5-42.4 cm, 6% logs 43-52.4 cm, and 1% logs 52.5+ cm. The remainder of the harvest is logs from natural existing stands and is not categorized by size.

Note that the quadratic mean diameter (dbh) of the harvested managed stands, plotted against the right-hand axis on Figure 3-5, remains relatively constant — between 20-25 cm — out to the planning horizon.

Figure 3-6

Figure 3-6 plots the area harvested on the left-hand axis, and the harvest volume per hectare on the right-hand axis. The trend in volume per hectare is positive over the first 6 decades. The trend in volume per hectare becomes erratic, increasing when harvest is concentrated in existing stands, and decreasing when harvest is from managed stands. Note that there is no commercial thinning in the base case.

[4] All log diameters are top diameters.

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

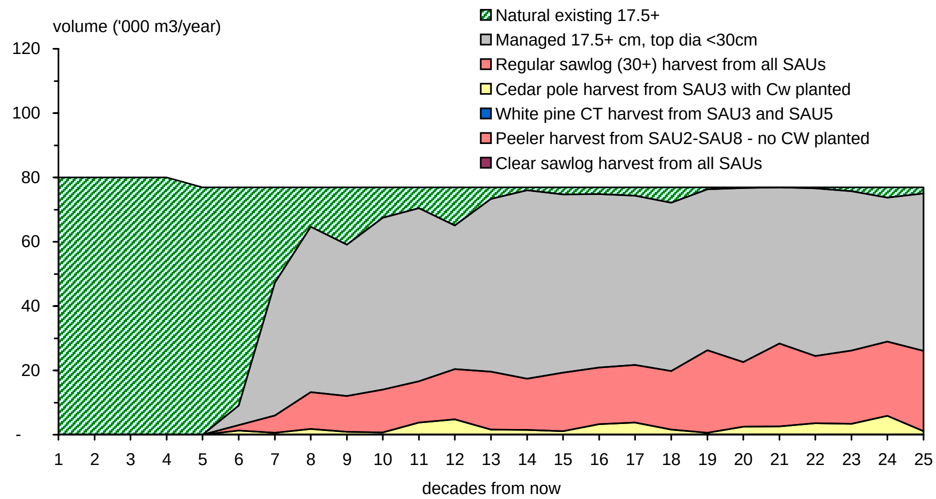


Figure 3-5. Composition by diameter limit (dbh) of forecast harvest of managed stands, silviculture base case (S01b).

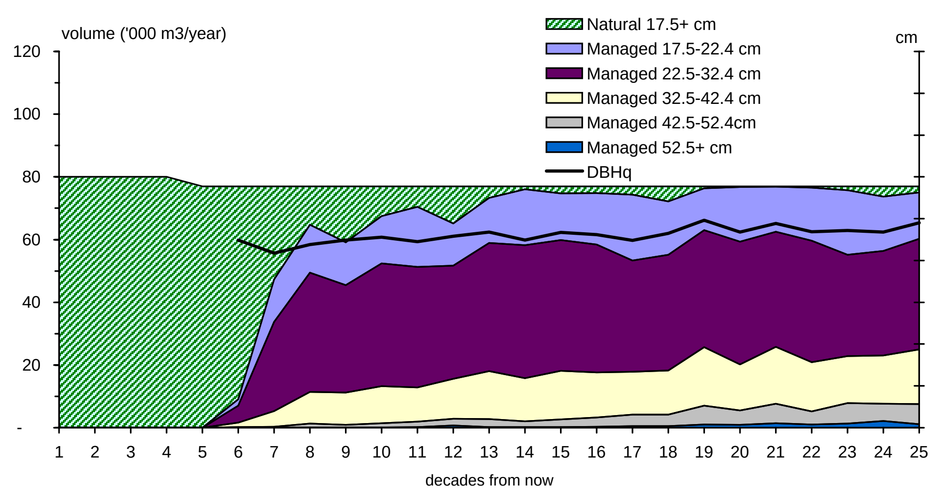
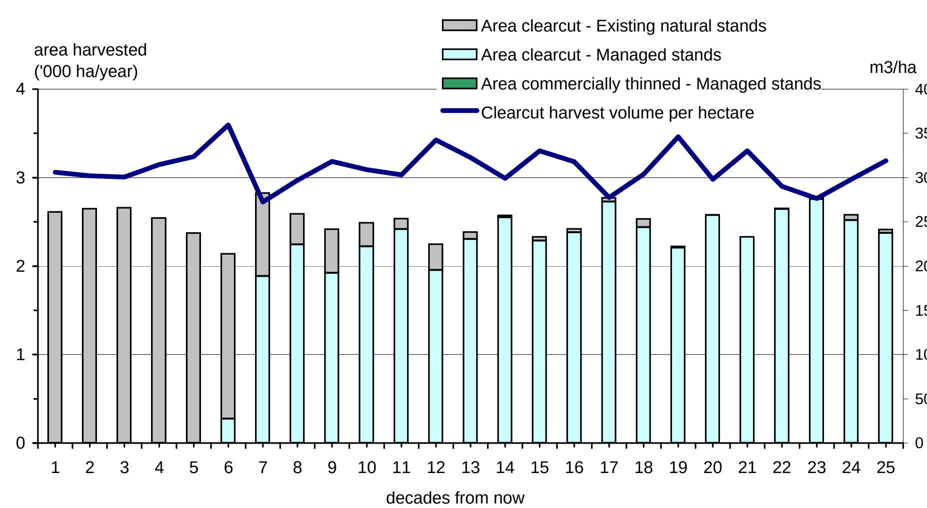


Figure 3-6. Total area and volume per unit area of the forecast harvest, silviculture base case (S01b).



Changes in the Silvicultural State of the Base Case

Figure 3-7
Stable inventory measures indicates sustainable LTHL

Figure 3-7 plots the total and operable growing stock over the planning horizon. The total growing stock declines from its initial level, before rising back and maintaining the initial level of growing stock out to the planning horizon. The operable growing stock follows a similar path, declining through the transition to managed stands and recovering in the long term (decades 15-25). The stability of these inventory measures strongly indicates that the long-term harvest level (LTHL) is sustainable.

Figure 3-8
Some poor site fir and spruce is not harvested

Figure 3-8 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 18 319 ha natural existing stands, and 9 517 ha of existing and future (created by the model) managed stands. The areas of natural stands and existing managed stands are steadily reduced as the harvesting and regeneration convert them to future managed stands. Note that at the end of decade 25 there remains approximately 3 292 ha of natural stands that have not been harvested. These natural stands are predominantly poor site fir and spruce / 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 (150 m3 / ha for SAU 1 to 8) again for a long period of time (approximately 50 years for SAU 5, 60 years for SAU 1, 3, 8, 80 years for SAU 2, 4 and 100 years for SAU 7). 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 3-9
THLB age class distribution

Table 3-9 shows the progression of the age class distribution of operable timber on the TFL over the planning horizon. Age class 400 includes all stands 400 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 or poor site spruce.

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

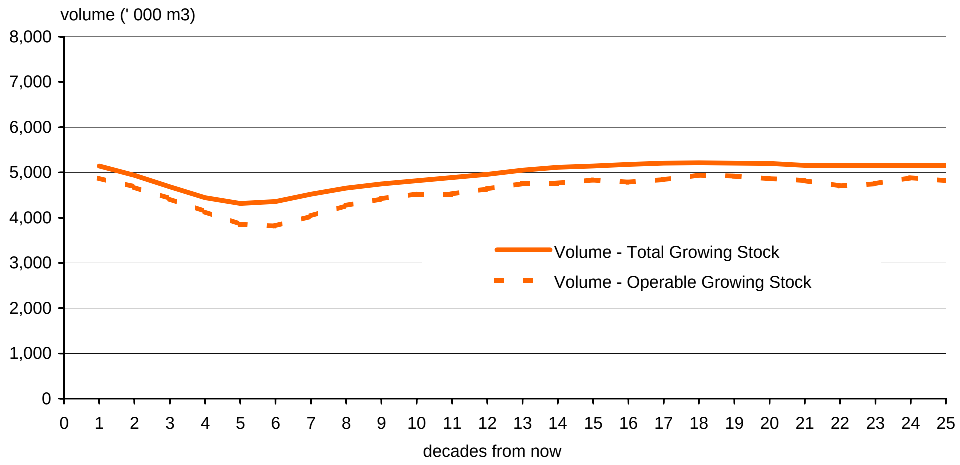


Figure 3-8. Aggregate silviculture state area forecast, silviculture base case (S01b).

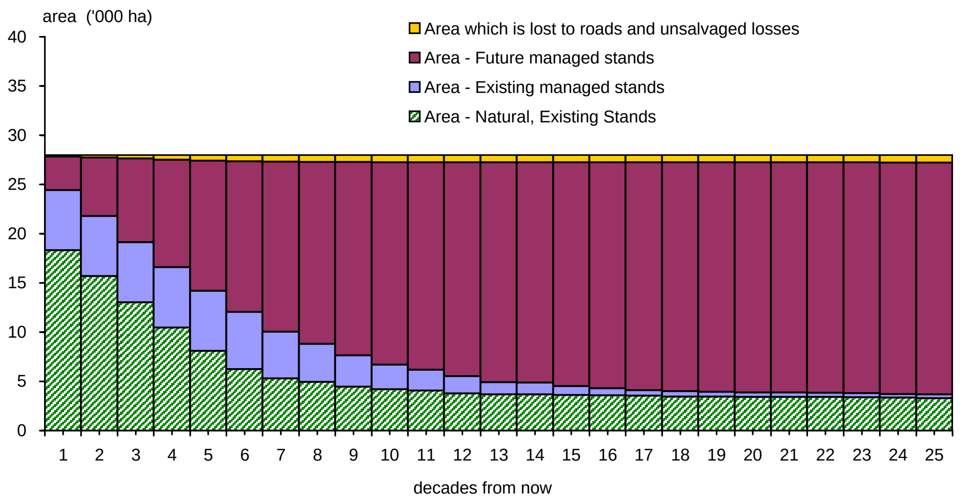
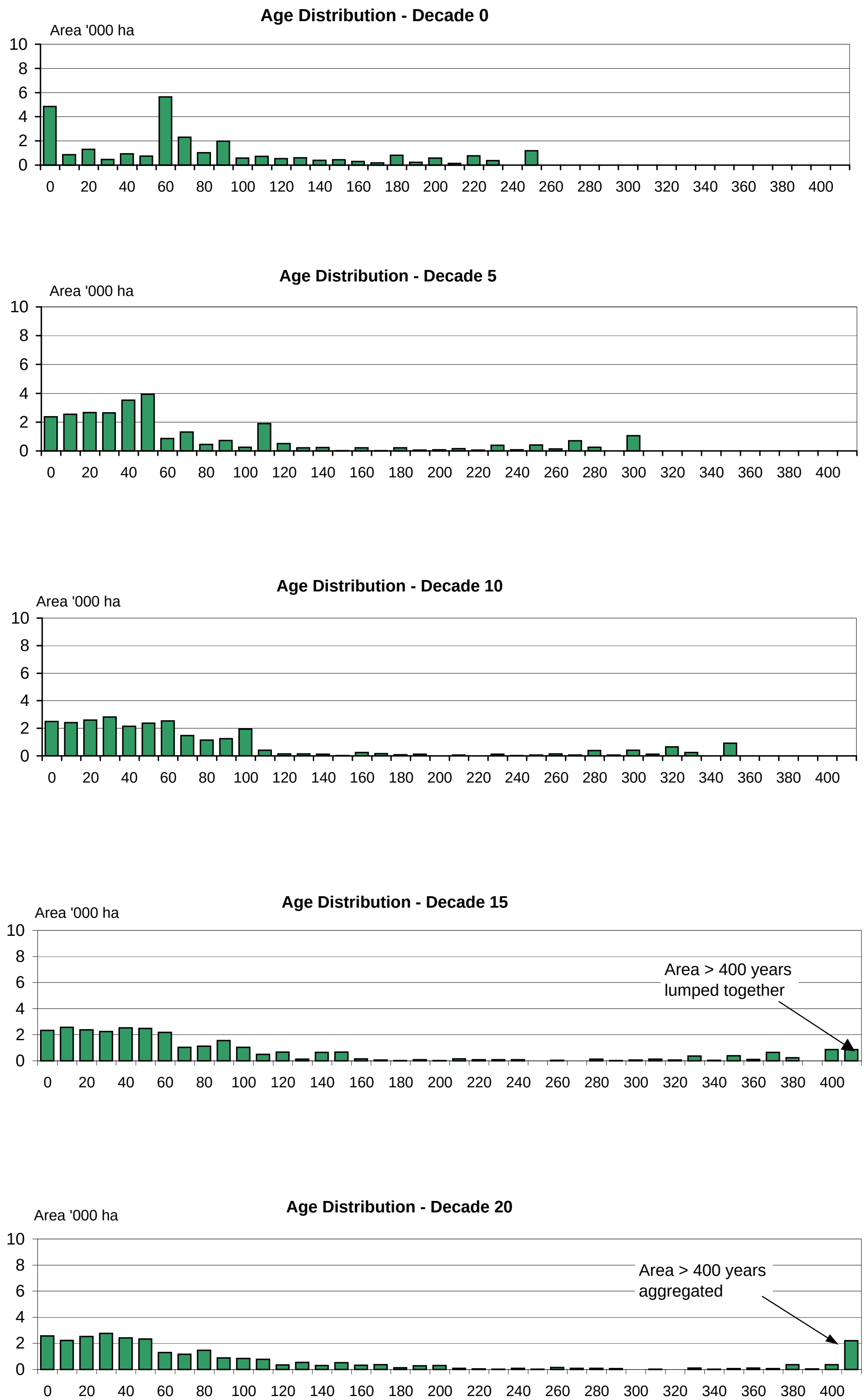


Figure 3-9. Forecast age distribution of operable area for total inventory, silviculture base case (S01b).



3.2 Management for Timber Quantity

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

Incorporating the management regimes requires two 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, pruning and fertilization. Second, harvesting is expanded to include commercial thinning.

Select Stock, Commercial Thinning and Intensive Silviculture Scenarios

Figure 3-10

Figure 3-10 shows the impact of excluding backlog NSR (S02) and the incremental benefits from planting select stock (S03), commercial thinning (S04) and spacing and fertilization (S05). These scenarios were implemented with the management objective of maximizing the quantity of timber harvested, and assumed an unlimited silviculture budget.

S02 Backlog

Excluding backlog NSR from the THLB (i.e., not treating it) reduces the harvest level below the silviculture base case by 2.4% from decade 6 out to the planning horizon. [5]

S03 Select stock

The volume benefits from planting select stock are first apparent in decade 2 (7% increment), due to the effect of releasing for harvest in decades 2, current mature stands that were rationed for later harvest under S01b (Figure 3-10). The harvest level achieved in decade 2 can be sustained out to decade 25, providing an increment in the LTHL over S01b of 13.7%.

S04 Commercial thinning

Commercial thinning regimes, including the juvenile spacing activities intrinsic to those regimes, increases the harvest in decades 2-25 by 0.2%.

In accordance with the model's schedule of priorities, commercial thinning is used to bring harvest forward substitute for rationed mature stands. In the long term, the increment from commercial thinning may be due to loosening up the harvest queue and allowing stands to be harvested closer to their culmination ages.

S05 Spacing and fertilization

Implementing spacing and fertilization regimes, in addition to select stock and commercial thinning regimes, returns a further increment of 0.6% in decades 2 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 14.5%, beginning in decade 2. If the increment due to planting NSR is included, the total increment increases to 17%. This scenario (S05) will be subsequently referred to as the maximum harvest volume scenario.

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

Figure 3-10. Contribution of planting select stock, commercial thinning, spacing and fertilization on the forecast harvest.

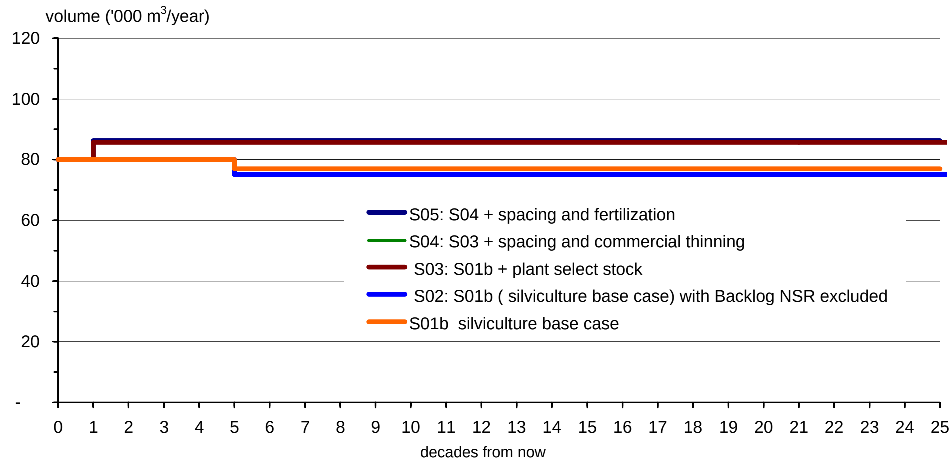


Figure 3-11. Total and operable growing stock forecasts with intensification of management.

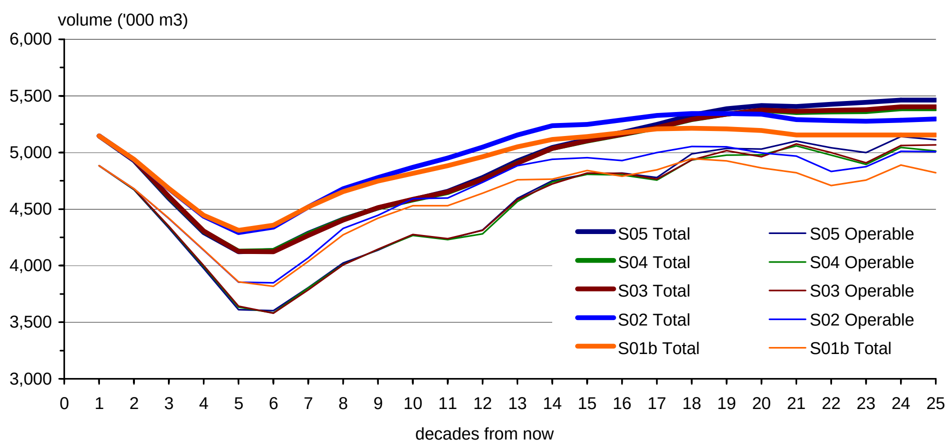


Figure 3-12. Composition of forecast harvest by existing natural and managed stands, maximum harvest volume scenario (S05).

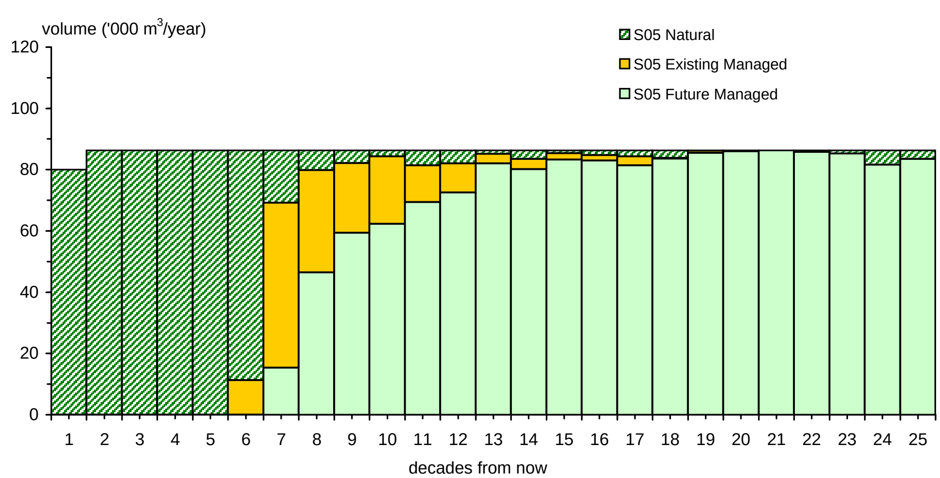


Figure 3-11
Growing stock

Figure 3-11 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 and the scenarios that include spacing and fertilization regimes lift inventory levels higher. Commercial thinning has little effect on growing stock, except to reduce operable growing stock in decades 13-16. 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 3-12
Transition to managed stands

Figure 3-12 shows the transition in the timber supply from natural stands to managed stands. Comparing this figure with the base case transition plotted in Figure 3-3, with the intensification of management, the transition is completed sooner (decade 13 versus decade 14). Also, continued management (especially fertilization) of existing managed stands has increased the yield from these stands, allowing the initial harvest even-flow harvest level to continue from period 2 to the end of the planning horizon.

Figure 3-13
Clearcut vs commercial thinning

Figure 3-13 compares the area harvested by clearcutting versus commercial thinning. Commercial thinning is low due to scarcity of elegible stands. Higher levels of commercial thinning in decades 21 to 25 allow the model to keep the even-flow harvest level in decades 11-13 before the end of the transition to dependence on managed stands.

Figure 3-14
Composition of harvest by diameter limit (dbh).

Figure 3-14 shows the composition of the harvest by diameter limit from managed stands in the long term (average, decades 14-25). Table 3-1 compares the harvest by diameter limit for the maximum harvest volume (HV) scenario (S05) and the silvicultural base case (S01b). The largest increment is in smallest diameter categories, i.e., stems with dbh exceeding 17.5 cm (the TSR lower limit) and less than 32.4 cm.

Table 3-1. Distribution of harvest by diameter limit in base case (S01b) and maximum volume scenario (S05).

Diameter Limit	Silviculture Base Case Harvest Level (S01b)		Max HV Scenario Harvest Level (S05)		Difference (S05-S01b)
	'000 m3/yr	%	'000 m3/yr	%	'000 m3/yr
Managed 17.5+ cm	75.3	98%	84.7	98%	9.43
Natural 17.5+ cm	1.7	2%	1.6	2%	-0.12
Managed 17.5-22.4 cm	16.8	22%	19.9	23%	3.06
Managed 22.5-32.4 cm	37.5	49%	45.1	52%	7.62
Managed 32.5-42.4 cm	15.5	20%	16.2	19%	0.64
Managed 42.5-52.4 cm	4.5	6%	3.0	4%	-1.44
Managed 52.5+ cm	0.9	1%	0.4	1%	-0.45

Figure 3-13. Total area and volume per unit area of the forecast harvest, maximum harvest volume scenario (S05).

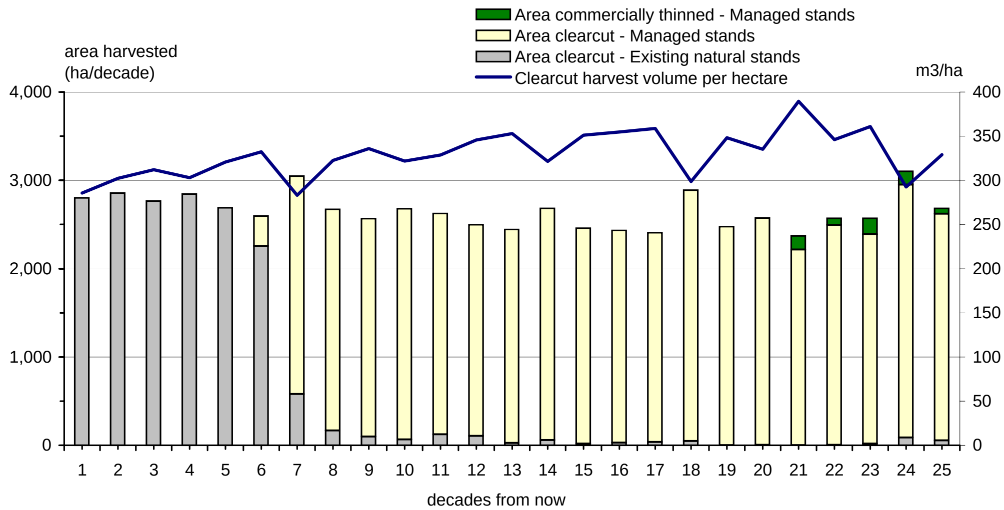


Figure 3-14. Composition by diameter limit (dbh) of the forecast harvest of managed stands, maximum harvest volume scenario (S05).

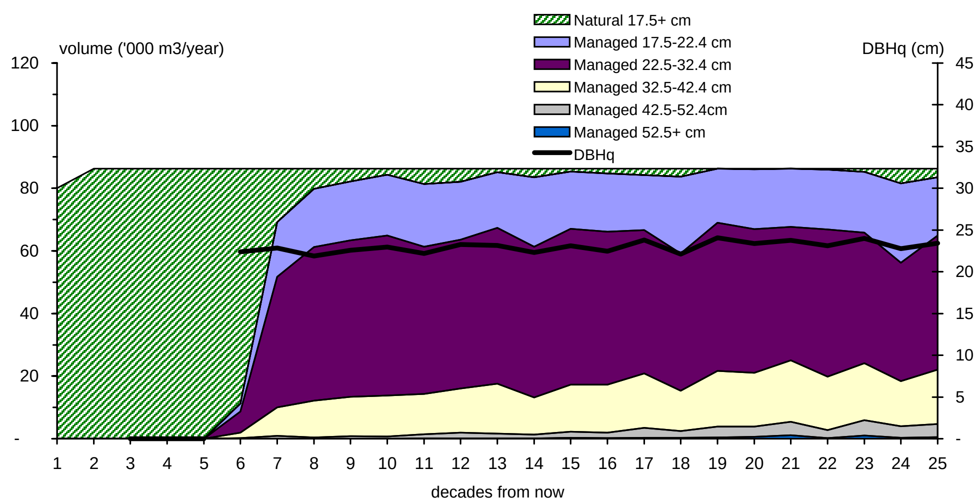


Figure 3-15. Composition by product of forecast harvest of managed stands, maximum harvest volume scenario (S05).

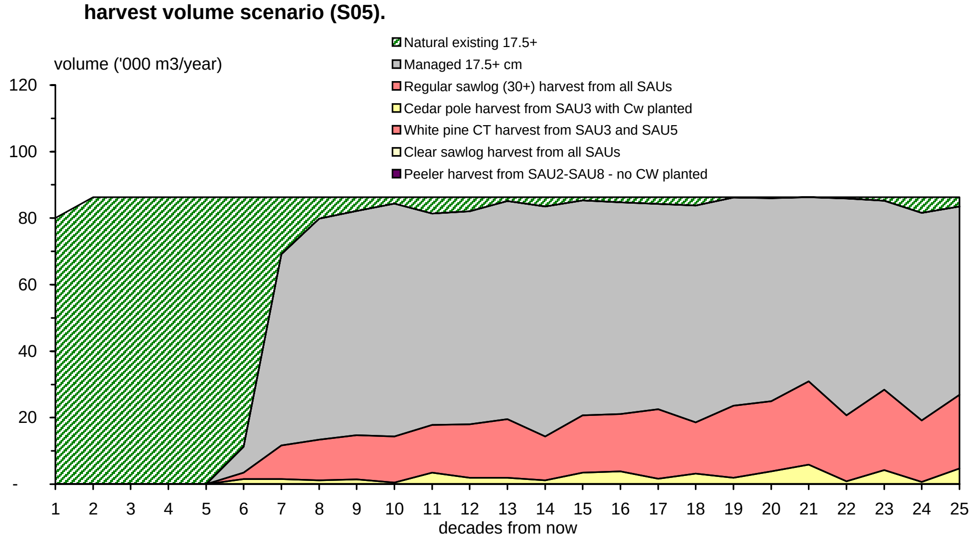


Figure 3-15
Composition of harvest by product mix.

Figure 3-15 shows the composition by product objective of the harvest from managed stands. Comparing this figure with the equivalent base case Figure 3-4, there is no discernable shift in product objective for the regimes implemented by the model. This result is not unexpected, given that the objective of this scenario was to maximize harvest volume.

Optimal Management for Maximizing Harvest Quantity

Figures 3-16, 3-17, and 3-18 plot the area by treatment, treatment costs, and direct silviculture employment benefits, respectively, for the maximize harvest volume scenario.

Figure 3-16
Treatment area

Figures 3-16 shows that the fertilization program more than doubles in size from 4 ha per year in decade 1 to an average of 23 ha per year in decades 2-25. The area juvenile spaced per year grows from 20 ha in decade 1 to an average of 43 ha per year in decades 2-25.

Figure 3-17
Treatment cost

Figure 3-18
Employment

The cost of spacing and fertilization (Figures 3-17) and the silviculture employment outputs of these programs (Figures 3-18) follow a similar pattern. The average cost of spacing and fertilization over the planning horizon is $50 564 per year.

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

Figure 3-16. Treatment area forecast, maximum intensive management scenario. harvest volume scenario (S05).

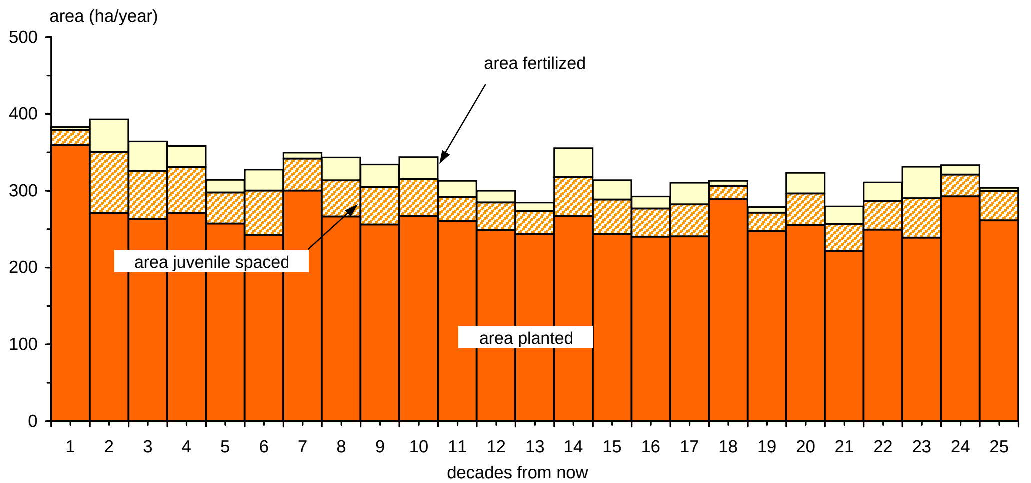


Figure 3-17. Treatment cost forecast, maximum harvest volume scenario (S05).

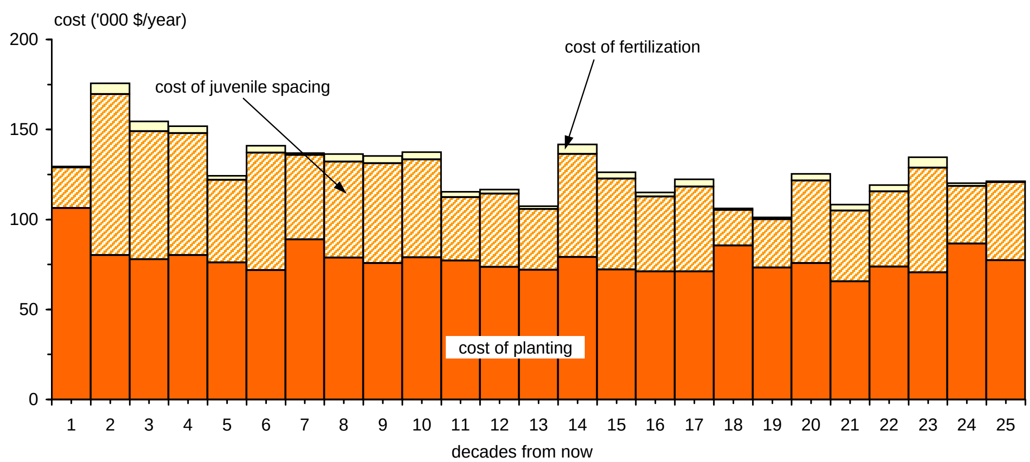
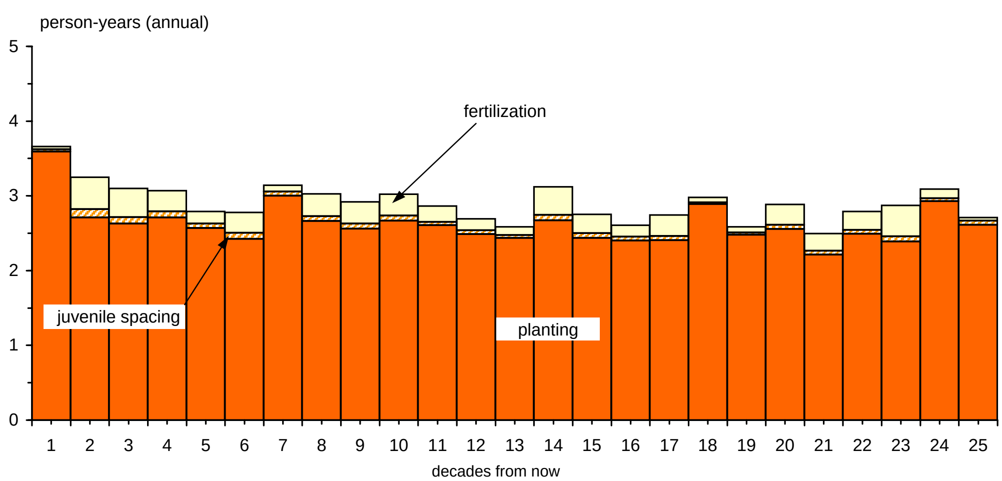


Figure 3-18. Silviculture direct employment forecast, maximum harvest volume scenario (S05)



3.3 Management for a Product Profile

This section presents the results of scenario S08, which implements silviculture treatments in order to satisfy, as closely as possible, a product mix profile. All silviculture treatments (including planting select stock) employed in S05 are eligible. Table 3-2 lists the products and the targets specified by SFP, and summarizes the extent to which each scenario is able to achieve the target profile.

S08a,b,c:
Differ by harvest level

In order to produce these products, and regardless of any intensification of silviculture, the model will increase harvesting ages, which in turn, will reduce long-term harvest levels. To model the trade-off between product mix and harvesting age, scenario S08 was evaluated with the harvest level constrained at three levels:

- S08a: ≥ the maximum volume production level (timber supply) achieved with unlimited silviculture (S05)
- S08b: ≥ the timber supply achieved in TSR2
- S08c: ≥ 60% of the maximum level (S05)

Before examining the product mix summary results in Table 3-2, it will be useful to consider the harvest levels and harvest ages achieved by the scenarios.

Figure 3-19
Trade-off between harvest and product mix objectives

Figure 3-19 shows the harvest forecasts for S08a, S08b and S08c, with S01b—the silviculture base case—included for reference. Note that the harvest levels plotted of S08a and S08b are coincident with S05 and the TSR2 harvest levels, respectively, but the scenarios were modeled with the objective of satisfying as closely as possible the target product mix. S08c declines at a rate of 10% per decade until it reaches the specified “floor” of 60% of the S05 harvest level.

Figure 3-20
Average harvest age

Figure 3-20 plots the average age of harvested stands (managed only) for S08a,b,c, S01b, and S05—the maximum volume scenario. Note that in the long term the scenarios with product mix objectives (S08a,b,c) have average harvesting ages 50-60 years older than the scenarios driven by the objective of maximizing volume (S01b, S05). The model is lengthening rotations in order to attain the dimension and clear wood requirements of the product target.

Table 3-2
Product mix objective percentages

Returning to Table 3-2, the components of the harvest in terms of products and diameter limits are listed for five scenarios. Scenario S01b—driven by the objective of maximizing volume but applying basic silviculture only—produces 3% cedar poles, 28% regular sawlogs and 69% small logs. Allowing unlimited incremental silviculture, planting select stock and maximizing harvest volume (scenario S05) increases the volume harvested per year (84 699 m^3 per year vs. 76 951 m^3 per year) but the main increment accrues to the small log product (62 058 m3 per year vs. 51 772 m3 per year), with a small increment in cedar poles (2948 m3 per year vs. 2529 m3 per year). In fact, the component of the harvest in regular sawlogs and peelers actually declines.

Scenario S08a
Shift to sawlogs

Scenario S08a maintains the harvest flow at the S05 level but is driven by the product mix objective. The harvest volume in small logs drops by 34 000 m^3 per year, with most of the volume shifting to regular sawlogs which more than double from 19 680 m^3 per year to 49 453 m^3 per year and comprise 57% of the total harvest volume. The target for regular sawlogs is 65%.

Table 3-2. Components (products and diameter limits) of the harvest achieved at alternative harvest levels.

		scenario:	Target	S01b		S05		S08a		S08b		S08c	
		harvest flow:	na	Base Case		Max Volume		Harvest ≥ S05		Harvest ≥ TSR2		Harvest ≥ 60% S05	
Products[1]	**SAUs**	**Description**	%	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%
Clear sawlogs	All	All, clear, top dia 30+ cm	**15**	-	-	-	-	1,501	2	1,555	2	1,924	4
Cedar poles	SAU 3 Fd40Lw30Pl10Cw20	Cw, 32.5=< top dia <= 57.5	**5**	2,529	3	2,948	3	4,313	5	4,000	5	2,362	5
Peelers	All except SAUs that plant Cw	Fd, Lw, Sx, Pl top dia 46+ cm	**10**	39	0	14	0	83	0.1	145	0.2	198	0.4
White pine	SAU3 Fd40Pw30Lw30, SAU5 Fd25Lw25Pw50	SAU03, SAU05, Species mix with Pw in it, CT product	**5**	-	-	-	-	2,857	3	2,710	3	2,235	5
Regular sawlog	All	All, top dia 30+ cm	**65**	20,927	28	19,680	23	49,453	57	49,748	62	30,705	65
Small logs	All	All, top dia 17.5-29.9 cm	**0**	51,772	69	62,058	73	28,056	33	21,841	27	9,815	21
Total harvest from managed stands				75,267	100	84,700	100	86,263	100	80,000	100	47,239	100
Harvest from unmanaged stands				1,684		1,563		-		-		-	
Total harvest (LTHL)				76,951		86,263		86,263		80,000		47,239	
		Diameter limits (cm)											
		17.5-22.4 cm		16,839	22	19,896	23	8,975	10	7,302	9	4,775	10
		22.5-32.4 cm		37,500	50	45,124	53	27,835	32	22,950	29	11,758	25
		32.5-42.4 cm		15,547	21	16,188	19	29,816	35	28,308	35	17,205	36
		42.5-52.4 cm		4,485	6	3,048	4	15,333	18	16,372	20	10,135	21
		52.5+ cm		896	1	444	1	4,304	5	5,068	6	3,365	7
		Total harvest from managed stands		75,267		84,700	100	86,263	100	80,000	100	47,239	100

[1] Product descriptions and targets were provided by Kathy Howard, Slocan Forest Products Ltd.

Figure 3-19. Harvest forecast corresponding to product mix targets.

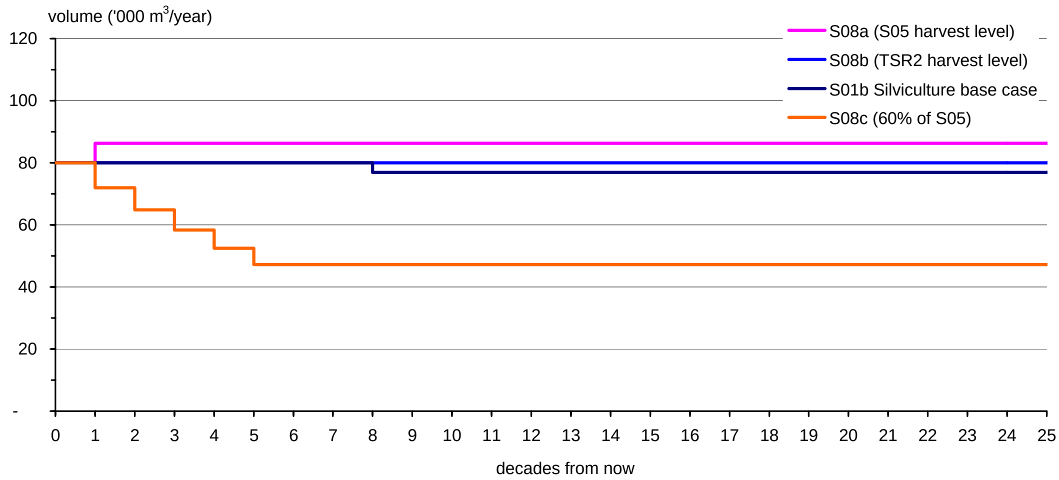
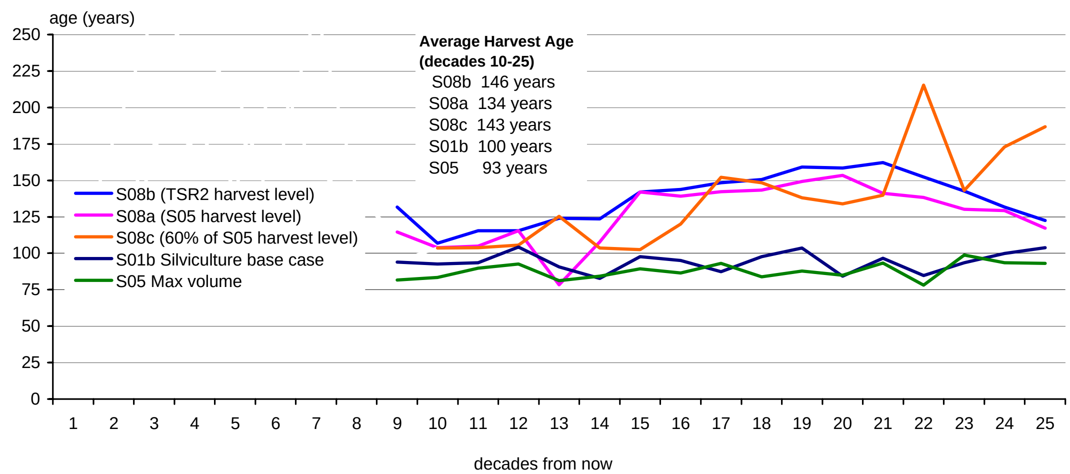


Figure 3-20. Average age of harvested stands.



A smaller portion of the volume that has shifted out of small logs is distributed among clear sawlogs, cedar poles, peelers and white pine.

Scenario S08b
Maintain sawlogs

Scenario S08b allows the harvest schedule to drop to TSR2 levels—a reduction of 6 263 m^3 per year. However, the regular sawlog component of the cut is increased slightly to 49 748 m^3 per year, with most of the reduction in harvest coming from the small log category.

Scenario S08c
Reduce cut, meet product target %

Scenario S08c allows the harvest schedule to drop substantially (by 39 000 m^3 per year) from the S08a level (maximum harvest volume, unlimited silviculture). Only the volume of peelers increases, and the sawlog and small log categories drop by 19 000 m^3 per year and 12 000 m^3 per year, respectively. However, the profile mix target is met for sawlogs (65%), white pine (5%), and cedar poles (5%).

Summary

To summarize, the maximum harvest levels obtained with select planting stock and incremental silviculture (scenario S05) can be maintained with 57% of the harvest as regular sawlogs. Reducing the long-term harvest level (and, hence, extending rotations) initially results in small volume shifts to quality, but as the reduction becomes more severe, all product categories are reduced. However, as harvest levels are reduced, the proportion of the harvest in the product target categories increases—the harvest yields a lower volume but the value per unit volume is higher.

The peeler and clear sawlog targets could not be met, even at the lowest harvest level. Clear wood volume can only be obtained from stands that have pruning regimes—SAU3 and SAU5. Providing additional pruning regimes in these SAU's or allowing pruning in other SAU's will increase the volume of peelers and clear sawlogs

Figure 3-21
Commercial thinning and extended rotations

Figures 3-21a,b,c plot the area harvested by clearcut and commercial thinning and provide an explanation as to how the maximum harvest volume can be maintained while increasing the harvest of sawlogs from 23% to 57%.
Figure 3-21a corresponds to scenario S08a which maintains the maximum harvest level obtained in S05, but is driven by the product mix scenario. Comparing this figure with Figure 3-13 (scenario S05), note that S08a schedules much more commercial thinning than S05. Commercial thinning maintains the harvest level while allowing the lengthening of rotations and the improvement of the harvest product profile in the long term.

Decade 13 stress point

Note that in decade 13 a large portion of the harvest is obtained by commercial thinning. Decade 13 is near the end of the transition when the harvest is almost entirely dependent on managed stands. Extending the rotation lengths of these stands causes a stress point in the timber supply that is alleviated by extensive commercial thinning.

As the long-term harvest levels are reduced to TSR2 levels (S08b), this spike in commercial thinning moves forward to decade 11 (Figure 3-21b), and essentially disappears when the cut is reduced to 60% of its maximum level (S08c; Figure 3-21b). Commercial thinning is employed at all three levels of harvest to maintain harvest levels while allowing longer rotations.

Figure 3-22
Figure 3-23

Figures 3-22 and 3-23 provide additional detail on the composition of the harvest by product category and diameter limit, respectively.

Figure 3-21a. Total area and volume per unit area of the forecast harvest, product profile scenario (S08a), with harvest levels set at maximum (S05) levels.

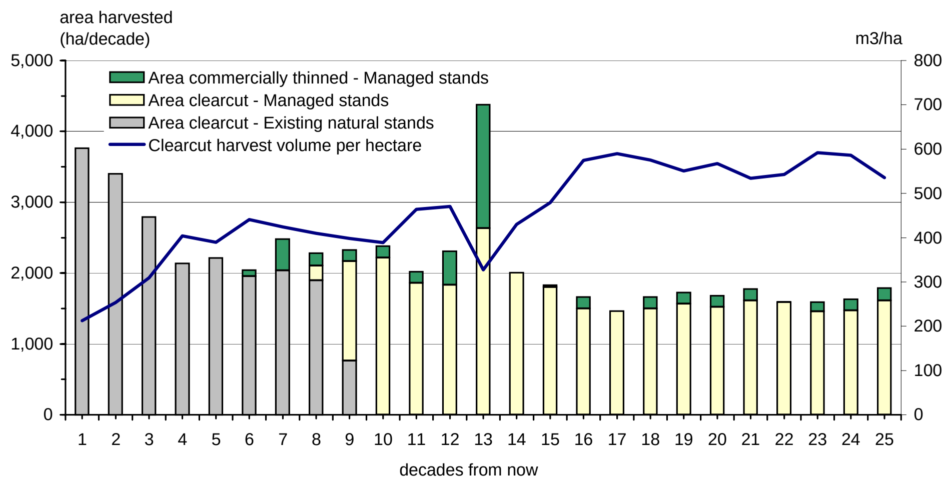


Figure 3-21b. Total area and volume per unit area of the forecast harvest, product profile scenario (S08b), with harvest levels set at MP 9 levels.

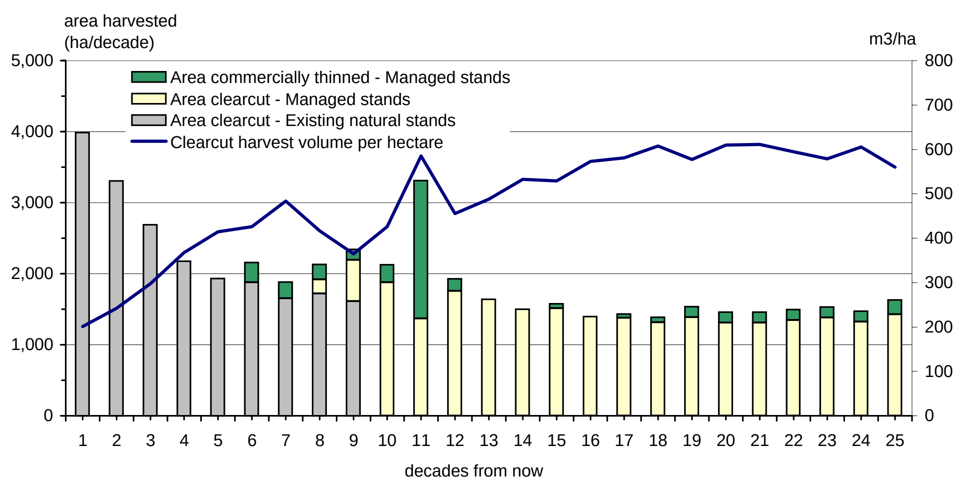


Figure 3-21c. Total area and volume per unit area of the forecast harvest, product profile scenario (S08c), with harvest levels set at 60% of maximum (S05) levels.

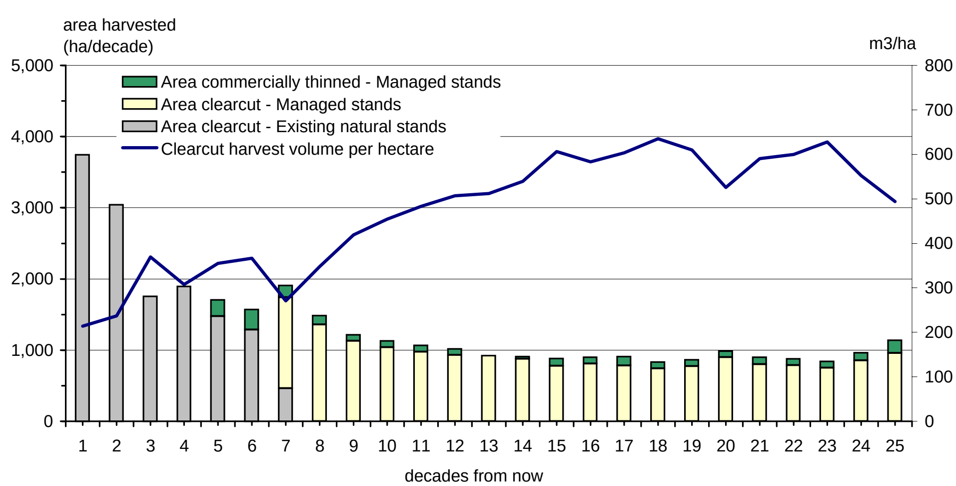


Figure 3-22a. Composition by diameter limit (dbh) of the forecast harvest, product profile scenario (S08a), with harvest levels set at maximum (S05) levels.

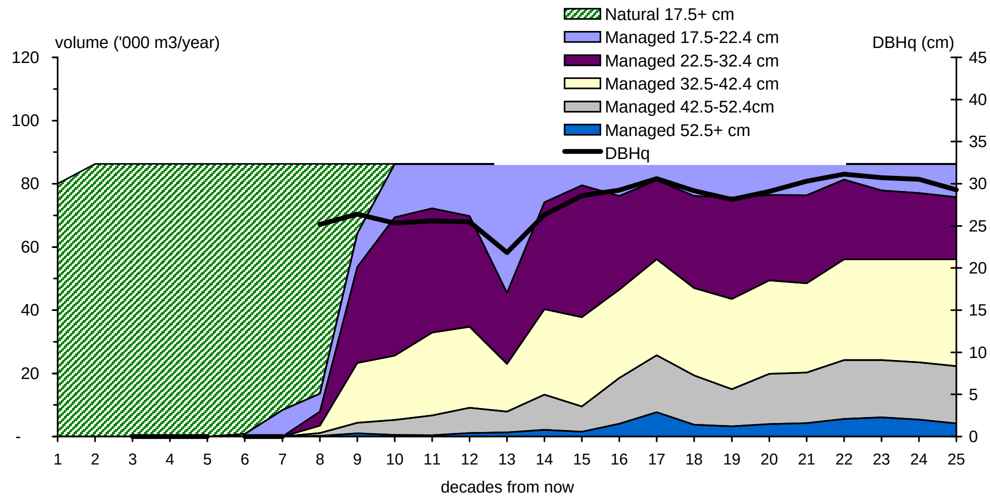


Figure 3-22b. Composition by diameter limit (dbh) of the forecast harvest, product profile scenario (S08b), with harvest levels set at MP 9 levels.

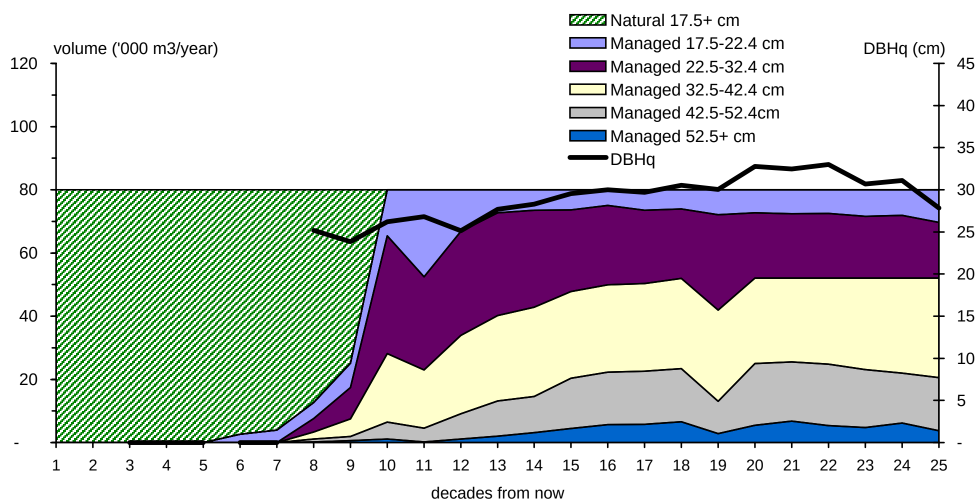


Figure 3-22c. Composition by diameter limit (dbh) of the forecast harvest, product profile scenario (S08c), with harvest levels set at 60% of maximum (S05) levels.

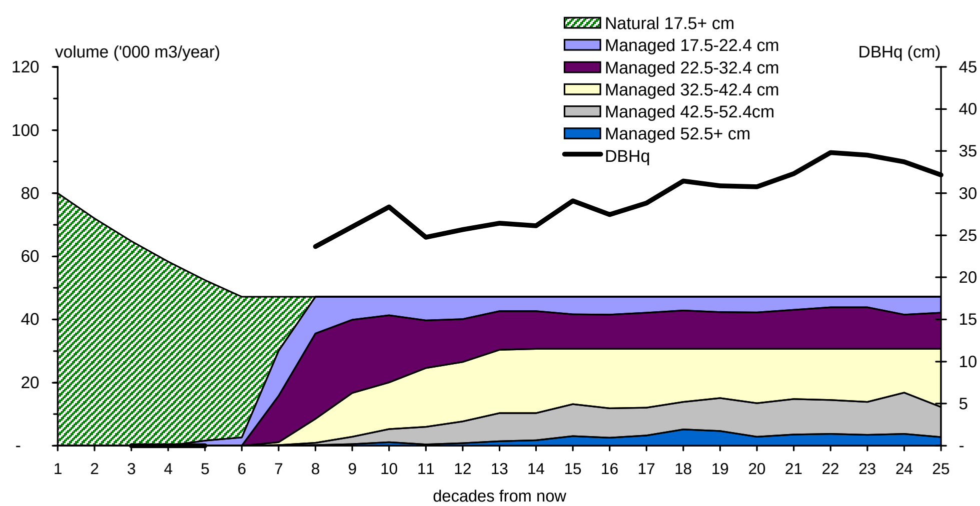


Figure 3-23a. Composition by product of the forecast harvest, product profile scenario (S08a), with harvest levels set at maximum (S05) levels.

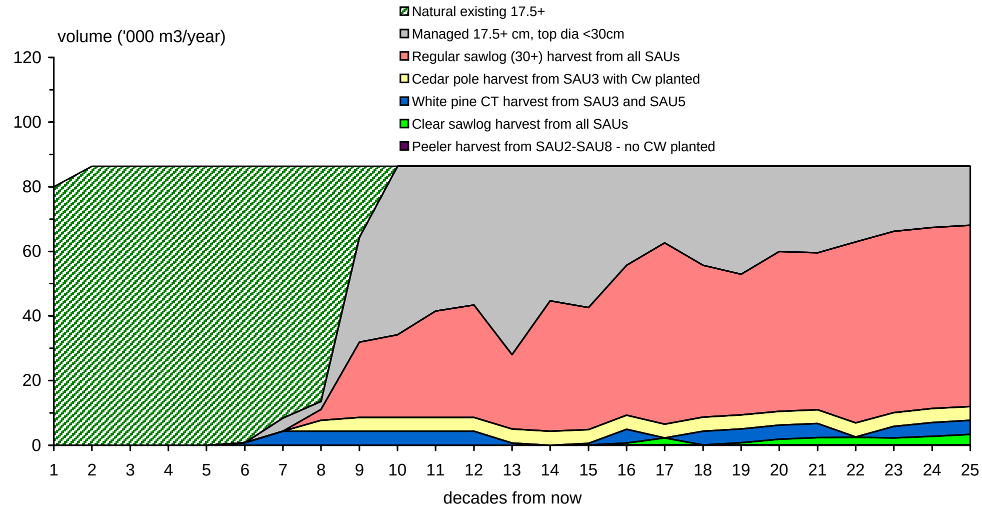


Figure 3-23b. Composition by product of the forecast harvest, product profile scenario (S08b), with harvest levels set at MP 9 levels.

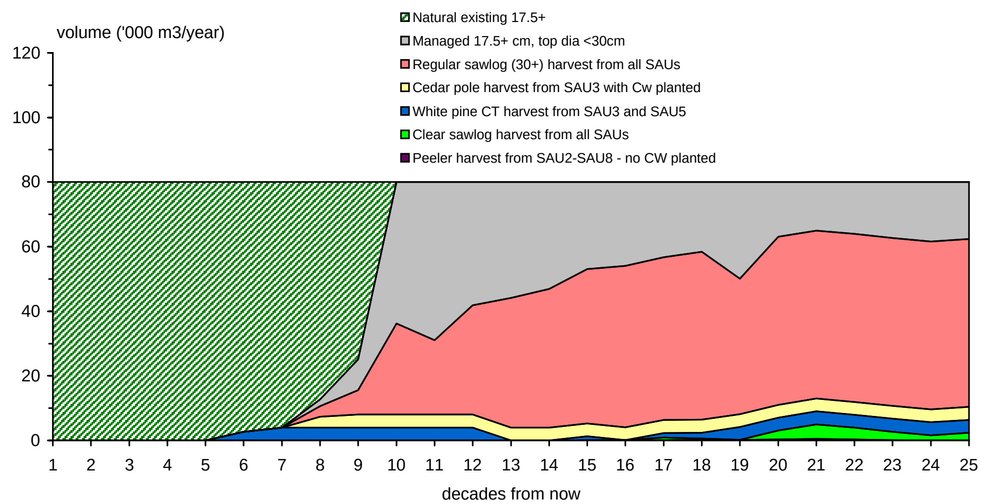
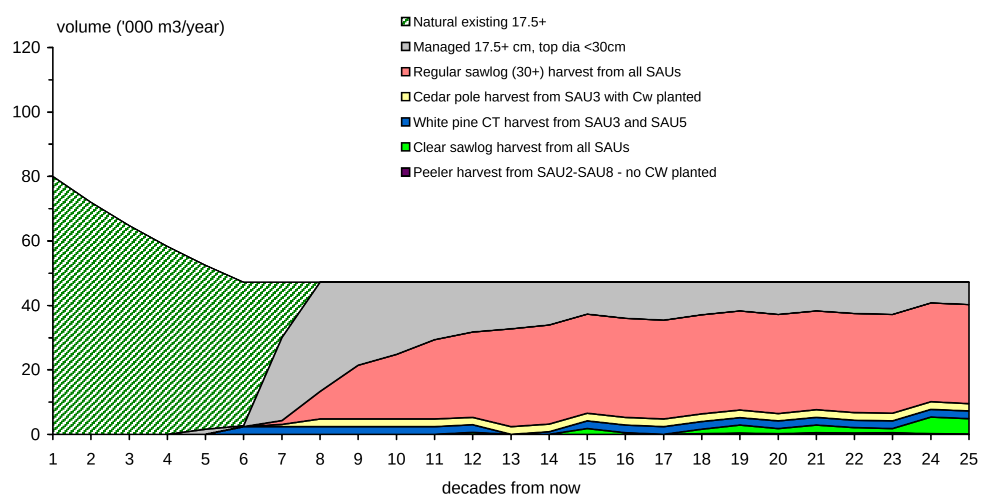


Figure 3-23c. Composition by product of the forecast harvest, product profile scenario (S08c), with harvest levels set at 60% of maximum (S05) levels.



4.0 Silviculture Strategy

The previous section (3.0) described the potential productive capacity of TFL 3 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 three management objectives embodied by scenarios S05, S08a and S08c, i.e.,

- S05–Maximize harvest volume, volume complied to TSR utilization standards, employing select stock, spacing, fertilization and commercial thinning
- S08a–Satisfy, as closely as possible, a product mix profile, employing the silviculture activities of S05, and maintaining the harvest levels achieved with S05.
- S08c–Same as S08a, but allow the harvest level to decline to 60% of the S05 LTHL.

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 fist 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

Table 4-1

The strategic plan is reported in Table 4-1.

SAU01
SAU02
SAU04
S0U07
SAU08

Five of the silviculture analysis units did not have regimes specified that employed incremental silviculture and the only activities (other than harvesting) tracked by the model was planting. These silviculture analysis units and planting densities selected are listed in Table 4-1, together with the areas planted across the planning horizon (decades 1-25). Note that the first decade includes hectares of NSR that are scheduled for planting.

The remaining silviculture analysis units (SAU03, SAU05, and SAU06) are managed with regimes that include incremental silviculture.

SAU03
CH ESSF SI=20.6

If the management objective is to maximize volume production without regard to product mix (S05), then the dominant regime employed on SAU03 is to plant FdLwPlCw and subsequently space those stands that are operationally feasible for spacing (≤ 30%). A small portion of the landbase (5%) is planted to FdPwLw and then held until harvest with no further management.

However, if the management objective includes the product mix profile (S08a and S08c), then the portion of the SAU planted to FdLwPlCw declines and the

Table 4-1. Strategic plan– area managed by each silviculture regime for three management objectives, decade 1-25.

Silvicultural Regime	----- Decades 1-25 ----- S05 ha	S08a ha	S08c ha
SAU01: SB, ITG=18-26, ICH, all sites, WSI=18.4			
Plant 1200 sph Se50Pl25Fd15Cw10, clearcut	5,663	4,528	3,877
SAU02: SB, ITG=18-26, ESSF, all sites, WSI=14.8			
Plant 1200 sph Se80Pl20 clearcut	7,023	8,634	8,566
SAU03: C,H ITG=9-17 ESSF all sites WSI=20.6			
Total area regenerated	9,566	7,028	6,803
Plant 1400 sph Fd40Lw30Pl10Cw20, clearcut	6,488	3,107	2,812
Plant 1400 sph Fd40Lw30Pl10Cw20, ingress to 5000 sph, JS to 2000 sph, clearcut	2,621	468	454
Plant 1400 sph Fd40Pw30Lw30, ingress to 5000 sph, clearcut	432	2,627	2,686
Plant 1400 sph Fd40Pw30Lw30, ingress to 5000 sph, JS to 1600 sph, clearcut	25	132	125
Plant 1400 sph Fd40Pw30Lw30, ingress to 5000 sph, JS to 1600 sph, Pr, clearcut	-	694	726
Plant 1400 sph Fd40Lw30Pl10Cw20, ingress to 5000 sph, clearcut	68%	44%	41%
Plant 1400 sph Fd40Lw30Pl10Cw20, ingress to 5000 sph, JS to 2000 sph, clearcut	27%	7%	7%
Plant 1400 sph Fd40Pw30Lw30, ingress to 5000 sph, clearcut	5%	37%	39%
Plant 1400 sph Fd40Pw30Lw30, ingress to 5000 sph, JS to 1600 sph, clearcut	0%	2%	2%
Plant 1400 sph Fd40Pw30Lw30, ingress to 5000 sph, JS to 1600 sph, Pr, clearcut		10%	11%
SAU04: CH, ITG=9-17 SI<20, ICH ESSF,WSI=17			
Plant 1400 sph Pl40Fd40Lw20, ingress to 3000 sph, clearcut	2,830	4,161	2,644
SAU05: Fd ITG=1-8,27-34 ICH,ESSF SI>20 WSI=22.2			
Total area regenerated	19,667	12,401	11,895
Plant 1400 sph Fd40Lw30Pl30, ingress to 2000 sph, clearcut	12,837	1,130	915
Plant 1400 sph Fd40Lw30Pl30, ingress to 2000 sph, Fe, clearcut	22	67	61
Plant 1400 sph C80, ingress to 2000 sph,JS FdLwPl to 1200 sph, clearcut	53	137	122
Plant 1400 sph Fd40Lw30Pl30, ingress to 2000 sph,JS FdLwPl to 1200 sph, Fe, clearcut	5,536	298	293
Plant 1400 sph Fd40Lw30Pl30, ingress to 2000 sph,JS FdLwPl to 1600 sph, clearcut	22	67	61
Plant 1400 sph C82, ingress to 2000 sph, clearcut	1,197	7,808	7,562
Plant 1400 sph Fd25Lw25Pw50, ingress to 2000 sph, JS to 1200 sph, Pr, clearcut	-	688	669
Plant 1400 sph Fd25Lw25Pw50, ingress to 2000 sph, JS to 1200 sph, Pr, CT and Fe, clearcut	-	759	772
Plant 1400 sph Fd25Lw25Pw50, ingress to 2000 sph, Pr, clearcut	-	688	669
Plant 1400 sph Fd25Lw25Pw50, ingress to 2000 sph, Pr, CT, Fe, clearcut	-	759	772
Plant 1400 sph Fd40Lw30Pl30, ingress to 2000 sph, clearcut	65%	9%	8%
Plant 1400 sph Fd40Lw30Pl30, ingress to 2000 sph, Fe, clearcut	0%	1%	1%
Plant 1400 sph Fd40Lw30Pl30, JS FdLwPl to 1200 sph, clearcut	0%	1%	1%
Plant 1400 sph Fd40Lw30Pl30, JS FdLwPl to 1200 sph, Fe, clearcut	28%	2%	2%
Plant 1400 sph Fd40Lw30Pl30, JS FdLwPl to 1600 sph, clearcut	0%	1%	1%
Plant 1400 sph Fd25Lw25Pw50, ingress to 2000 sph., clearcut	6%	63%	64%
Plant 1400 sph Fd25Lw25Pw50, ingress to 2000 sph, JS to 1200 sph, Pr, clearcut		6%	6%
Plant 1400 sph Fd25Lw25Pw50, ingress to 2000 sph, JS to 1200 sph, Pr, CT and Fe, clearcut		6%	6%
Plant 1400 sph Fd25Lw25Pw50, ingress to 2000 sph, Pr, clearcut		6%	6%
Plant 1400 sph Fd25Lw25Pw50, ingress to 2000 sph, Pr, CT, Fe, clearcut		6%	6%

Table 4-1 (continued). Strategic plan– area managed by each silviculture regime for three management objectives, decade 1-25.

Silvicultural Regime	----- Decades 1-25 ----- S05 ha	S08a ha	S08c ha
SAU6: Fd ITG=1-8,27-34 ICH,ESSF 16<=SI<=20 WSI=18			
Total area regenerated	16,394	9,097	7,102
Plant 1400 sph C100, ingress to 2000 sph, clearcut	4,561	4,566	3,856
Plant 1400 sph Fd30Lw30Pl40, ingress to 2000 sph, JS to 1200 sph, clearcut	749	949	688
Plant 1400 sph Pl90Fd5Lw5, ingress to 2000 sph, clearcut	9,629	1,980	973
Plant 1400 sph Pl90Fd5Lw5, ingress to 2000 sph, JS to 1600 sph, clearcut	1,454	1,601	1,585
Plant 1400 sph Fd30Lw30Pl40, ingress to 2000 sph, clearcut	28%	50%	54%
Plant 1400 sph Fd30Lw30Pl40, ingress to 2000 sph, JS to 1200 sph, clearcut	5%	10%	10%
Plant 1400 sph C114, ingress to 2000 sph, clearcut	59%	22%	14%
Plant 1400 sph Pl90Fd5Lw5, ingress to 2000 sph, JS to 1600 sph, clearcut	9%	18%	22%
SAU07: Fd, ITG=1-8 27-34, ICH ESSF, SI<15, WSI=13.8			
Plant 1400 sph Fd40Pl40Lw20, ingress to 2000 sph, clearcut	342	668	668
SAU08: SB, ITG=18-26, ESSF, SI>=16, <1700m, WSI=20			
Plant 1400 sph Sx70Pl30, ingress to 2500 sph, clearcut	4,370	3,745	3,462
Average area planted annually (ha/year)	263	201	180
Average area spaced annually (ha/year)	36	17	16
Average area pruned annually (ha/year)	-	9	9
Average area fertilized annually (ha/year)	22	8	8
Average area commercially thinned annually (ha/year)	-	6	6

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

Silvicultural Activity	----- Decade 1 ----- S05 ha	S08a ha	S08c ha
SAU01: SB, ITG=18-26, ICH, all sites, WSI=18.4			
Plant 1200 sph Se50Pl25Fd15Cw10	159	263	263
SAU02: SB, ITG=18-26, ESSF, all sites, WSI=14.8			
Plant 1200 sph Se80Pl20	832	1,046	1,046
SAU03: C,H ITG=9-17 ESSF all sites WSI=20.6			
Plant 1400 sph Fd40Lw30Pl10Cw20	639	905	905
SAU04: CH, ITG=9-17 SI<20, ICH ESSF,WSI=17	168	131	152
Plant 1400 sph Pl40Fd40Lw20			
SAU05: Fd ITG=1-8,27-34 ICH,ESSF SI>20 WSI=22.2			
Plant 1400 sph Fd40Lw30Pl30	1,305	-	-
JS FdLwPl to 1200 sph	38	29	23
Plant 1400 sph Fd25Lw25Pw50	-	1,579	1,579
SAU6: Fd ITG=1-8,27-34 ICH,ESSF 16<=SI<=20 WSI=18			
Plant 1400 sph Fd30Lw30Pl40	21	160	354
Plant 1400 sph Pl90Fd5Lw5	142	-	-
JS PlFdLw to 1600 sph	161	126	110
SAU07: Fd, ITG=1-8 27-34, ICH ESSF, SI<15, WSI=13.8			
Plant 1400 sph Fd40Pl40Lw20	-	-	-
SAU08: SB, ITG=18-26, ESSF, SI>=16, <1700m, WSI=20			
Plant 1400 sph Sx70Pl30	329	431	431

portion planted to FdPwLw increases. Subsequent management of the FdPwLw includes spacing and pruning.

SAU05
Fd ICH,ESSF SI=22.2

If the management objective is to maximize volume production without regard to product mix (S05), then the dominant regime employed on SAU05 is to plant FdLwPl and hold for late fertilization 10 years prior to harvest. A small portion of the landbase (6%) is planted to FdLwPw and then held until harvest with no further management.

However, if the management objective includes the product mix profile (S08a and S08c), then the portion of SAU05 planted to FdLwPl declines and the portion planted to FdLwPw increases substantially. Subsequent management of the FdLwPw includes spacing, pruning, commercial thinning and late fertilization.

SAU06
Fd ICH,ESSF SI=18

If the management objective is to maximize volume production without regard to product mix (S05), then four regimes are employed on SAU06.The dominant regime (59% of SAU06) is to plant PlFdLw and hold for harvest, with a smaller portion (9%) planted and spaced. A second planting mix is treated in a similar manner—28% (of SAU06) is planted to FdLwPl and held to harvest, while 5% is planted and subsequently spaced.

If the management objective includes the product mix profile (S08a and S08c), then the second planting mix FdLwPl is emphasized and the proportion of the stands that are subsequently spaced is increased. Although the area of SAU06 that is planted to PlFdLw is reduced to less than half the area planted under S05, the area subsequently spaced doubles.

Strategy Summary

Under the management objective of maximizing volume production, regimes are selected that allow harvesting of younger stands through spacing (e.g. SAU03) or spacing that leads to fertilization (SAU05). However, when the management objective includes the product mix profile, the emphasis shifts to regimes include planting Pw; spacing is employed to improve dimension and as part of regimes that include pruning. Fertilization is reduced.

Under the product mix management objective, commercial thinning helps maintain harvest levels while allowing the residual stand to be held long enough to develop the dimensional characteristics of the desired product profile.

A final general observation is that planting rates are highest when the management objective is to maximize volume without regard to product mix (S05) and decrease when meeting the product profile is included in the objectives (S08a and S08c). This is consistent with the observation (Section 3.3, Figure 3-20) that the model lengthens rotations in order to attain the dimension and clear wood requirements of the product profile.

In general, the strategy developed above is limited in its ability to meet the timber quantity and product mix objectives by the restricted scope of the silvicultural regimes provided to the analysis, and by the constraints specified on the operability of various silvicultural activities.

4.2 Tactical Plan

Table 4-2

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

Only two incremental silviculture activities are scheduled in decade 1. Spacing is indicated for existing FdLwPl on SAU05 and for PlFdLw on SAU06.

Comment

There may well be other silvicultural opportunities apparent on the TFL in the current (first decade) that are consistent with the silviculture strategy discussed in Section 4.1. The modelling methods employed in this study are designed for the efficient determination and evaluation of strategic plans. Greater resolution in the first decade requires spatial methods operating at a finer time scale.

5.0 Limitations of the Study

This study is a descriptive analysis. It quantifies the changes in productive capacity of the TFL 3 that result from alternative management objectives with respect to timber quantity and quality.

This study is not prescriptive: it makes no recommendations concerning the appropriateness of 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

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 necessitates a “work-around” procedure 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.

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.

The operability constraints that were specified for TFL 3 tightly constrain the employment of incremental silviculture to help meet the TFL's product mix objectives. These operability constraints should be reviewed.

Appendix A – The Current Silvicultural State of TFL3

Problem: existing managed stands

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 TFL3 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 TFL 3 Phoenix data, a table was constructed that listed for each analysis unit and age class combination the total area recorded as planted and juvenile spaced. Only the data recorded in the Phoenix system since MP9 was used in the analysis.

The first step in the assignment process was to adjust the inventory for harvesting of older age classes and planting in age class 1 (<= 10 years) that has occurred since MP9. The 3439 ha reported as planted since MP 9 was added to the inventory age class 1 of each silviculture analysis unit (SAU), prorated by the area of the SAU. The area added to each SAU age class 1 (planted) was removed (harvested) from the oldest age class of the SAU after netting out the NSR.

In the next step, 498 hectares of juvenile spacing were assigned to SAUs, based on the recent silviculture practices for existing managed stands as recorded in the regime tables (Appendix B).

While it is unlikely that applying this procedure to the Phoenix data has resulted in the exact silviculture state of the TFL, the procedure is unambiguous and results in a unique set of silviculture states for each age class of each analysis unit. Table A-1 reports the resulting silvicultural state of the TFL, with the silvicultural history recorded in the Phoenix database allocated across the inventory as existing managed stands.

Table A-1. Area of silvicultural analysis unit by silvicultural state.

Code	Silvicultural State	SAU1	SAU2	SAU3	SAU4	SAU5	SAU6	SAU7	SAU8	Total
N	Natural	959	3,324	2,490	2,286	4,730	5,153	520	1,490	20,953
NSR	NSR	47	232	192	49	268	29		91	908
e12	Establised at 1200 sph	1,166	1,794							2,960
e20	Establised at 2000 sph							169		169
e25	Establised at 2500 sph								421	421
e30	Establised at 3000 sph				251					251
e201	Establised (Fd, Lw, Pl) at 2000 sph					232	1,184			1,416
e201x	Establised (Fd, Lw, Pl) at 2000 sph, no further management					395				395
e201S12	Establised (Fd, Lw, Pl) at 2000 sph, spaced to 2000 sph					84				
e501S20	Establised (Fd, Lw, Pl, Cw) at 5000 sph, spaced to 2000 sph			415						415
		2,172	5,350	3,097	2,586	5,709	6,366	690	2,003	27,888

Definitions of silvicultural analysis units:

SAU1	Se-Ba, ICH, all evelvations, prod class 1,2,&3, SI=18.4
SAU2	Se, ESSF, >1700m, prod class 1,2,&3, SI=14.8
SAU3	Cw-Hw, ICH/ESSF, all evelvations, prod class 1&2, SI=20.6
SAU4	Cw, ICH, all evelvations, prod class 3, SI=17
SAU5	Lw-Fd-Pl, ICH/ESSF, all evelvations, prod class 1, SI=22.2
SAU6	Lw-Fd-Pl, ICH/ESSF, all evelvations, prod class 2, SI=18.2
SAU7	Lw-Fd, ICH/ESSF, all evelvations, prod class 3, SI=13.8
SAU8	S, ESSF, <1700 m, prod class 1&2, SI=20

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 the stand to change silviculture state, 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 of the 8 silviculture analysis units defined for TFL 3 by Slocan staff, and the alternative development pathways were plotted (Figures B-1 to B-10). These 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 these diagrams and Tables B-3 and B-4 list the treatment specification for each feasible regime. Table B-5 is the spreadsheet of specifications for the TASS managed stand yield tables. 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 stands
NSR	In period 1 NSR will be converted to managed based on base case assumptions
12	Planted to 1200 sph, ingrowth to 1200 sph
13	Planted to 1300 sph, ingrowth to 1300 sph
20	Planted to 1400 sph, ingrowth to 2000 sph
201	Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph
201---F	Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, fertilized
201S12	Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, PCT to 1200 sph
201S12--F	Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, PCT to 1200 sph, fertilized
201S16	Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, PCT to 1600 sph
201S16-T	Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, PCT to 1600 sph, CT
201S16-TF	Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, PCT to 1600 sph, CT, fertilized
201--T	Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, CT
201--TF	Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, CT, fertilized
201x	Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph - no further treatment
202	Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph
202-P	Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph, pruned
202-PT	Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph, pruned, CT
202-PTF	Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph, pruned, CT, fertilized
202S12	Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph, PCT to 1200 sph
202S12P	Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph, PCT to 1200 sph, pruned
202S12PT	Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph, PCT to 1200 sph, pruned, CT
202S12PTF	Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph, PCT to 1200 sph, pruned, CT, fertilized
202--T	Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph, CT
202x	Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph - no further treatment
25	Planted to 1400 sph, ingrowth to 2500 sph
30	Planted to 1400 sph, ingrowth to 3000 sph
501	Planted (FdLwPlCw) to 1400 sph, ingrowth to 5000 sph
501S20	Planted (FdLwPlCw) to 1400 sph, ingrowth to 5000 sph, PCT to 2000 sph
501x	Planted (FdLwPlCw) to 1400 sph, ingrowth to 5000 sph - no further treatment
502	Planted (FdPwLw) to 1400 sph, ingrowth to 5000 sph
502S16	Planted (FdPwLw) to 1400 sph, ingrowth to 5000 sph, PCT to 1600 sph
502S16P	Planted (FdPwLw) to 1400 sph, ingrowth to 5000 sph, PCT to 1600 sph, pruned
502S16PT	Planted (FdPwLw) to 1400 sph, ingrowth to 5000 sph, PCT to 1600 sph, pruned, CT
502x	Planted (FdPwLw) to 1400 sph, ingrowth to 5000 sph - no further treatment
e12	Existing Planted to 1200 sph, ingrowth to 1200 sph
e20	Existing Planted to 1400 sph, ingrowth to 2000 sph
e201	Existing Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph
e201---F	Existing Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, fertilized
e201S12	Existing Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph, PCT to 1200 sph
e201S12--F	Existing Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, PCT to 1200 sph, fertilized
e201S16	Existing Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, PCT to 1600 sph
e201S16-T	Existing Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, PCT to 1600 sph, CT
e201S16-TF	Existing Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, PCT to 1600 sph, CT, fertilized
e201--T	Existing Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, CT
e201--TF	Existing Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph, CT, fertilized
e201x	Existing Planted (FdLwPl) to 1400 sph, ingrowth to 2000 sph - no further treatment
e202	Existing Planted (FdLwPw) to 1400 sph, ingrowth to 2000 sph
e25	Existing Planted to 1400 sph, ingrowth to 2500 sph
e30	Existing Planted to 1400 sph, ingrowth to 3000 sph
e501	Existing Planted (FdLwPlCw) to 1400 sph, ingrowth to 5000 sph
e501S20	Existing Planted (FdLwPlCw) to 1400 sph, ingrowth to 5000 sph, PCT to 2000 sph
e502	Existing Planted (FdPwLw) to 1400 sph, ingrowth to 5000 sph

Table B-2. Activity Codes

Code	Activity Description
ADD_NSR	Add NSR
CLC_EXIST	Clearcut existing natural
CLC_MANAGED	Clearcut managed
CTHIN	Commercial thin
FERTONLY	Ingrowth (FdPlLw) 2000, fertilize
PLNT1200	Ingrowth 1200
PLNT2000	Ingrowth 2000
PLNT2000SG1	Ingrowth 2000 SG1
PLNT2000SG1X	Ingrowth 2000 SG1 - no further mgmt
PLNT2000SG2	Ingrowth 2000 SG2
PLNT2000SG2X	Ingrowth 2000 SG2 - no further mgmt
PLNT2500	Ingrowth 2500
PLNT3000	Ingrowth 3000
PLNT5000SG1	Ingrowth 5000 SG1
PLNT5000SG1X	Ingrowth 5000 SG1 - no further mgmt
PLNT5000SG2	Ingrowth 5000 SG2
PLNT5000SG2X	Ingrowth 5000 SG2 - no further mgmt
PRUNECTFERTONLY	Ingrowth 2000 SG2, prune, CT, fertilize
PRUNEONLY	Ingrowth 2000 SG2, prune
REDUCELB	Reduce landbase
SPACE1200	Ingrowth 2000 SG1, JS to 1200
SPACE1200FERT	Ingrowth 2000 SG1, JS to 1200, fertilize
SPACE1200PRUNE	Ingrowth 2000 SG2, JS to 1200 sph, prune
SPACE1200PRUNECTFERT	Ingrowth 2000 SG2, JS to 1200 sph, prune, CT, fertilize
SPACE1600	Ingrowth 2000 SG1 or 5000 SG2, JS to 1600
SPACE1600PRUNE	Ingrowth 5000 SG2, JS to 1600 sph, prune
SPACE2000	Ingrowth 5000 SG1, JS to 2000

Table B-3. Fertilization schedule - TFL 3

Managed Regime #	State Label	SAU	Sp	SI	Fertilize at age:
3012	201---F	5	FdLwPl	22.2	60
3013	201S12--F	5	FdLwPl	22.2	60
3015	201S16-TF	5	FdLwPl	22.2	60
3016	201S16-TF	5	FdLwPl	22.2	60
3017	201S16-TF	5	FdLwPl	22.2	60
3018	201--TF	5	FdLwPl	22.2	60
3019	201--TF	5	FdLwPl	22.2	60
3020	201--TF	5	FdLwPl	22.2	60
3024	202S12PTF	5	FdLwPw	22.2	60
3025	202S12PTF	5	FdLwPw	22.2	60
3026	202S12PTF	5	FdLwPw	22.2	60
3028	202-PTF	5	FdLwPw	22.2	60
3029	202-PTF	5	FdLwPw	22.2	60
3030	202-PTF	5	FdLwPw	22.2	60

Table B-4. Management assumptions for generation of TASS yield curves- TFL 3

1.0 Utilization levels

	min dbh	max stump	min top dib
lodgepole pine, whitebark pine	12.5	30	10
all other types	17.5	30	10

Note: all figures in centimetres.

2.0 Operational adjustment factors

OAF 1	15
OAF 2	5

3.0 Juvenile spacing
- leave well-spaced trees, favouring tallest

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

5.0 Pruning
- retain 30% live crown on first lift
- retain 40% live crown on second lift
- prune all trees that meet the crown ratio condition, OR the largest trees (ordered by diameter) that meet the CR condition up to the max number specified in the spreadsheet, e.g., the "best 300"

Table B-5. TASS run specifications TFL 3

SAU	Managed Regime #	Height Adjustment	State Label	Plant species	site index range	Weighted average site index	Regen Lag	Plant tph	natural ingress species	natural ingress tph	Density after ingrowth	Pct Age	PCT leave tph	1st prune dominant ht (m)	1st prune age (yrs)	1st prune lift (m)	2nd prune dominant ht (m)	2nd prune age (yrs)	2nd prune lift (m)	CT age	CT remove > m3/ha	CT leave >tph
1	1001	yes	12	Se50Pl25Fd15Cw10	SI>=13	18.4	2	1200	SePlFdCw	0	1200	0	0	0	0	0	0	0	0	0	0	0
1	3001	yes	13	Se50Pl25Fd15Cw10	SI>=13	18.4	2	1300	SePlFdCw	0	1300	0	0	0	0	0	0	0	0	0	0	0
2	1002	yes	12	Se80Pl20	SI>=13.5	14.8	4	1200	SePl	0	1200	0	0	0	0	0	0	0	0	0	0	0
2	3002	yes	13	Se80Pl20	SI>=13.5	14.8	4	1300	SePl	0	1300	0	0	0	0	0	0	0	0	0	0	0
3	1003	yes	501	Fd40Lw30Pl10Cw20	SI>=17.7	20.6	2	1400	FdLwPlCw	3600	5000	0	0	0	0	0	0	0	0	0	0	0
3	1004	yes	501S20	Fd40Lw30Pl10Cw20	SI>=17.7	20.6	2	1400	FdLwPlCw	3600	5000	15	2000	0	0	0	0	0	0	0	0	0
3	1005	yes	502	Fd40Pw30Lw30	SI>=17.7	20.6	2	1400	FdPwLw	3600	5000	0	0	0	0	0	0	0	0	0	0	0
3	1006	yes	502S16	Fd40Pw30Lw30	SI>=17.7	20.6	2	1400	FdPwLw	3600	5000	15	1600	0	0	0	0	0	0	0	0	0
3	1007	yes	50216P	Fd40Pw30Lw30	SI>=17.7	20.6	2	1400	FdPwLw	3600	5000	15	1600	7	18	2.8	11	27	5.6	0	0	0
3	1008	yes	50216PT	Fd40Pw30Lw30	SI>=17.7	20.6	2	1400	FdPwLw	3600	5000	15	1600	7	18	2.8	11	27	5.6	50	75	350
3	1009	yes	50216PT	Fd40Pw30Lw30	SI>=17.7	20.6	2	1400	FdPwLw	3600	5000	15	1600	7	18	2.8	11	27	5.6	60	75	450
3	1010	yes	50216PT	Fd40Pw30Lw30	SI>=17.7	20.6	2	1400	FdPwLw	3600	5000	15	1600	7	18	2.8	11	27	5.6	70	75	500
3	3003	yes	13	Fd40Pw30Lw30	SI>=17.7	20.6	2	1300	FdPwLw	0	1300	0	0	0	0	0	0	13	0	0	0	0
4	1011	yes	30	Pl40Fd40Lw20	SI>=14	17	2	1400	PlFdLw	1600	3000	0	0	0	0	0	0	0	0	0	0	0
4	3004	yes	13	Pl40Fd40Lw20	SI>=14	17	2	1300	PlFdLw	0	1300	0	0	0	0	0	0	0	0	0	0	0
5	1012	yes	201	Fd40Lw30Pl30	SI>=22	22.2	2	1400	FdLwPl	600	2000	0	0	0	0	0	0	0	0	0	0	0
5	1013	yes	201S12	Fd40Lw30Pl30	SI>=22	22.2	2	1400	FdLwPl	600	2000	15	1200	0	0	0	0	0	0	0	0	0
5	1014	yes	201S16	Fd40Lw30Pl30	SI>=22	22.2	2	1400	FdLwPl	600	2000	15	1600	0	0	0	0	0	0	0	0	0
5	1015	yes	201S16-T	Fd40Lw30Pl30	SI>=22	22.2	2	1400	FdLwPl	600	2000	15	1600	0	0	0	0	0	0	50	75	600
5	1016	yes	201S16-T	Fd40Lw30Pl30	SI>=22	22.2	2	1400	FdLwPl	600	2000	15	1600	0	0	0	0	0	0	60	75	600
5	1017	yes	201S16-T	Fd40Lw30Pl30	SI>=22	22.2	2	1400	FdLwPl	600	2000	15	1600	0	0	0	0	0	0	70	75	600
5	1018	yes	201--T	Fd40Lw30Pl30	SI>=22	22.2	2	1400	FdLwPl	600	2000	0	0	0	0	0	0	0	0	50	75	600
5	1019	yes	201--T	Fd40Lw30Pl30	SI>=22	22.2	2	1400	FdLwPl	600	2000	0	0	0	0	0	0	0	0	60	75	600
5	1020	yes	201--T	Fd40Lw30Pl30	SI>=22	22.2	2	1400	FdLwPl	600	2000	0	0	0	0	0	0	0	0	70	75	600
5	1021	yes	202	Fd25Lw25Pw50	SI>=22	22.2	2	1400	FdLwPw	600	2000	0	0	0	0	0	0	0	0	0	0	0
5	1022	yes	202S12	Fd25Lw25Pw50	SI>=22	22.2	2	1400	FdLwPw	600	2000	15	1200	0	0	0	0	0	0	0	0	0
5	1023	yes	202S12P	Fd25Lw25Pw50	SI>=22	22.2	2	1400	FdLwPw	600	2000	15	1200	7	16	2.8	11	25	5.6	0	0	0
5	1024	yes	202S12PT	Fd25Lw25Pw50	SI>=22	22.2	2	1400	FdLwPw	600	2000	15	1200	7	16	2.8	11	25	5.6	50	75	450
5	1025	yes	202S12PT	Fd25Lw25Pw50	SI>=22	22.2	2	1400	FdLwPw	600	2000	15	1200	7	16	2.8	11	25	5.6	60	75	450
5	1026	yes	202S12PT	Fd25Lw25Pw50	SI>=22	22.2	2	1400	FdLwPw	600	2000	15	1200	7	16	2.8	11	25	5.6	70	75	450
5	1027	yes	202-P	Fd25Lw25Pw50	SI>=22	22.2	2	1400	FdLwPw	600	2000	15	1200	7	16	2.8	11	25	5.6	0	0	0
5	1028	yes	202-PT	Fd25Lw25Pw50	SI>=22	22.2	2	1400	FdLwPw	600	2000	15	1200	7	16	2.8	11	25	5.6	50	75	450
5	1029	yes	202-PT	Fd25Lw25Pw50	SI>=22	22.2	2	1400	FdLwPw	600	2000	15	1200	7	16	2.8	11	25	5.6	60	75	450
5	1030	yes	202-PT	Fd25Lw25Pw50	SI>=22	22.2	2	1400	FdLwPw	600	2000	15	1200	7	16	2.8	11	25	5.6	70	75	450
5	3005	yes	13	Fd40Lw30Pl30	SI>=22	22.2	2	1300	FdLwPl	0	1300	0	0	0	0	0	0	0	0	0	0	0
6	1031	yes	201	Fd30Lw30Pl40	SI>=18.4	18	2	1400	FdLwPl	600	2000	0	0	0	0	0	0	0	0	0	0	0
6	1032	yes	201S12	Fd30Lw30Pl40	SI>=18.4	18	2	1400	FdLwPl	600	2000	15	1200	0	0	0	0	0	0	0	0	0
6	1033	yes	201S16	Fd30Lw30Pl40	SI>=18.4	18	2	1400	FdLwPl	600	2000	15	1600	0	0	0	0	0	0	0	0	0
6	1034	yes	201S16-T	Fd30Lw30Pl40	SI>=18.4	18	2	1400	FdLwPl	600	2000	15	1600	0	0	0	0	0	0	50	75	450
6	1035	yes	201S16-T	Fd30Lw30Pl40	SI>=18.4	18	2	1400	FdLwPl	600	2000	15	1600	0	0	0	0	0	0	60	75	550
6	1036	yes	201S16-T	Fd30Lw30Pl40	SI>=18.4	18	2	1400	FdLwPl	600	2000	15	1600	0	0	0	0	0	0	70	75	650
6	1037	yes	201--T	Fd30Lw30Pl40	SI>=18.4	18	2	1400	FdLwPl	600	2000	0	0	0	0	0	0	0	0	50	75	550
6	1038	yes	201--T	Fd30Lw30Pl40	SI>=18.4	18	2	1400	FdLwPl	600	2000	0	0	0	0	0	0	0	0	60	75	600
6	1039	yes	201--T	Fd30Lw30Pl40	SI>=18.4	18	2	1400	FdLwPl	600	2000	0	0	0	0	0	0	0	0	70	75	650
6	1040	yes	202	Pl90Fd5Lw5	SI>=18.4	18.2	2	1400	PlFdLw	600	2000	0	0	0	0	0	0	0	0	0	0	0
6	1041	yes	202--T	Pl90Fd5Lw5	SI>=18.4	18.2	2	1400	PlFdLw	600	2000	0	0	0	0	0	0	0	0	50	75	600
6	1042	yes	202--T	Pl90Fd5Lw5	SI>=18.4	18.2	2	1400	PlFdLw	600	2000	0	0	0	0	0	0	0	0	60	75	700
6	1043	yes	202--T	Pl90Fd5Lw5	SI>=18.4	18.2	2	1400	PlFdLw	600	2000	0	0	0	0	0	0	0	0	70	75	700
6	3006	yes	13	Fd30Lw30Pl40	SI>=18.4	18	2	1300	FdLwPl	0	1300	0	0	0	0	0	0	0	0	0	0	0
7	1044	yes	20	Fd40Pl40Lw20	SI>=13	13.8	2	1400	FdPlLw	600	2000	0	0	0	0	0	0	0	0	0	0	0
7	3007	yes	13	Fd40Pl40Lw20	SI>=13	13.8	2	1300	FdPlLw	0	1300	0	0	0	0	0	0	0	0	0	0	0
8	1045	yes	25	Sx70Pl30	SI>=18	20	2	1400	SxPl	1100	2500	0	0	0	0	0	0	0	0	0	0	0
8	3008	yes	13	Sx70Pl30	SI>=18	20	2	1300	SxPl	0	1300	0	0	0	0	0	0	0	0	0	0	0

Figure B-1. SAU1,2,4 Alternate Development Pathways for Existing Natural Stands

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

SAU01
Se, Ba leading
ICH
all elevations
Productivity Class 1 , 2 & 3
8% THLB

SAU02
Se leading
ESSF
>1700 m
Productivity Class 1 , 2 & 3
19% THLB

SAU04
Cw, Hw leading
ICH
all elevations
Productivity Class 3
9% THLB

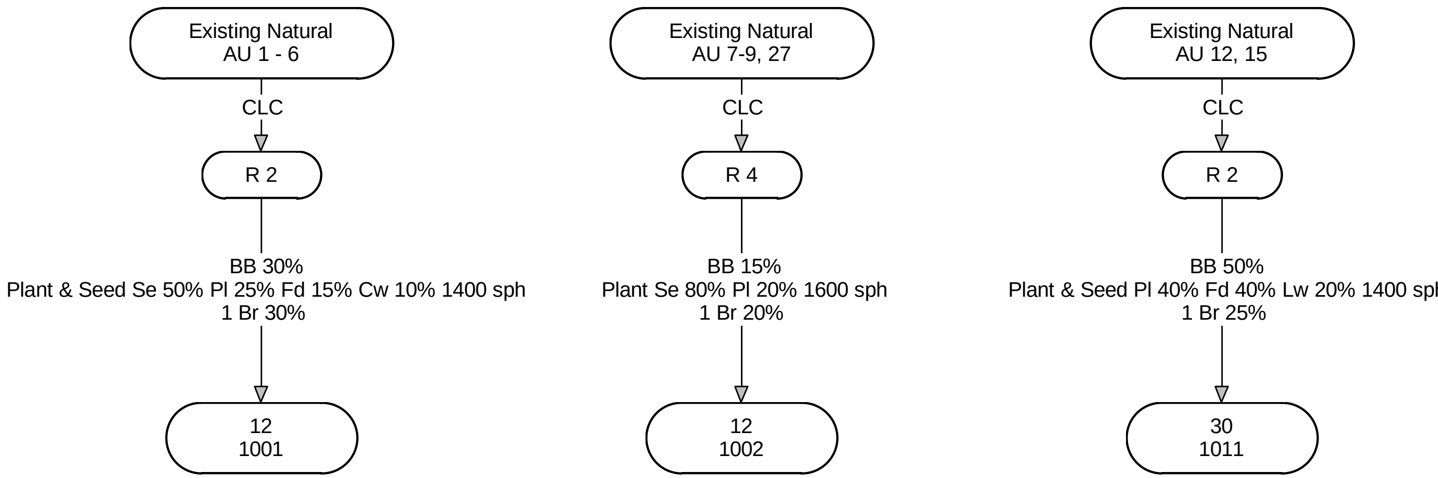


Figure B-2. SAU1,2 4 Alternate Development Pathways for Existing Managed Stands

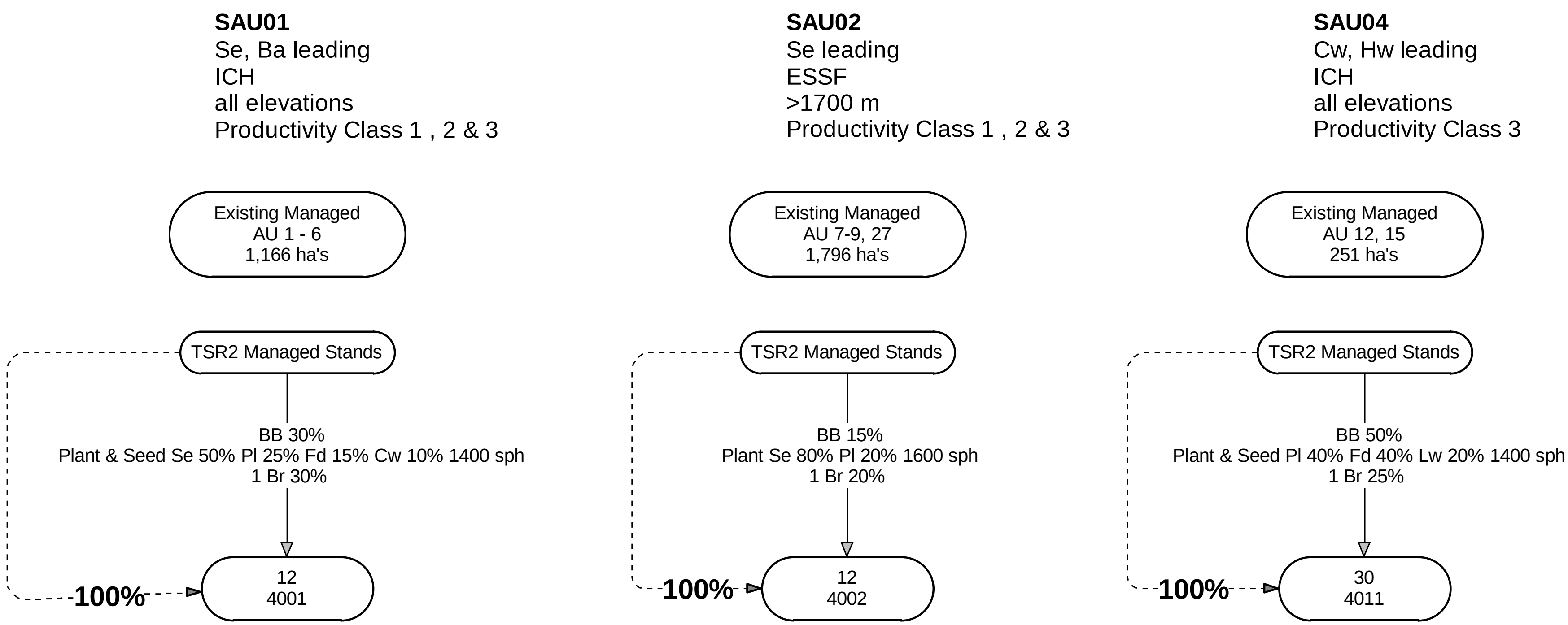
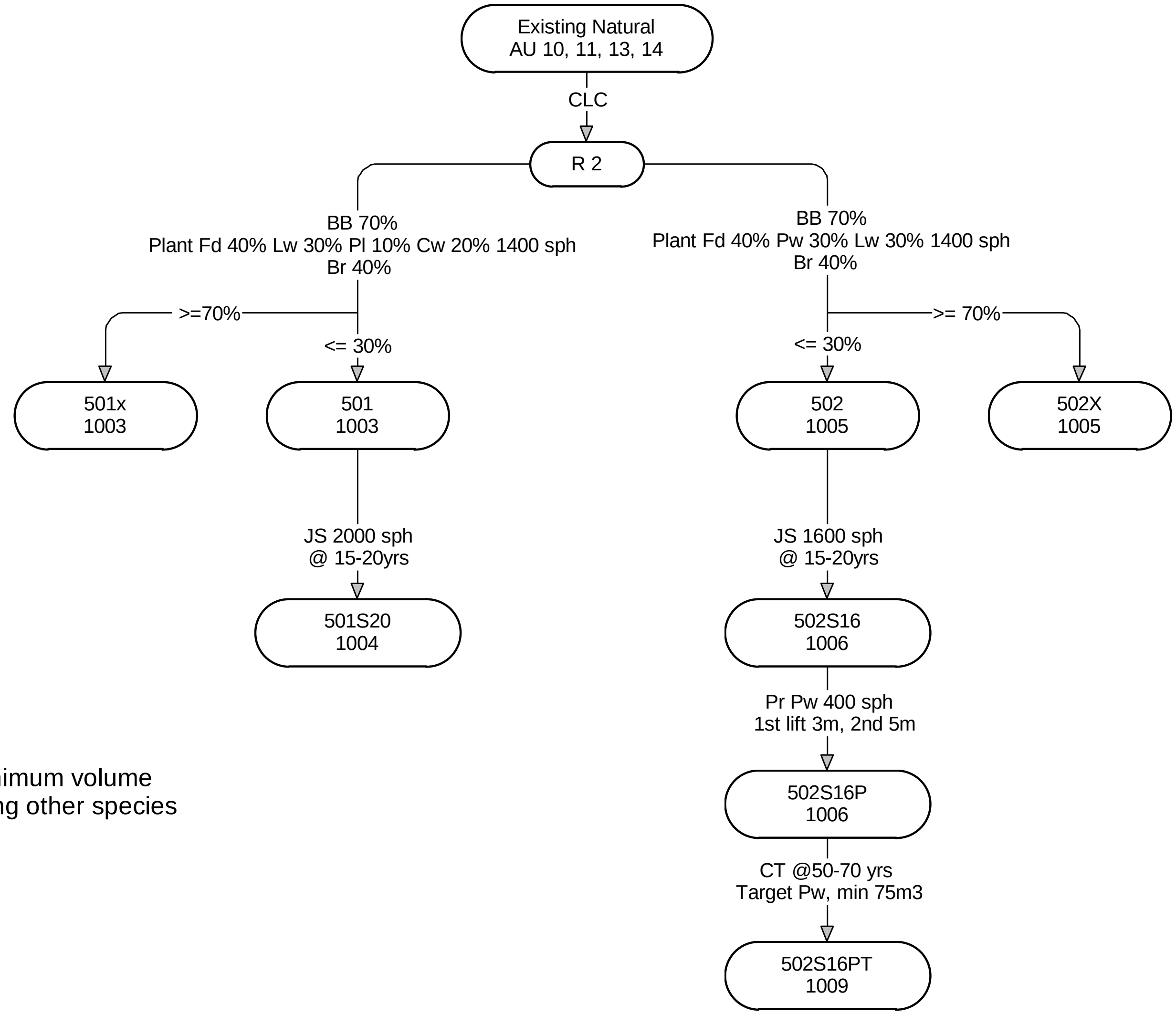


Figure B-3. SAU3 Alternate Development Pathways for Existing Natural Stands

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

SAU03
Cw, Hw leading
ICH/ESSF
all elevations
Productivity Class 1& 2
11% THLB



Notes:

The CT first attempts to harvest the minimum volume from the target species before harvesting other species

Figure B-4. SAU3 Alternate Development Pathways for Existing Managed Stands

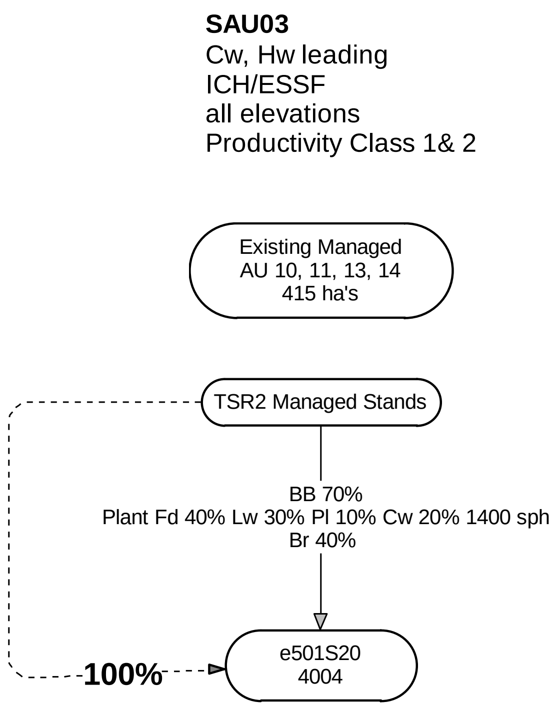


Figure B-5. SAU5 Alternate Development Pathways for Existing Natural Stands

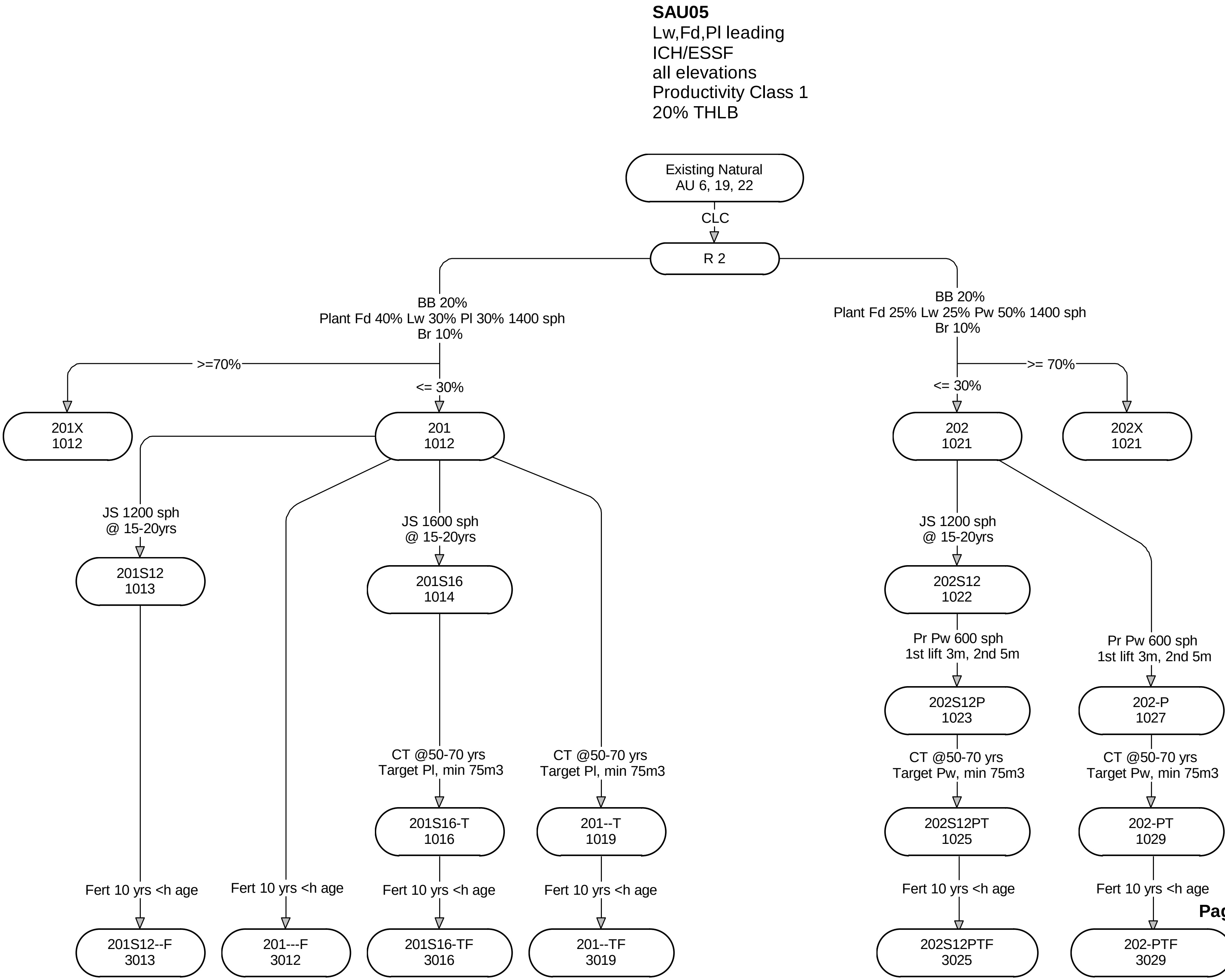


Figure B-6. SAU5 Alternate Development Pathways for Existing Managed Stands

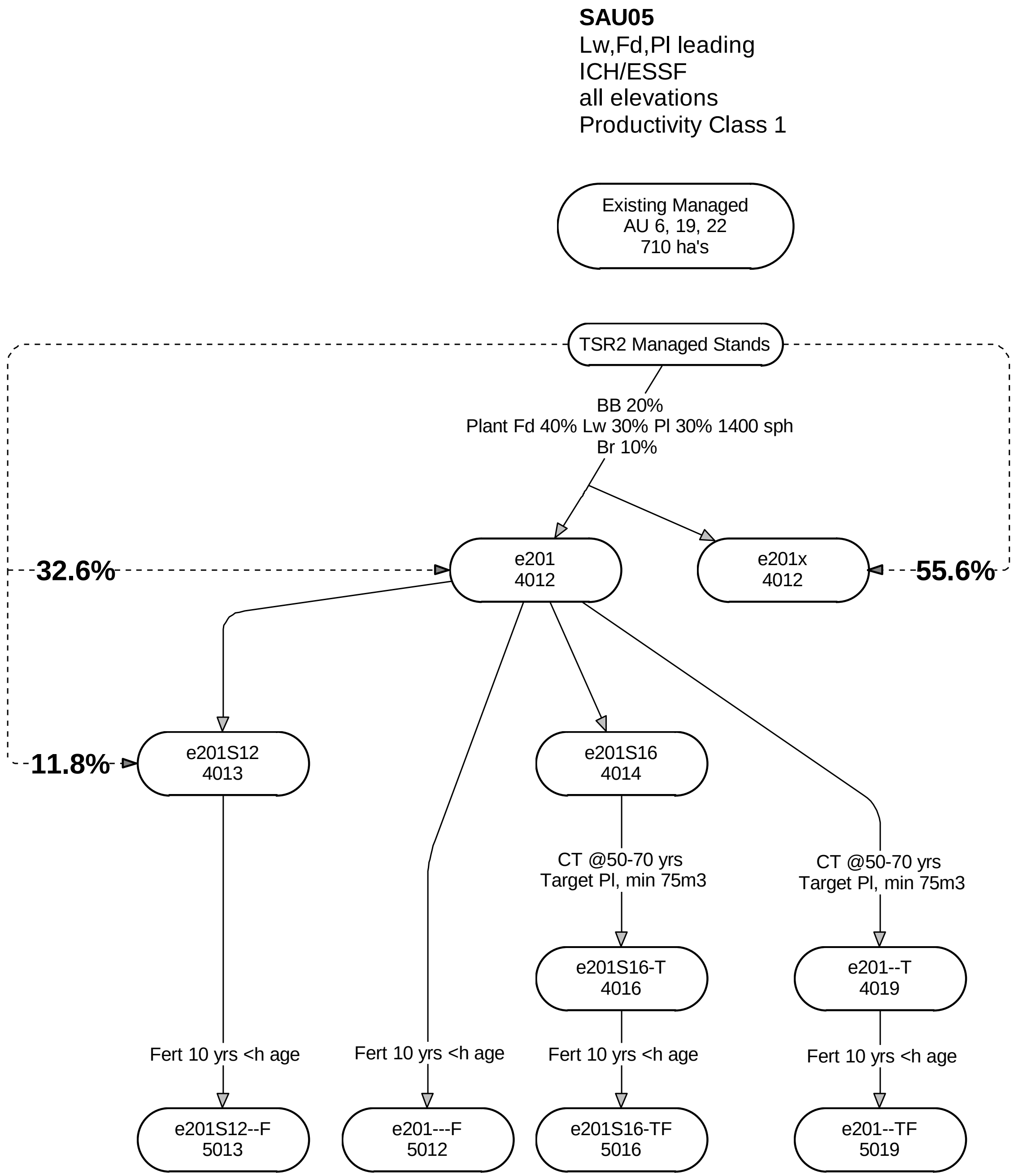


Figure B-7. SAU6 Alternate Development Pathways for Existing Natural Stands

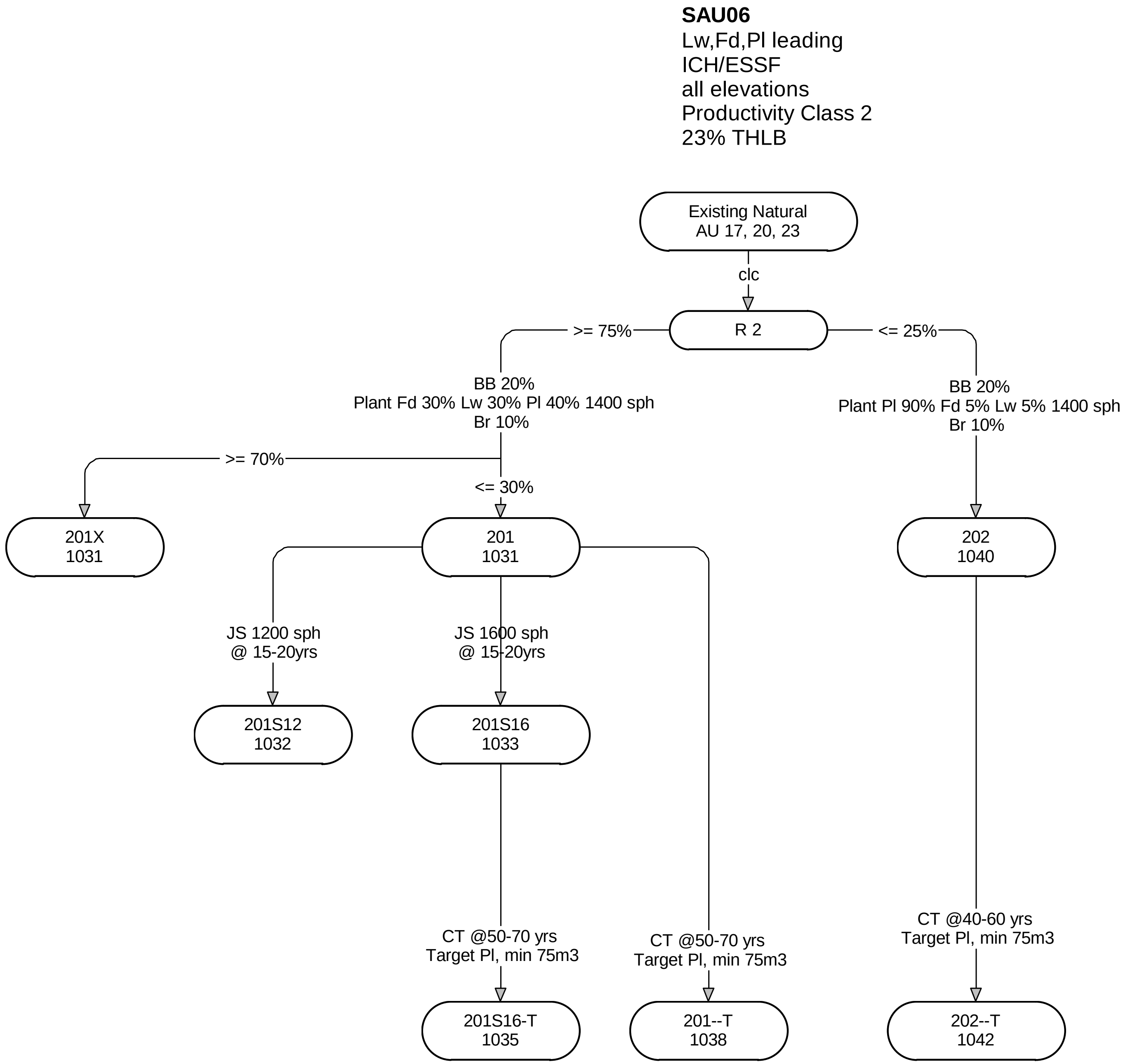


Figure B-8. SAU6 Alternate Development Pathways for Existing Managed Stands

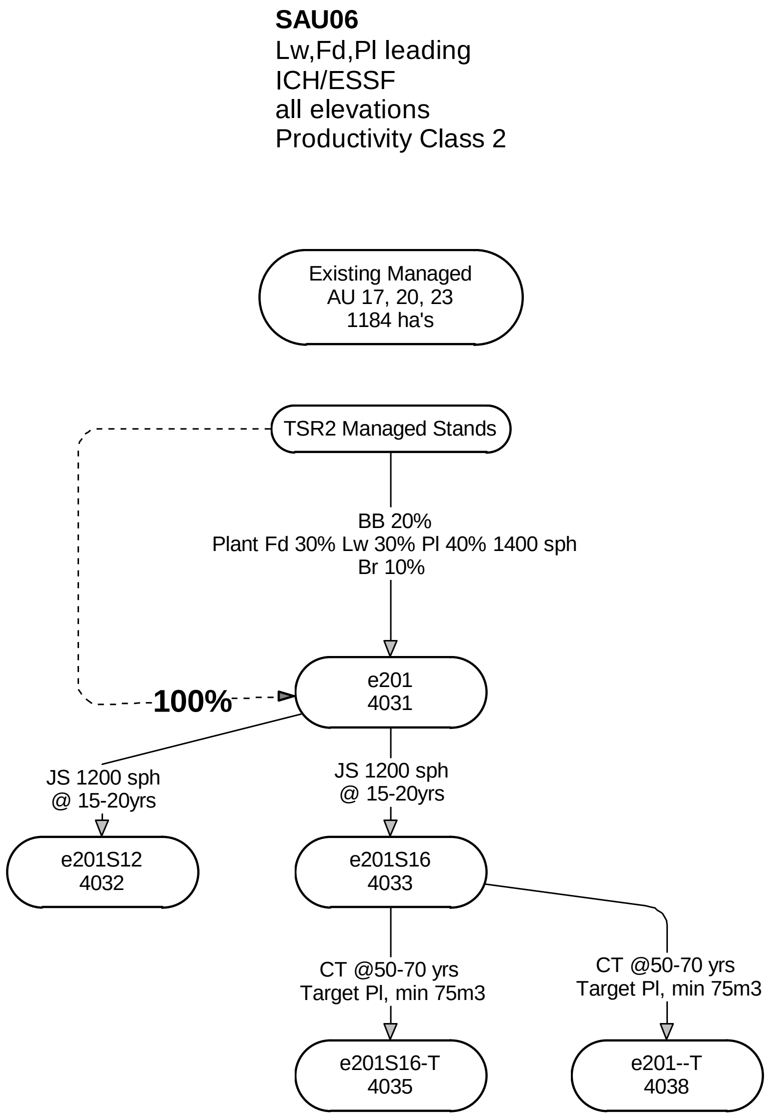


Figure B-9. SAU7,8 Alternate Development Pathways for Existing Natural Stands

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

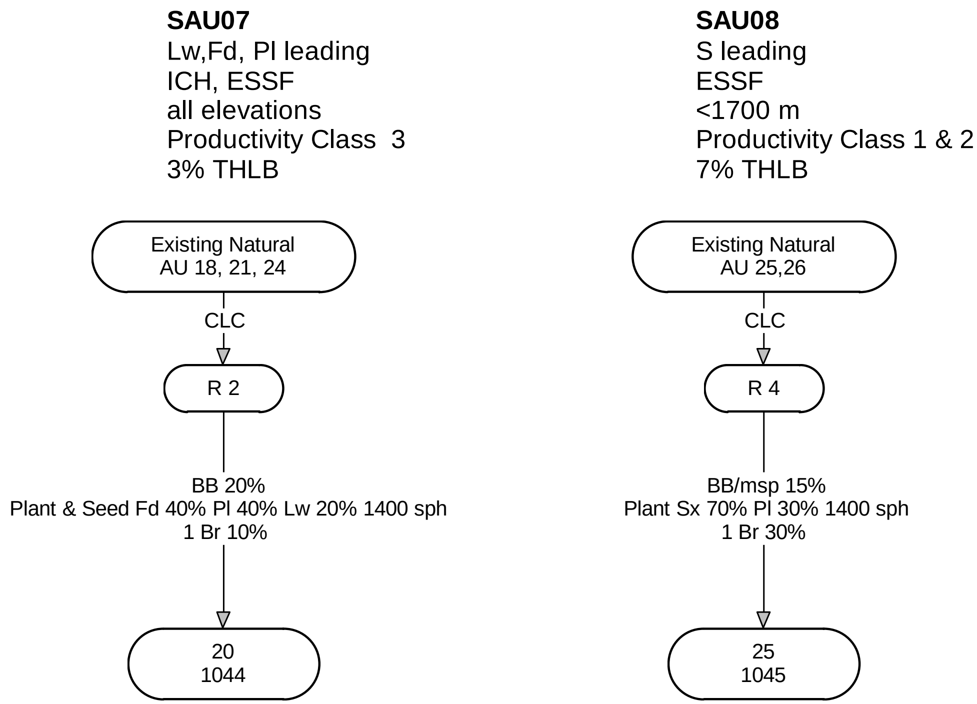
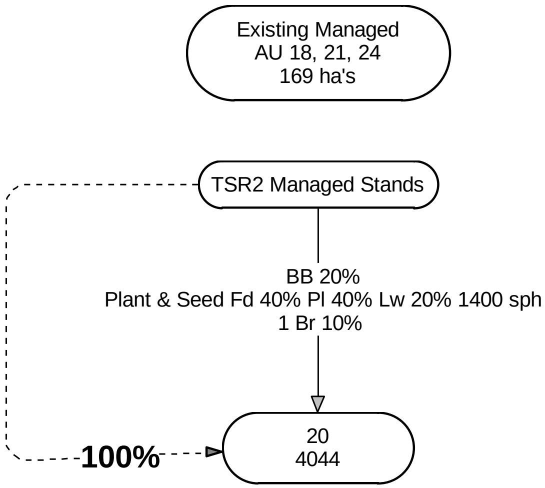
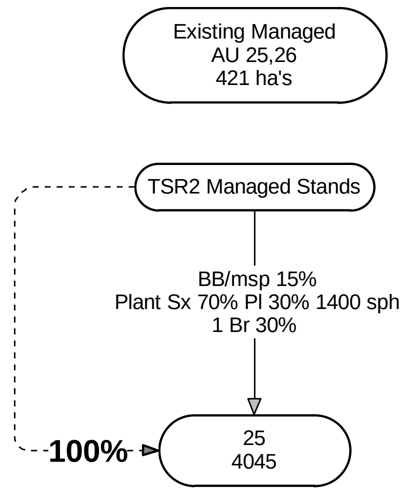


Figure B-10. SAU7,8 Alternate Development Pathways for Existing Managed Stands

SAU07
Lw,Fd, Pl leading
ICH, ESSF
all elevations
Productivity Class 3



SAU08
S leading
ESSF
<1700 m
Productivity Class 1 & 2



Appendix C — Genetic Gain

The forecast gain in volume from improved seed (Table C-1) for TFL 3 was obtained from the Forest Genetics Council and Slocan Forest Products Ltd. The gain forecast for 2010 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 TFL and the proportion of the TFL in each elevation zone (Table C-2).

Table C-1. Forecast genetic gain, TFL 3. (Source: FGC)

Species	Seed Zone	Availability date	Elevation (m)	% Elevation by species	Species % gain
Sx	NE	1995	1000-1500	59	15
Sx	NE	1995	>1500	41	18
Lw	NE	2000	<1300	100	7
Fdi	NE	2003	<1000	100	26
Fdi	NE	2003	>1000	0	22
Pli	NE	2000	<1400	100	7
Pw	NE	2010	no data	no data	no data

Data obtained from "Impact of the Current and Planned Seed Orchard Program on Timber Flow in the Arrow TSA Spetember 1, 2000"
% Elevation by species obtained from inventory file

Table C-2. Forecast genetic gain by silvicultural analysis unit.

SAU		Species	Species %	Elevation	% Elevation	% Gain	% Gain by Elevation	Species % Gain
SAU1	SB, ITG=18-26, ICH,	Se	50	<1500	59	15	8.9	
	all sites, WSI=18.4			>1500	41	18	7.4	
	Se50Pl25Fd15Cw10						**16.2**	**8.1**
		Pli	25	<1400	69	7	4.8	
				>1400	31	0	0.0	
							4.8	**1.2**
		Fdi	15	<1000	100	26	**26.0**	**3.9**
		Cw	10	no data	0	0	**0.0**	**0.0**
							% Gain SAU1	**13.2**
SAU2	SB, ITG=18-26, ESSF,	Se	80	<1500	59	15	8.9	
	all sites, WSI=14.8			>1500	41	18	7.4	
	Se80Pl20						**16.2**	**13.0**
		Pli	20	<1400	69	7	4.8	
				>1400	31	0	0.0	
							4.8	**1.0**
							% Gain SAU2	**14.0**
SAU3	C,H ITG=9-17 ESSF	Fdi	40	<1000	100	26	**26**	**10.4**
	all sites WSI=20.6	Lw	30	<1300	100	7	**7**	**2.1**
	Fd40Lw30Pl10Cw20	Pli	10	<1400	69	7	4.8	
				>1400	31	0	0.0	
							4.8	**0.5**
		Cw	20	no data	0	0	**0.0**	**0.0**
							% Gain SAU3, Fd40Lw30Pl10Cw20	**13.0**
	Fd40Pw30Lw30	Fdi	40	<1000	100	26	**26**	**10.4**
		Pw	30	no data	0	0	**0.0**	**0.0**
		Lw	30	<1300	100	7	**7**	**2.1**
							% Gain SAU3, Fd40Pw30Lw30	**12.5**
SAU4	CH, ITG=9-17 SI<20, ICH ESSF,	Pli	40	<1400	69	7	4.8	
	WSI=17			>1400	31	0	0.0	
	Pl40Fd40Lw20						**4.8**	**1.9**
		Fdi	40	<1000	100	26	**26.0**	**10.4**
		Lw	20	<1300	100	7	**7**	**1.4**
							% Gain SAU4	**13.7**
SAU5	SAU05: Fd ITG=1-8,27-34 ICH,	Fdi	40	<1000	100	26	**26.0**	**10.4**
	ESSF SI>20 WSI=22.2	Lw	30	<1300	100	7	**7**	**2.1**
	Fd40Lw30Pl30	Pli	30	<1400	69	7	4.8	
				>1400	31	0	0.0	
							4.8	**1.4**
							% Gain SAU5, Fd40Lw30Pl30	**13.9**
	Fd25Lw25Pw50	Fdi	25	<1000	100	26	**26.0**	**6.5**
		Lw	25	<1300	100	7	**7**	**1.75**
		Pw	50	no data	0	0	**0**	**0**
							% Gain SAU5, Fd25Lw25Pw50	**8.3**
SAU6	Fd ITG=1-8,27-34 ICH,ESSF	Fdi	30	<1000	100	26	**26.0**	**7.8**
	16<=SI<=20 WSI=18	Lw	30	<1300	100	7	**7**	**2.1**
	Fd30Lw30Pl40	Pli	40	<1400	69	7	4.8	
				>1400	31	0	0.0	
							4.8	**1.9**
							% Gain SAU6, Fd30Lw30Pl40	**11.8**
	Pl90Fd5Lw5	Pli	90	<1400	69	7	4.8	
				>1400	31	0	0.0	
							4.8	**4.3**
		Fdi	5	<1000	100	26	**26.0**	**1.3**
		Lw	5	<1300	100	7	**7**	**0.4**
							% Gain SAU6, Pl90Fd5Lw5	**6.0**
SAU7	Fd, ITG=1-8 27-34, ICH ESSF,	Fdi	40	<1000	100	26	**26.0**	**10.4**
	SI<15, WSI=13.8	Pli	40	<1400	69	7	4.8	
	Fd40Pl40Lw20			>1400	31	0	0.0	
							4.8	**1.9**
		Lw	20	<1300	100	7	**7**	**1.4**
							% Gain SAU7	**13.7**
SAU8	SB, ITG=18-26, ESSF, SI>=16,	Sx	70	<1500	59	15	8.9	
	<1700m, WSI=20			>1500	41	18	7.4	
	Sx70Pl30						**16.2**	**11.4**
		Pli	30	<1400	69	7	4.8	
				>1400	31	0	0.0	
							4.8	**1.4**
							% Gain SAU8	**12.8**

Appendix D – Analysis Method

The key component of the analysis method the development a silvicultural planning model that is consistent with the MP 9 timber supply analysis model and base case for TFL 3, 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 MP 9 base case if incremental silviculture activities are turned off (i.e., the silviculture budget is constrained to $0). 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 TFL from the silviculture treatments specified for each SAU.

3.1 Develop a LP Model of the TSR Base Case

The silviculture model is constructed with Woodstock/LP

One of the major differences between this analysis and the MP 9 timber supply analysis is the choice of the forest estate model. While MP 9 uses 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.

3.2 Implement Silviculture Activities in the Forest-Level Model

Regime diagrams are the "blueprint" for the 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.

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[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 a summed to the appropriate objective functions in the model.

3.3 Implement Forest Level Objectives

Multiple objectives guide the analysis

Each forest-level objective must be implemented in the silviculture planning. The current version of the TFL 3 model has two objectives implemented:

- maximize a priority-structured harvest schedule
- minimize the deviation from a specified product mix

The priority-structuredobjective 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.

3.4 Implement Management Rules as LP Constraints

Forest cover constraints

Forest cover constraints, as specified in TSR2, are represented explicitly in the LP model of the base case.

Harvest-flow guidelines

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 TSR2 base case, the following constraints were added to the model.

decade 1:	annual harvest = the current AAC (1998) of 80 000m³
decade 2:	annual harvest ≤ annual harvest decade 1
decade 3-5:	annual harvest ≥ 88% of annual harvest previous decade
decade 6 –25:	annual harvest ≥ annual harvest of previous decade

Disturbance constraints

Constraints on the area disturbed (not “greened up”) and old growth in the management zones recognized in the TSR are applied.

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) from periods 21 to 25 must be non-declining.

Harvest profile

The first-decade harvest profile (Section 2.4) for clear cutting is 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 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. TSR2 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. TSR2 Base Case excluding backlog NSR – This scenario excludes backlog NSR and does not assume that this area will be included in the THLB. The management objective is to maximize priority-structured timber supply.

S03. 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.

S04. 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.

S05 Maximum Harvest Volume– 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.

S08 Product Mix Scenario– This scenario attempts to meet a product mix specified by the TFL:

Product	Target (% of total harvest)
Clear sawlogs	15
Cedar poles	5
Log peelers	10
White pine	5
Regular sawlog	65

This scenario is evaluated while constraining the forecast harvest to:

- S05 maximum volume production
- TSR 2 harvest level
- 60% of S05