Weyerhaeuser Company Limited

Tree Farm Licence 39

Type 2 timber supply analysis
in support of an

Incremental Silviculture Program

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Executive Summary

This report describes a Type 2 timber supply analysis of incremental silviculture opportunities in TFL 39, held by Weyerhaeuser Company Ltd. The analysis uses the Forest Service Simulator (FSSIM) to assess interactions between silviculture and timber supply. The analysis assumes static, current conditions for relative timber values and social use of the forest.

The analysis inspects a broad range of incremental silviculture treatments, as identified at two workshops held with Forest Renewal BC, Ministry of Forests and Weyerhaeuser foresters. Specific treatments and treatment combinations (regimes) are tested for their ability to meet timber quality, harvest level, and wildlife habitat objectives. Some treatments are found to have negative impacts, while others are substantially positive. Table 9 provides a ranking of the treatment alternatives.

The analysis demonstrates that if all identified suitable forest areas were treated according to discussions at the workshop and corresponding assumptions in the analysis, $16.1 million might be spent annually in TFL 39 on incremental silviculture activities. From among these candidate investments, a recommended silviculture program with a budget of $3.8 million is presented in Table 11. This budget level is a 25% increase from recent silviculture levels in TFL 39.

Investment of $3.8 million will increase future harvest levels by 3.4%, or 114,000 m^3/yr. The investment will also improve visual scenery values. Approximately 15% of the budget is allocated to wildlife habitat restoration. Incremental silviculture activities will directly create an estimated 35 full time equivalent jobs. Increased harvest levels will result in 210 direct and indirect jobs within 20 years and 480 jobs in the longer term. Including income taxes and stumpage fees, government will realize a return of $7.8 million from the investment.

There are many uncertainties inherent in such an analysis, including stand responses to silviculture, selection of appropriate treatment areas, and economic assumptions projected over long time horizons. The analysis attempts to make reasonable estimates within the scope of the existing information.

Acknowledgements

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1. Introduction and Basic Data

Tree Farm Licence (TFL) 39 is held by Weyerhaeuser Company Ltd. As part of its licence obligations, Weyerhaeuser must submit to government every five years a management plan that describes conditions and planned activities within TFL 39. This report, funded by Forest Renewal BC, partial fulfills of those obligations.

This report describes a Type 2 timber supply analysis of incremental silviculture opportunities in TFL 39. A Type 1 analysis uses existing published documents to estimate potential gains and budgets for silviculture investment. A Type 2 analysis uses a standard model to explicitly test interactions between silviculture activity and timber supply. A Type 3 analysis develops custom models to assess habitat conditions and other forest attributes that may be influenced by silviculture.

The analysis uses the Forest Service Simulator (FSSIM) to assess interactions between silviculture and timber supply. FSSIM models of each timber supply block in TFL 39 were developed in the summer of 2000 as part of the Management Plan #8 (MP#8) analysis for the Timber Supply Review (TSR2). The same models were then expanded to include silviculture treatments of interest to this project and Weyerhaeuser. Expansions added ability to track log size and quality, thinning yields, budget expenditures and job creation. All the components of the TSR2 models, including compliance with Forest Practices Code forest cover requirements and recognition of Weyerhaeuser's forest stewardship practices were retained in the models.

TFL 39 is modelled as six separate sustained yield units. Fifteen silviculture scenarios were modelled in some units, and five attributes were reported for most scenarios. A data CD, attached as Appendix 4, includes maps of the blocks and detailed graphical summaries of inputs and outputs for the analysis, organized with an HTML interface for easy viewing with a web browser.

Managing a forest for product objectives is a very long-term issue. The shortest time to harvestable return on investment in the analysis is 7–21 years for aerial fertilization. Many treatments, such as prompt stand establishment, have an investment horizon of 50 years or more. Market conditions and social preferences can change dramatically over that length of time. Unable to predict the direction of change, this analysis assumes static, current conditions for relative timber values and social use of the forest.

The timber supply analysis report for MP#8 (September 2000) is included on the data CD. This section presents highlights from that report describing the TFL 39 land base and the base case results of the timber supply analysis. Section 2 of this report highlights some sensitivity analyses in the MP#8 analysis that may be interpreted for assessment of silviculture issues. This analysis may be considered an extension of the MP#8 analysis, which together with the map-based 20-year plan, forms a cohesive description of management direction in TFL 39. Figure 1 illustrates the location of TFL 39 on the coast of British Columbia.

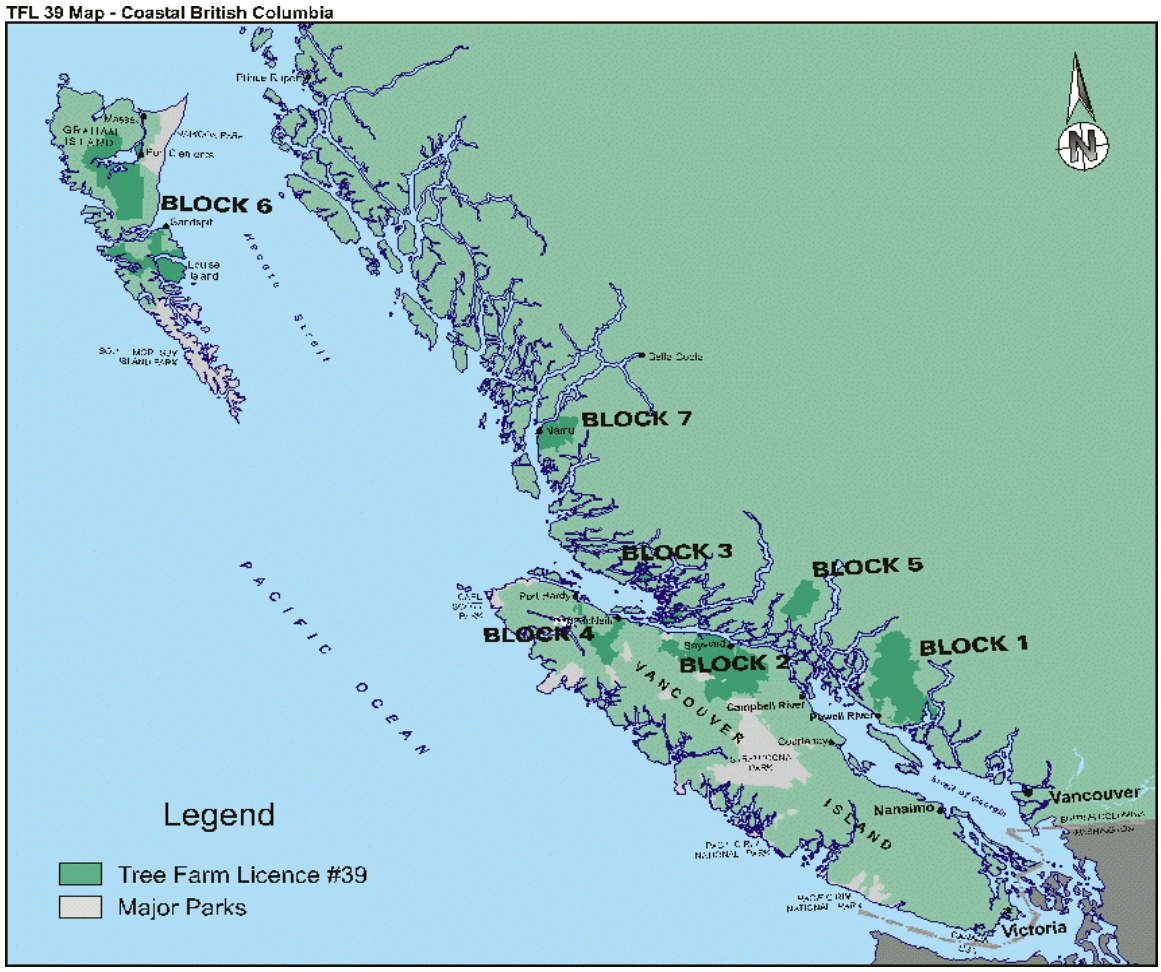


FIGURE 1. Key map to the location of supply blocks in TFL 39.

1.1 Description of TFL 39

TFL 39 consists of seven supply blocks on the coast of British Columbia, from north of Vancouver to west of Bella Coola, with units on Vancouver Island, the south and mid coasts, the Queen

Charlotte Islands, and smaller islands along the coast. TFL 39 is managed by four Weyerhaeuser timberlands operations; Queen Charlotte (Queen Charlotte Islands), Port McNeill, North Island (north of Campbell River), and Stillwater (Powell River). Figure 1 shows a key map of the supply blocks. TFL 39 is divided into six working circles (Blocks 3 and 4 are combined into one working circle). This analysis separately models current management within each working circle and reports aggregated results.

TFL 39 covers 801,393 ha in total, of which 68% is stocked with productive forest. The majority of this area is in the Coastal Western Hemlock biogeoclimatic zone, with some higher elevation areas in the Mountain Hemlock zone. The dominant tree species is western hemlock, although stands of Douglas-fir are common in southern areas. The total area considered available and suitable for timber production is 369,970 ha, which is 67% of the productive forest and 46% of the total TFL 39 area. Approximately 43% of the area suitable and available for timber production is presently stocked with old-growth stands, and the remaining 57% is stocked with regenerating forest up to 130 years of age.

The annual allowable cut (AAC) for TFL 39 is 3.74 million m^3/yr. This harvest rate is apportioned among the supply blocks as listed in Table 1.

TABLE 1. Administration and allowable annual cut apportionment for TFL 39.

Supply Block	Block Name	MoF Forest District	Weyerhaeuser Operations	AAC contribution (m^3/yr)
Block 1	Powell River	Sunshine Coast	Stillwater	445,000
Block 2	Adam River	Campbell River	North Island	1,335,000
Block 3|4	Coast Islands|Port Hardy	Port McNeill	Port McNeill	415,000
Block 5	Phillips River	Campbell River	Stillwater	100,000
Block 6	Queen Charlotte Islands	Queen Charlotte	Queen Charlotte	1,210,000
Block 7	Namu	Mid-Coast	Port McNeill	195,000
Sub-total	TFL 39			3,700,000
Deciduous	(Not block specific)			40,000
Total AAC	TFL 39			3,740,000

Weyerhaeuser maintains the land base and forest inventory information for TFL 39 in a geographic information system (GIS). The inventory describes in great detail the geographic location, area and nature of forest cover and administrative boundaries. The inventory includes information for all areas within TFL 39. However, many areas do not contribute to the timber harvesting land base (THLB). These areas are sequentially removed in a netdown process when building the THLB description for the timber supply models. Table 2 summarizes the netdowns for each working circle.

TABLE 2. Derivation of the timber harvesting land base

Netdown category	Block 1 (ha)	Block 2 (ha)	Block 3|4 (ha)	Block 5 (ha)	Block 6 (ha)	Block 7 (ha)	TFL 39 (ha)
TFL 39 total area	**186,979**	**203,065**	**67,288**	**47,411**	**240,311**	**56,339**	**801,393**
Non-forest	34,983	4,756	3,518	12,731	12,112	6,169	74,269
Non-productive	55,562	28,031	8,364	19,588	35,163	20,283	166,991
Permanent roads	1,893	4,414	1,663	298	3,460	164	11,892
Productive forest	**94,542**	**165,864**	**53,743**	**14,793**	**189,576**	**29,723**	**548,241**
Inoperable	4,349	6,985	501	1,739	1,135	1,388	16,096
Environmentally sensitive	7,331	19,514	3,333	2,836	28,863	5,680	67,556
Mapped riparian	2,972	5,567	2,060	348	9,284	1,032	21,264
Uneconomic	1,382	2,003	1,077	315	7,909	2,950	15,636
Deciduous	1,189	744	139	17	833	2	2,924
Unmapped riparian	773	1,310	466	95	1,416	187	4,247
Wildlife tree patches	2,295	3,113	1,496	189	2,803	185	10,081
Variable retention patches	4,187	9,376	2,328	1,169	15,251	5,105	37,415
Culturally modified trees	0	0	0	0	3,052	0	3,052
Net current THLB area	**70,064**	**117,251**	**42,343**	**8,086**	**119,030**	**13,196**	**369,970**
Less future roads	2,003	3,063	810	89	4,061	420	10,446
Long-term THLB area	**68,061**	**114,188**	**41,533**	**7,997**	**114,969**	**12,776**	**359,524**

Figure 2 shows the present composition of forests within the THLB by leading species and site class, and whether old- or second-growth timber. The two species groups are modelled. The Douglas-fir group includes lodgepole pine and yellow-cedar stands, and the hemlock group includes spruce, balsam fir and western redcedar. Four site classes are defined in the models: high (SI 33+), good (SI 27-30), medium (SI 21-24), and poor (SI 12-18). The THLB is presently stocked 82% with hemlock and 18% with Douglas-fir. The THLB is 22% high site, 41% good site, 24% medium site, and only 12% poor site. Younger stands generally occur on the better growing sites within the THLB.

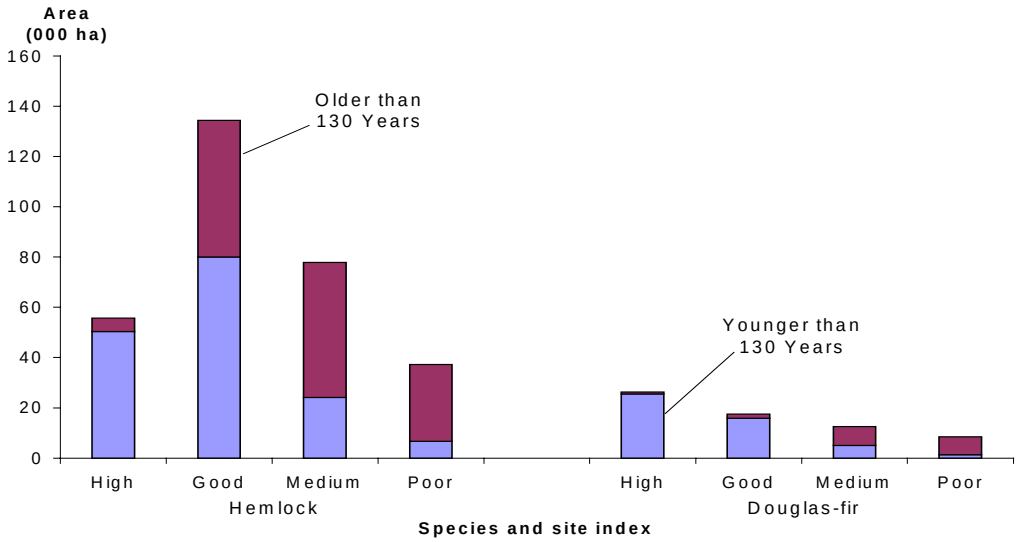


FIGURE 2. THLB area distribution by species and site index.

Figure 3 illustrates the distribution of area within the THLB by age class. The older forest (>130 years) occupies 43% of the THLB area and is 90% hemlock. Older second-growth (ages 33–130 years) occupies 25% of the THLB and is 68% hemlock. The youngest class of forest (less than 33 years old) occupies 31% of the THLB and is 84% hemlock. The Douglas-fir inventory mainly occurs (46%) in the 33–130 yr age class.

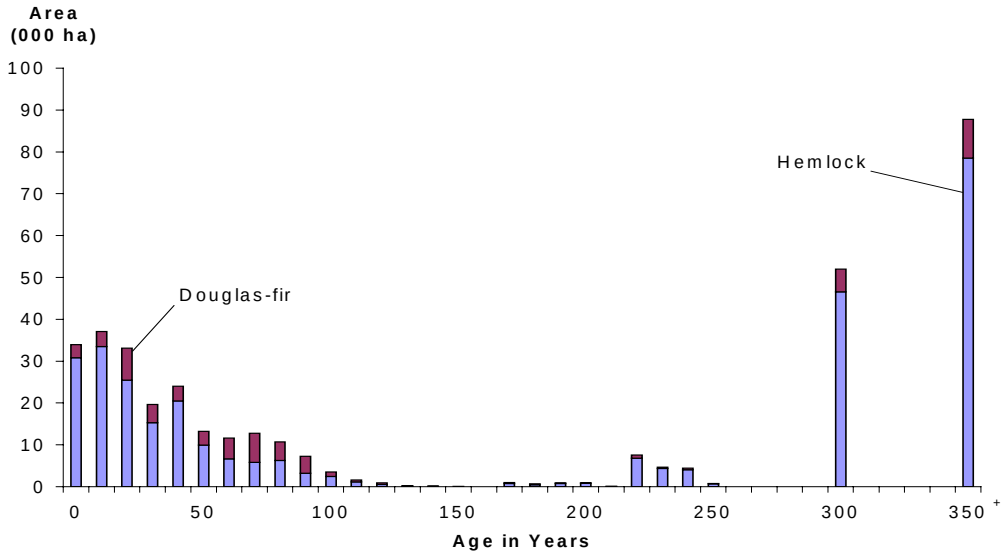


FIGURE 3. THLB age class distribution.

1.2 Timber growth and yield

The Weyerhaeuser in-house growth and yield model Y-XENO was used to develop estimates of existing timber volumes, future regenerated volume development and responses to silviculture treatments. Y-XENO is calibrated to approximately 2,200 company growth and yield plots in coastal British Columbia, 900 of which are located within TFL 39. Most of the plots are located in Douglas-fir and hemlock stands. Y-XENO accepts inputs for species, growing site quality, establishment density, establishment site occupancy, planted and natural stand establishment, and thinning and spacing treatments. Y-XENO simulates growth of an individual stand according to the input parameters, and reports total and merchantable volumes, average stand diameters, height, basal area, and stocking over time.

Yield adjustments (reductions) applied to the Y-XENO yield tables include losses for decay, waste and breakage (Douglas-fir 5%, hemlock 6.5%), losses to insects (2%), and deductions for incomplete stocking (6% in Blocks 1 and 5, 4% elsewhere). The yield tables assigned to future regenerated stands are additionally reduced by 30% in the Old Growth zone, 11% in the Habitat zone, and 3% in the Timber zone to account for competition effects from in-block variable retention patches. For the base case, yields for future planted stands assume genetic gains of 13% for Douglas-fir and 6.5% for hemlock.

Stocking levels in stands regenerating after harvest are modelled according to a biological probability matrix. Weyerhaeuser has developed a set of assignment matrices that describe the probabilities of a regenerating stand developing along particular pathways. Each stand type (species and geographic location) may have up to 10 post-harvest development pathways. Using local knowledge and professional judgement, Weyerhaeuser has developed a grid of assignment probabilities for the proportion of each stand that would follow each pathway. Some pathways involve planting with varying degrees of natural in-seeding, while other pathways consist of varying degrees of low-, medium-, or high-density natural regeneration.

Timber stands must reach 350 m^3/ha before being harvested in the timber supply model. This volume is achieved by 40 years of age on some high-site hemlock stands, and not until 200 years of age for lower-density poor-site Douglas-fir stands.

1.3 Base case harvest forecast

The TFL 39 harvest flow was modelled in five-year periods for the first 20 years and in decades for subsequent planning periods. Figure 4 shows the base case harvest forecast for TFL 39. An initial harvest level of 3.66 million m^3/yr is maintained for the first 5-year period. This is followed by an orderly decline in the harvest level, to a long-term sustainable level of 3.33 million m^3/yr, 9.1% lower than the starting level. The harvest level declines at an average rate of 1.3% per 5-year period. Unsalvaged losses to natural forces such as insects, fire, windthrow, and disease are

estimated to be 36,600 m³/yr (1% of the harvest level) and have been subtracted from all harvest forecasts shown in this report.

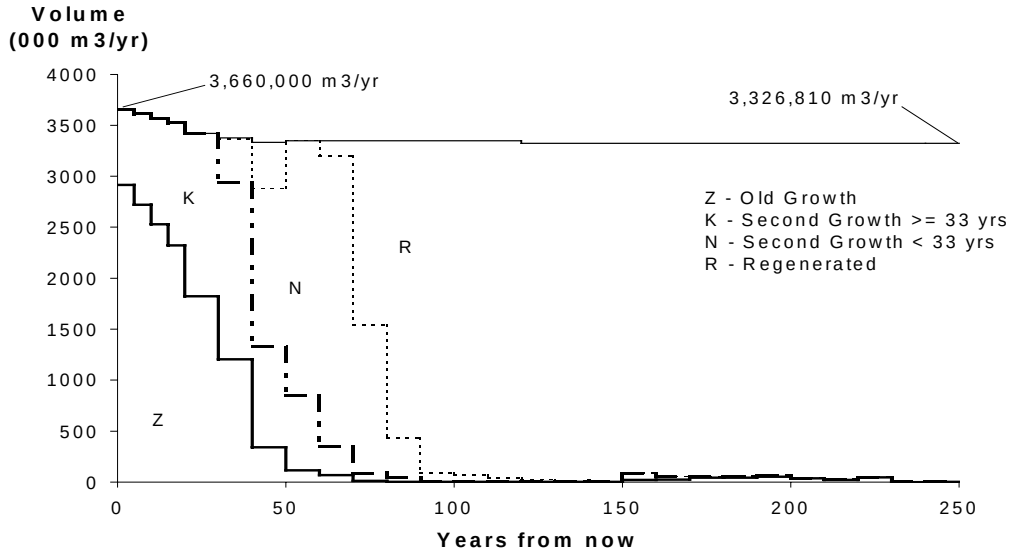


FIGURE 4. Base case harvest forecast for TFL 39.

Figure 4 also illustrates the transition from the harvest of old-growth timber stands to the harvest of managed second-growth stands. In the first period the harvest consists of 2.92 million m³/yr of old-growth timber and 0.74 million m³/yr of older second-growth timber. The ratio of old-growth harvesting to second-growth harvesting is 80:20. By 20 years from now the ratio becomes 53:47; thereafter second-growth harvesting contributes the majority of the cut.

Figure 5 illustrates the standing inventory (growing stock) and the changing composition of the future forest under the base case harvest flow. The categories in Figure 5 identify the forest according to stand ages now. For example, at year 50 in the planning horizon, the area identified as “N”, which then constitutes 50% of the TFL 39 growing stock, would be 50 to 83 years old. The volume of standing growing stock stabilizes at 117 million m³, down 23% from the current standing volume of 151 million m³. The long-term growing stock divided by the long-term harvest level (117/3.33 = 35) indicates a conservative ratio of forest conditions in TFL 39 — on average, 35 year’s worth of harvest volume is standing in the forest at any time in the long term.

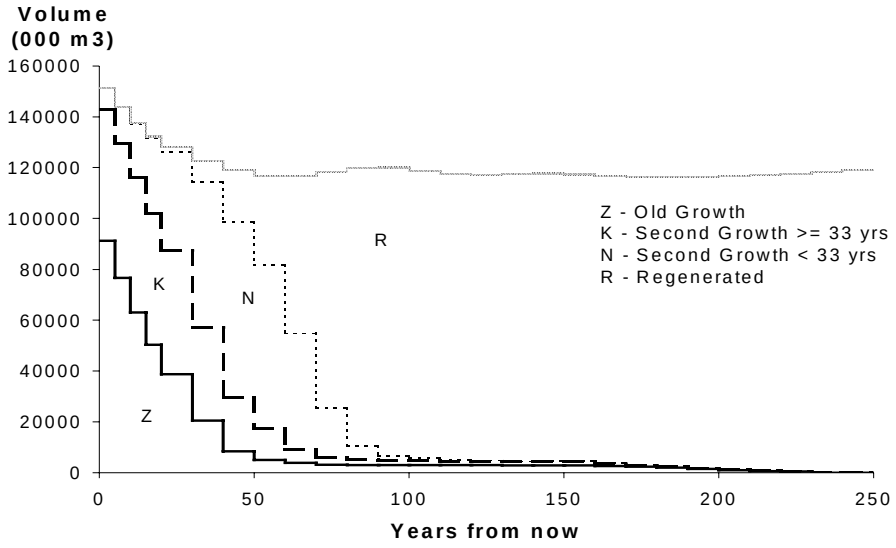


FIGURE 5. Growing stock levels over time for the base case.

Table 3 summarizes the MP#8 base case short- and long-term harvest flows for each supply block. Refer to Table 2 for land base area summaries. The MP#8 report contains graphs for each supply block similar to Figures 4, showing the transition of harvesting from old- to second-growth timber. These modelled harvest levels form the base case for the present analysis.

TABLE 3. Summary of short- and long-term base case harvest levels by block.

Supply block	**First-period harvest level (m^3/yr)**	**Long-term harvest level (m^3/yr)**	**Difference: first-period vs. long-term (%)**
Block 1	550,000	668,316	21.51
Block 2	1,335,000	1,079,207	-19.16
Block 3|4	400,000	400,000	0.00
Block 5	95,000	72,397	-23.79
Block 6	1,150,000	1,029,702	-10.46
Block 7	130,000	77,189	-40.62
Total TFL 39	3,660,000	3,326,811	-9.10

1.4 Objectives of the silviculture program

1.4.1 TFL 39 objectives

The objective of Weyerhaeuser's TFL 39 silviculture plan is to ease the transition to the long-term harvest level (LTHL) and to increase the LTHL. Weyerhaeuser also wants to provide employment opportunities that are related to silviculture activities.

Weyerhaeuser recognizes that silviculture activities can enhance habitat values. Treating areas otherwise reserved, according to the availability of government funding, can enhance habitat values while also being positive to timber supply.

1.4.2 Provincial goals

Government's goals can be characterized as:

- sustainable use;
- community stability; and
- a strong forest sector.

1.4.3 Provincial objectives

Until provincial targets for timber quantity and quality are established, management unit strategies are to consider the following interim provincial strategic objectives (B.C. Ministry of Forests 1998a):

- To maintain current harvest levels as long as possible without disruptive shortfalls in future timber supply.
- To create a long-term timber supply capable of supporting a steady long-term provincial harvest level similar to current levels.
- To minimize the interim shortfall in provincial harvest anticipated before a steady long term supply is achieved.
- To create a long-term timber supply which will enable the timber quality of the future harvest to be the same or better than the current profile.

Not every management unit has the same capability to contribute to these interim objectives. Further, these objectives may not be attainable at current funding levels. Their purpose is to provide general guidance to the application of available funds.

1.4.4 Regional objectives

The objectives of the Vancouver Forest Region incremental silviculture strategy (B.C. Ministry of Forests 1998b) are to:

- Ensure a long-term sustainable harvest which approximates the current harvest value and volume levels and that produces a diversified mix of products necessary to create and maintain sustainable forest employment.
- Balance treatments that enhance growth and yield such as fertilizing and forest health activities, with those that increase the value and/or reduce harvest and processing costs of the wood such as spacing and pruning.
- Use incremental silviculture treatments to contribute to sustainable management of non-timber values at the landscape level.

2. Issues Affecting Timber Supply

2.1 Variable retention harvesting practices

Weyerhaeuser is adopting a variable retention (VR) harvesting system throughout its B.C. coastal forest operations. In VR, harvested units retain a portion of their mature forest cover within the block. Minimum retention levels are 10% for much of the Timber zone, 15% in the Habitat zone, and 20% in the harvested portion (33%) of the Old Growth zone. The base case assumed that at least half the Timber and Habitat zone retention would coincide with other netdowns listed in Table 2. Additional netdowns of 5% and 7.5% were applied to account for incremental retention because of VR in the Timber and Habitat stewardship zones, respectively. The Old Growth zone was heavily constrained for timber harvesting in the base case.

A survey of VR blocks harvested during 1999 showed that total retention averaged 19% of the gross harvested block area. This accounting included areas reserved in riparian areas, wildlife tree patches and other area netdowns as well as incremental areas reserved because of VR. An initial sample of year 2000 blocks shows a gross retention percentage of between 15% and 17%. The intention is to learn from these early experiences to fine tune retention procedures closer to the minimum requirements. In addition, survey procedures will be refined to differentiate the reasons for retention (e.g. riparian, wildlife tree patches, sensitive soils, additional VR).

Figure 6 illustrates the potential effects of VR on timber supply. The upper line shows the potential harvest level over time if VR is excluded from the base case. The VR assumptions reduced the potential by 15.8%. The lower line illustrates the effect on harvest levels of higher levels of in-block mature timber retention—resulting in a 10.1% further reduction in the LTHL.

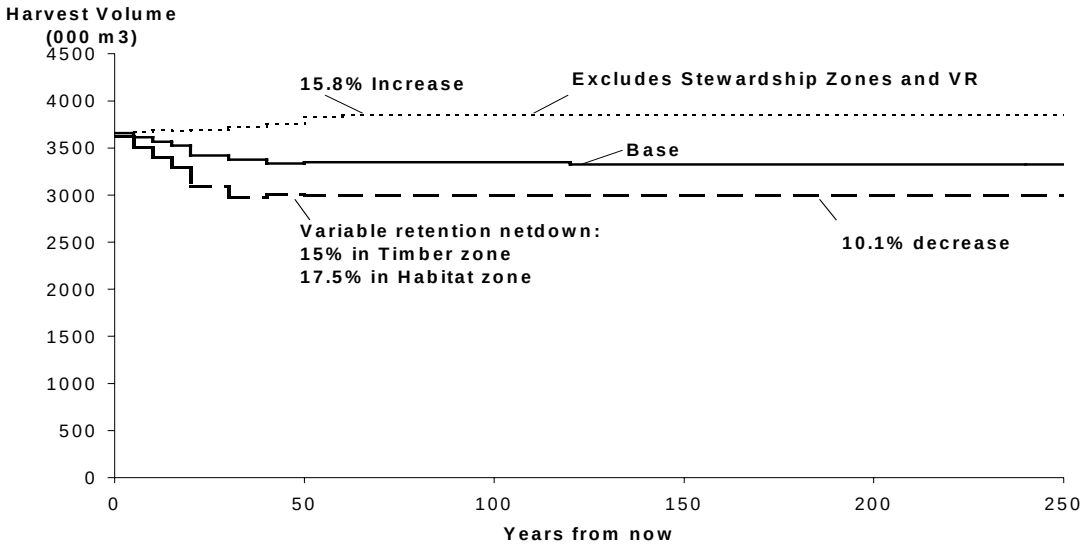


FIGURE 6. Harvest level effect of increased and decreased levels of variable retention

The VR silviculture system improves habitat values, and generally improves viewer perception of the harvested unit. In combination with developing harvesting methods (e.g. single tree harvesting by helicopter) VR provides opportunities for harvesting otherwise reserved areas without adverse impacts on important non-timber values. It also changes the nature of regenerating stands, by providing a more abundant seed source, and providing local shade and root competition. This analysis does not inspect silviculture regimes tailored to VR systems. Through an adaptive management approach, the company is presently collecting information that will lead to the evolution of second growth management around and in preparation for future VR harvesting.

2.2 Visual quality forest cover requirements

Visual landscape constraints limit the amount of area in a management unit that may be younger than the age of visually effective green-up (VEG). In the base case, VEG is achieved at 5 m height in Blocks 1–5, and 6 m height in Blocks 6 and 7. The base case assumed management to the upper end of the permitted range for each visual quality objective (VQO) class. Figure 7 illustrates that if social preference shifted management toward the low end of the permitted range for each VQO class, there would be a steeper rate of decline in harvest levels, and a timber supply shortfall 40–60 years from now. Conversely, gains from improved visual design and the contribution from VR would shift the harvest levels upward. In addition, silviculture can help offset VQO impacts by reducing the time to achieve VEG by ensuring prompt establishment and rapid early growth of regenerating forest stands.

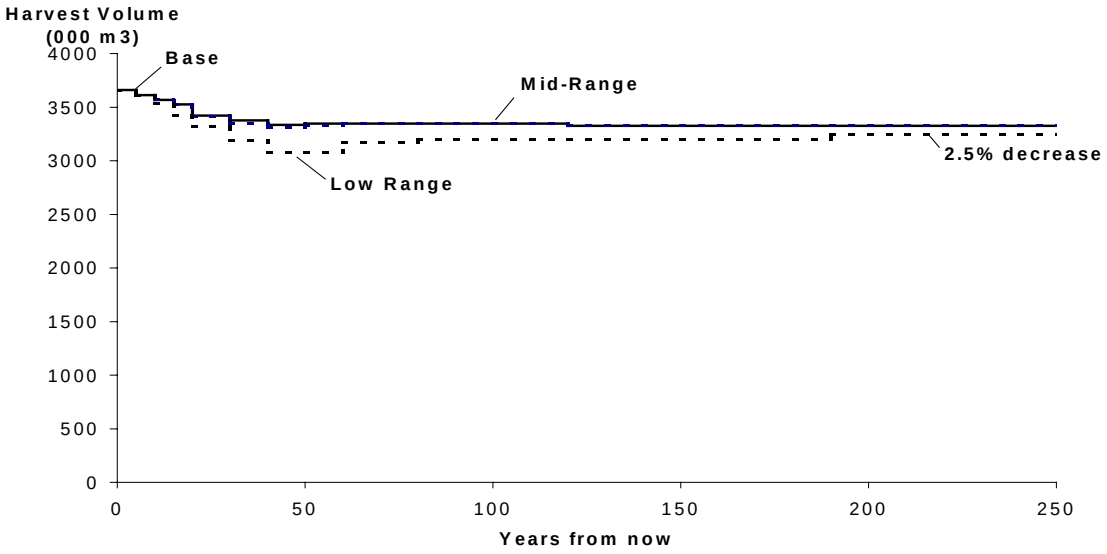


FIGURE 7. Harvest levels with more constraining visual quality requirements

2.3 Minimum harvest ages

In the base case the minimum harvest age (MHA) is set to the age when a stand achieves 350 m³/ha. Minimum harvest ages range from approximately 45 years on high growing sites, to 80–120 years on poor growing sites. Figure 8 illustrates the impact of raising the MHA by 10 years. The rate of harvest level reduction must be increased, to reserve timber supply until second-growth stands are more mature. A low point, 3% below the base case level, is reached 40 years from now. The issue here is that incremental silviculture treatments that require longer rotations will have a negative impact during the period of tight supply, expected 40–60 years from now in TFL 39.

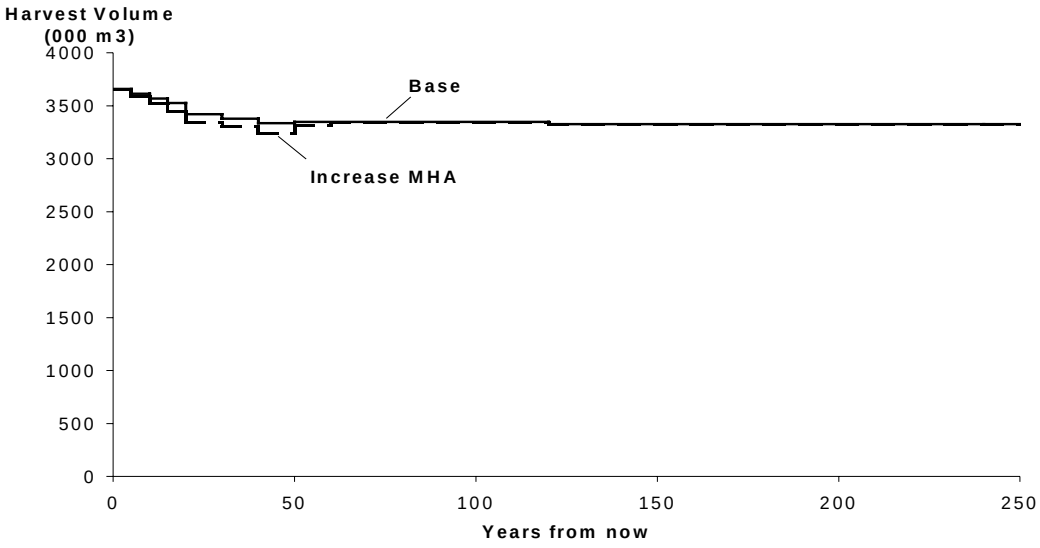


FIGURE 8. Harvest levels with minimum harvest ages increased 10 years.

2.4 Second growth volumes

Figure 9 illustrates the effect on harvest levels of a ± 10% change in assumed volumes from second-growth stands. The LTHL is effected roughly in proportion to the changed volume assumption. However, note that the increased second-growth volume (upper line in the graph) does not flow back to the early planning periods. It is still necessary to gradually reduce forecast harvest levels for the next thirty years. To fill the dip shown in the upper line of Figure 9, it is necessary to consider silviculture treatments that accelerate the volume production of existing young stands, rather than relying on future regenerated stands.

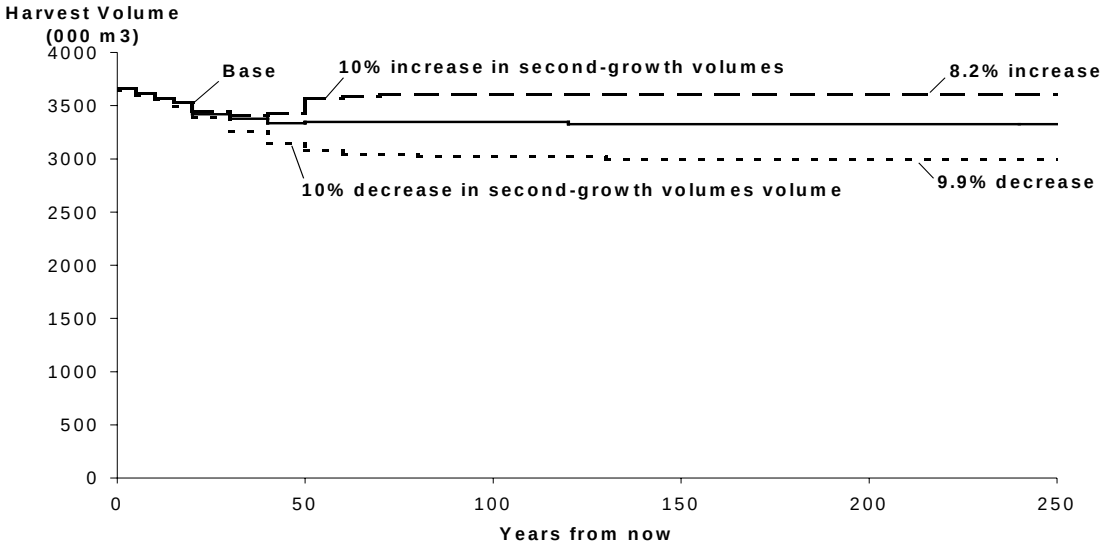


FIGURE 9. Harvest levels with second-growth volumes changed ± 10%.

2.5 Genetic gain assumptions

In the base case for MP#8, all planted stands are assumed to use genetically improved stock. The assumed gain over Y-XENO volume projections is 13% for Douglas-fir and 6.5% for hemlock. The terms of reference for this project specify that a scenario with only basic silviculture and no genetic gain be tested. Figure 10 illustrates the effect of removing the genetic gain assumption from the base case. The effect of using wild seed becomes apparent 30 years from now, and long-term harvest levels are 4.8% lower than the base case.

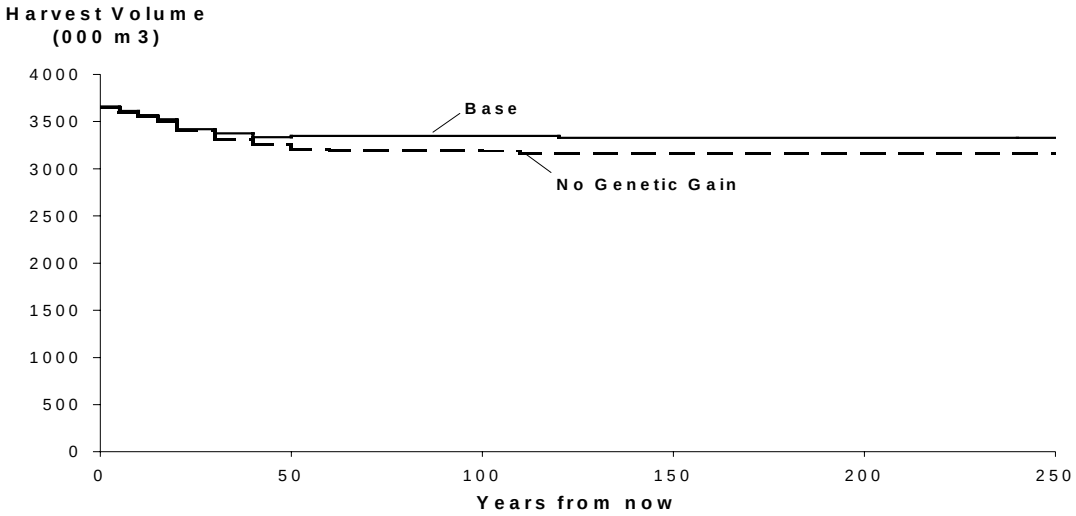


FIGURE 10. Harvest levels with the genetic gain assumptions removed from the base case.

2.6 Methods of analysis of silviculture opportunities

The purpose of this analysis is to quantify the short- and long-term benefits that may be realized by applying incremental silviculture treatments within the TFL 39 forests. The same computer model that was used in the MP#8 timber supply analysis was used to test investment options in this analysis. The model uses the Forest Service Simulator (FSSIM), and accessory programs that track dollars spent, thinning yields, diameter responses and employment creation.

Being a simulation environment, the model is not conducive to conducting direct investment optimization analysis. Instead, each recommended treatment was applied to all identified suitable stands in the inventory, and costs and responses were recorded. The treatments and responses were then scaled back proportionately, in recognition of budget levels and to assess trade-offs between alternative investments.

TFL 39 contains seven timber supply blocks. Blocks 3 and 4 are combined into one model in the analysis, and all other blocks are modelled independently. Treatments to increase volume production, and multiple spacing treatments to increase harvested stand diameters, were tested in all blocks and summed for the TFL. Pruning treatments and species conversion (from hemlock to Douglas-fir) were tested only in Blocks 1 and 2, which are closest to markets and have relatively better growing sites. Treatments to improve wildlife habitat were tested in Blocks 1, 2, and 3|4.

3. Incremental silviculture history and current program priorities

3.1 Current incremental silviculture history

Table 4 lists the recent incremental silviculture activity in TFL 36. Recent annual budgets average approximately $3 million/yr. Table 4 provides information for 1998 – 2000. Note the shift in emphasis over the three years. Although the brushing program is relatively stable, investments in spacing and pruning are now being replaced with increased investments in fertilization.

TABLE 4. Historical spending levels for incremental silviculture.

Block	Treatment	Actual 1998		Actual 1999		Plan 2000	
		(ha)	($ 000s)	(ha)	($ 000s)	(ha)	($ 000s)
1&5	Brushing	122	$132	80	$77	110	$150
	Spacing	218	$428	143	$262	87	$132
	Pruning	15	$41	38	$80	19	$47
	Surveys	1201	$65	2395	$80	1607	$96
2	Brushing	0	$0	147	$135	60	$63
	Spacing	256	$399	215	$579	100	$196
	Pruning	11	$30	58	$137	20	$50
	Surveys	2362	$83	2716	$130	4530	$171
	Fertilization	182	$49	1035	$248	1340	$304
3&4	Brushing	26	$25	82	$104	90	$100
	Spacing	56	$145	23	$66	29	$53
	Pruning	32	$78	0	$0	0	$0
	Surveys	3491	$166	6275	$104	1400	$54
	Fertilization	537	$280	388	$218	520	$260
6	Brushing	472	$715	568	$796	597	$758
	Spacing	155	$286	68	$117	100	$170
	Pruning	33	$126	0	$0	0	$0
	Surveys	705	$13	3720	$49	3100	$83
	Fertilization	0	$0	0	$0	60	$30
7	Spacing					30	$60
	Surveys	1110	$26			100	$4
Total TFL 39	Brushing	620	$872	877	$1,112	857	$1,071
	Spacing	685	$1,258	449	$1,024	346	$611
	Pruning	91	$275	96	$217	39	$97
	Surveys	8869	$353	15106	$363	10737	$408
	Fertilization	719	$329	1423	$466	1920	$594
Total budget			$3,087		$3,181		$2,780

3.2 Workshops discussion sessions

The objective of this analysis is to help the TFL 39 silviculturalists and forest planners make rational investment decisions about their specific management objectives. This is in contrast to an analysis that seeks to identify the best silviculture treatments to achieve broad provincial goals. The management objectives studied in this analysis are based on company philosophy of forest management and the experience of company foresters.

Two workshops were held with foresters from the company, the Ministry of Forests, and Forest Renewal BC. The first workshop, held in Campbell River, discussed management objectives and resulted in a list of treatments to meet the objectives. Stand criteria suitable for each treatment were identified. A summary list of objectives and treatments was developed following the workshop, and circulated to participants for review. Table 5 briefly summarizes the inputs received at the first workshop. Later sections of this report discuss each objective in more detail.

TABLE 5. Summary of objectives, treatments and candidate stands modelled

Objective	Treatment	Candidate stands
Volume production	1. Fertilize pre-harvest 2. Fertilize (SCHIRP) sites at establishment	Douglas-fir, SI 27+ Hemlock, Cedar, low and medium sites
Increase diameters	1. Multiple spacing Juvenile spacing 2. Pole thinning 3. Commercial thinning	D-fir 3000&1200 sph, SI 27+ Hemlock 7000+ sph, SI 27+ D-fir 3000 sph, SI 27+ D-fir 3000-9000 sph, SI 27+
Produce clear wood	Space, prune and fertilize	D-fir 3000&1200 sph, SI 27+
Grow valuable species	Convert hemlock to D-fir and Cedar	Hemlock, SI 27+
Enhance habitat	Wide spacing in riparian	D-fir & hemlock, SI 21+

SCHIRP = Salal-Cedar-Hemlock Integrated Resource Project; SI = site index; sph = stems per hectare

Stand responses to treatments were developed using the company growth and yield model Y-XENO. The stand responses for treated areas, and base case assumptions for untreated areas, were then incorporated as scenarios in the FSSIM models. Results were graphed and presented for discussion at a second workshop held in Nanaimo in the fall of 2000. The second workshop

resulted in further refinements to the modelling process, and clarification of issues. This report was developed following the second workshop.

4. Test of opportunities to increase volume production

Two regimes were tested. Both inspect assumed gains to fertilization treatments.

4.1 Fertilization of maturing Douglas-fir stands

The most direct way to increase tree and stand volumes is to provide the trees with optimal growing conditions. TFL 39 receives adequate rainfall for tree growth, so the limiting factors are soil depth and type, and the quantity of nutrients in the soil. Broadcast fertilization with urea adds nutrients which trees can readily absorb. Growth is accelerated for a period of 5 to 10 years.

The proposed practice is to give trees a three-time fertilizer boost before final harvest. Stands scheduled for harvest are fertilized 7, 14, and 21 years before the harvest date. Three fertilizer applications are assumed to increase stand volumes at harvest by 50 m^3/ha. All Douglas-fir stands on high and good growing sites were assumed to be fertilized. Timber supply response was modelled by raising the LTHL while maintaining a growing stock level equal to the base case over the planning horizon (i.e. capturing all the growth increase as harvest). The result for TFL 39 is a 1.3% increase in the LTHL. The gains vary by supply block, as listed in Table 6.

TABLE 6. Potential gains in LTHL with pre-harvest fertilization of high and good site Douglas-fir

Supply block	Short-term (10 year) treatable area (ha)	Long-term treatable area (ha/year)	Yield gain in LTHL (m^3/year)	Yield gain (% of base case LTHL)
Block 1	7,900	800	24,752	3.7
Block 2	4,519	700	14,851	1.4
Block 3|4	12	110	2,970	0.7
Block 5	0	30	672	0.9
Block 6	0	0	0	0.0
Block 7	0	5	77	0.1
Total TFL 39	12,431	1,645	43,322	1.3

The greatest potential gains occur in Blocks 1 and 2, since this is where most of the Douglas-fir stands occur in TFL 39. Figure 11 illustrates the area fertilized and effect on the LTHL for Block 1. In the long term, approximately 800 ha/yr are fertilized. Recall that each hectare is fertilized three times before harvest in the model, so the harvest level each year includes approximately 267 ha that were fertilized. Figure 11 represents fertilization of all candidate stands, and the actual area fertilized would possibly be less, depending on budget allocations (Section 13).

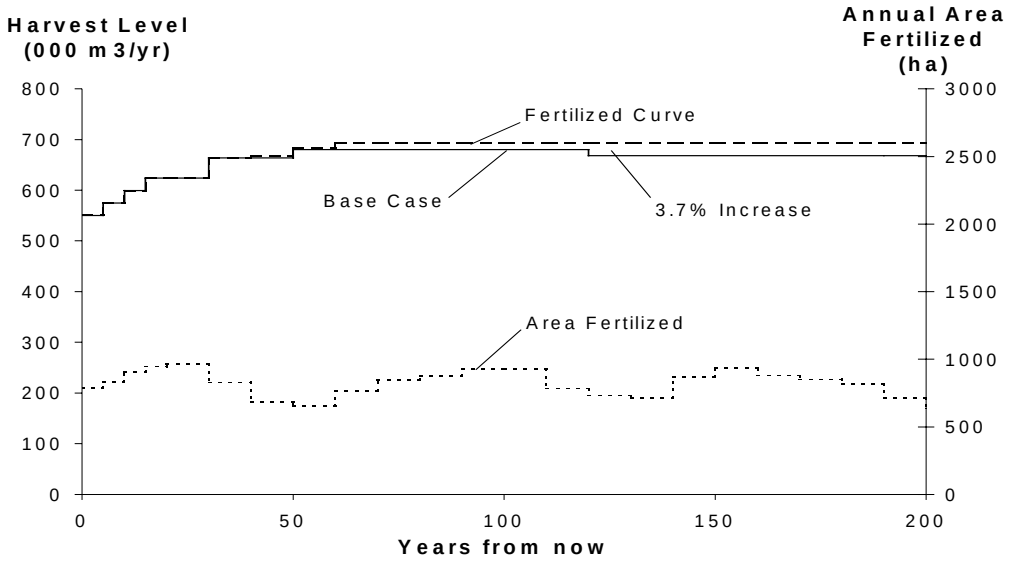


FIGURE 11. Block 1 areas aerial fertilized and yield gains with all candidate stands treated.

4.2 Fertilization of poor site cedar/hemlock stands at establishment

Cedar and hemlock stands on poor growing sites (generally wetter areas) are often slow to begin height growth. These sites also host salal, a woody shrub with evergreen leaves. Salal roots compete with the conifer roots, and dominate the uptake of the limited nutrient supply. The Salal-Cedar-Hemlock Integrated Research Project (SCHIRP) is a ten-year ongoing research project with Weyerhaeuser participation that is finding good response to fertilization with a mix of nitrogen and phosphorus.

SCHIRP fertilization was simulated on all hemlock poor sites. The treatment is expected to accelerate forest establishment by 20 years, which means that the stand matures 20 years earlier than it would have without the treatment. Minimum harvest ages were reduced by 20 years for treated sites. Diameters were also assumed to develop 20 years earlier. The cost of SCHIRP fertilization is at the date of establishment, which is the year after harvest. The result for TFL 39 is a 1.8% increase in mid-term harvest levels, and a 0.9% increase in the LTHL. Table 7 lists the gains by supply block.

TABLE 7. Potential gains in LTHL with SCHIRP fertilization of poor site hemlock

Supply Block	Short term (10 year) treatable area (ha)	Long-term treatable area (ha/year)	Yield gain in LTHL (m3/year)	Yield gain (% of base case LTHL)
Block 1	60	15	1,733	0.3
Block 2	1,400	60	6,931	0.6
Block 3|4	350	20	1,980	0.5
Block 5	20	1	103	0.1
Block 6	8,200	200	15,446	1.5
Block 7	1,200	50	3,860	5.0
Total TFL 39	11,230	346	30,053	0.9

The greatest potential gains occur in Block 6, since this is where the majority of the poor site hemlock stands occur in TFL 39. Figure 12 illustrates the area fertilized and effect on the LTHL for Block 6.

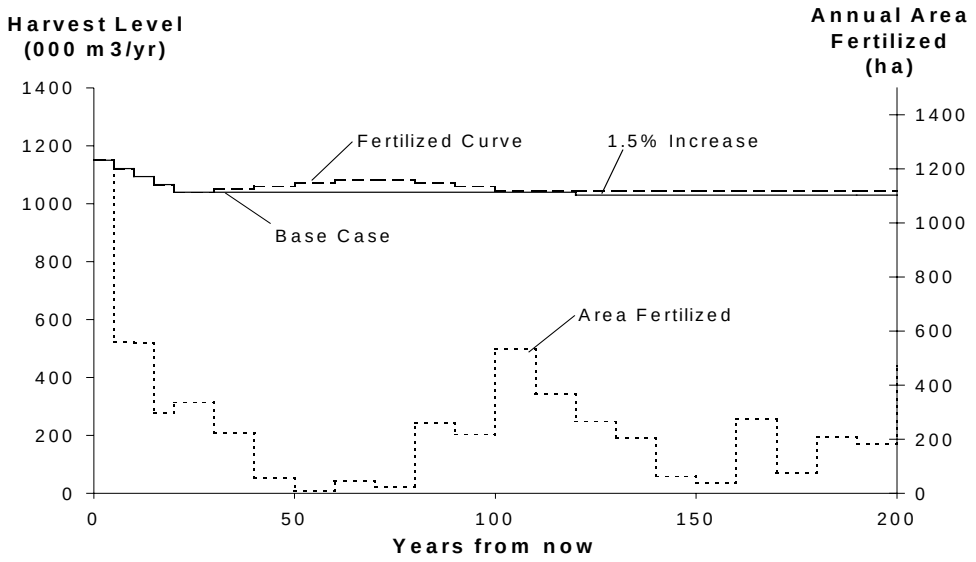


FIGURE 12. Block 6 areas SCHIRP fertilized and yield gains with all candidate stands treated.

5. Comparison of potential volume production treatments

Two components of the TFL 39 inventory were modelled to assess the benefits of fertilization treatments. Douglas-fir on high and good growing sites has the potential to add 50 m³/ha with three applications of urea. Hemlock and redcedar on poor growing sites has the potential to

achieve maturity 20 years earlier with a SCHIRP fertilizer application at establishment. Which investment is superior?

Table 6 showed that pre-harvest fertilization of 1,645 ha/yr results in an increase in timber supply of 43,322 m^3/yr. The cost of aerial fertilization (Appendix 1) is $231/ha. Annual investments of up to $380,000 in TFL 39 fertilizing Douglas-fir stands will therefore grow wood volume at a cost of $8.77/$m^3$, with an average 14-year investment commitment.

Table 7 showed that SCHIRP fertilization of 346 ha/yr results in an increase in timber supply of 30,053 m^3/yr. The cost of SCHIRP fertilization is $487/ha. Annual investments of up to $168,500 in TFL 39 fertilizing poor site hemlock stands will therefore grow wood volume at a cost of $5.61/$m^3$, with approximately a 70 – 100 year investment commitment.

Comparing the investments, Douglas-fir fertilization is clearly superior. The wood volume produced is approximately 40% more valuable, and the money can be invested and returned six times during one cycle of the hemlock fertilization regime. If the future value of hemlock is $50/$m^3$ and Douglas-fir is $80/$m^3$, then the total return on investment, using gross log value and ignoring harvesting costs, to hemlock SCHIRP fertilization is 2.6% while the Douglas-fir pre-harvest investment returns 17.1%.

6. Volume production strategy

It is thought that three applications of fertilizer, on a seven year cycle, are necessary to achieve 50 m^3/ha. Incremental growth diminishes with each application. The first application is thought to produce 25 m^3/ha, the second application adds 15 m^3/ha and the third application adds the final 10 m^3/ha. With the TFL 39 harvest profile rapidly moving into second growth (Figure 4), short-term harvest levels would benefit from even one application of fertilizer. At the stand level, one fertilizer application produces wood at a cost of $9.24/$m^3$, with a seven year investment commitment. In a Douglas-fir forest this implies a 36.1% compound annual rate of return.

The 20-year plan for TFL 39 identifies a schedule of second growth stands planned for harvest over the next two decades. Douglas-fir stands on high and good sites scheduled for harvest in the final year of the plan could receive a first fertilization this year, with two to follow. Stands scheduled for harvest in year 14 of the plan could receive a first fertilization this year, with one to follow. Stands scheduled for harvest in year 7 could receive a single fertilization this year. The budget required would be approximately $290,000 - $380,000/year.

Fertilization is not an employment-intensive activity. A Douglas-fir fertilization program on the scale described here would create one full-time job in application. However, the added timber

supply would support 61 long-term jobs in harvesting and processing, assuming 1.4 jobs per each additional 1000 m³/yr harvested (Coast Forest Lumber Association, 2000).

7. Objectives to improve timber quality

Sections 4-6 discussed fertilization as a means to increase the *volume* of timber production. The following sections discuss treatments that increase the *value* of the timber produced.

Weyerhaeuser's main emphasis is on volume production. The company believes that good timber quality will be ensured by maintaining full stocking. Trees in well-stocked stands typically have higher wood density, less juvenile wood, tighter grain, smaller knots and straighter form than trees in open stands. For most stands, adding value by juvenile spacing to increase piece size are viewed as unattractive. Costs are high, losses in volume production are thought likely, piece size gains appear less than previously estimated, and intrinsic wood quality factors are compromised by significantly faster stem growth. The company expects that technology, both products and processes, will reduce the current value premiums due to larger piece sizes over time.

Timber quality (price) is also influenced by species and proportion of clearwood. Strategies to increase piece size, upgrade the species mix, and produce clearwood were examined.

8. Methods to improve timber quality

Three quality objectives were inspected in the modelling. This section discusses each objective in turn.

8.1 Increase stand diameters

Hugh Hamilton Ltd., as part of their Type 2 analysis of the Soo TSA (draft, December 2000), investigated trends in value response to increasing piece size. Using data from the Howe Sound log market, it found a roughly linear relationship between log diameter and value. The value of a log, all else being equal, increases $1.87/m³ per cm of diameter increment.

A juvenile spacing and thinning regime was developed at the workshops. The treatment regime for Douglas-fir consists of: fertilization at planting, juvenile spacing to 1200 stems per hectare (sph) at age 14, pole thinning to 400 sph at age 40, commercial thinning to 200 sph at age 60, and fertilization 21, 14, and 7 years prior to final clear felling. In the model the regime was tested for all Douglas-fir stands on good and high sites (site index 27 and above). Alternative regimes for Douglas-fir, consisting of either pole thinning or commercial thinning, and fertilization prior to harvest, were also tested. Hemlock stands over 7000 sph on good and high sites (SI 27+) were

spaced to 1200 sph. Weyerhaeuser's growth and yield model Y-XENO was used to model diameter and volume responses to the treatments.

Figures 13 and 14 illustrate a tradeoff between volume production and diameter increment in a forest stand. These illustrations represent the merchantable volume component for a Douglas-fir stand on site index 27, 1500 sph establishment density, as modelled in Y-XENO. The very low-density treatment is considered for riparian habitat enhancement in Section 11 of the report. The stand manipulations result in increases of up to 19% in average stand diameters at 100 years of age, but reduce stand volumes by up to 67% at that age for the riparian management. Spacing for a compromise between diameter increase and volume loss results in a diameter increase of approximately 12% and a volume loss of also approximately 12% (juvenile spacing to 400 stems in the figures). An important aspect of juvenile spacing is the ability to influence the species composition of the remaining stand, favouring in this case Douglas-fir and western redcedar. However, the potential for changed species composition was not quantifiable, and therefore not included in the modelling.

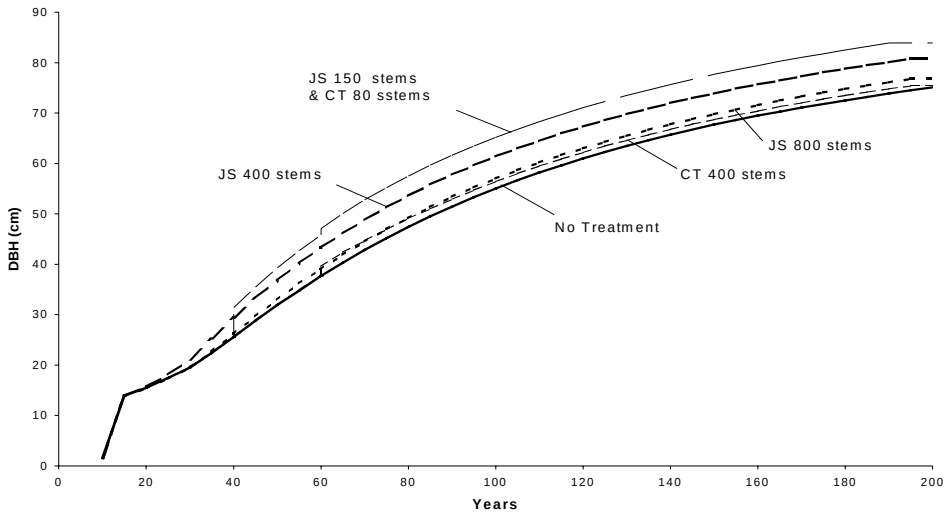


FIGURE 13. Y-XENO diameter comparisons for candidate treatments.

(JS = juvenile spacing; CT = commercial thinning)

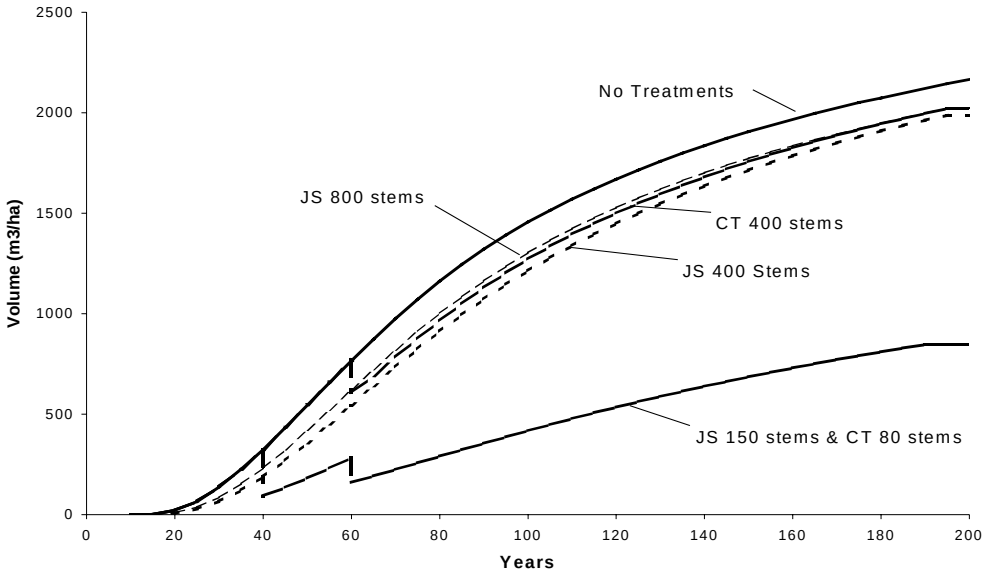


FIGURE 14. Y-XENO volume comparisons for candidate treatments.

(JS = juvenile spacing; CT = commercial thinning)

Note in Figure 14 that stand volumes following spacing projected by Y-XENO do not recover to the volume of an untreated stand. Some growth and yields models (i.e. TASS) do show volume catch-up following spacing.

The timber supply and diameter responses to multiple-entry spacing were tested for all blocks in TFL 39. The effects vary between blocks, due to relatively greater or lesser quantities of candidate stands. Individual block responses are included on the data CD (Appendix 4). Figure 15 illustrates the overall effect on TFL 39 harvest levels. The clear-felled harvest component declines 9.3% in the long term. The base case harvest level is maintained for only five years. Volumes removed in the thinnings compensate for half of the loss in clear felled timber. Reduced harvest levels are most pronounced in Block 1, which has the greatest proportion of high and good site Douglas-fir.

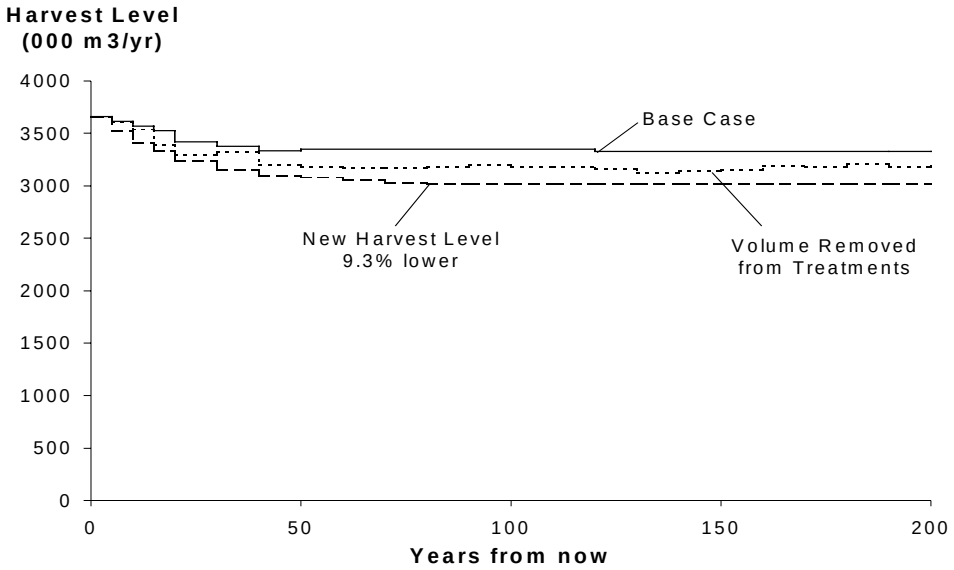


FIGURE 15. TFL 39 harvest levels with a spacing and thinning program applied in all suitable stands.

Figure 16 illustrates the gain in average harvested stand diameter at breast height. The first 40 years represent a majority of harvesting in existing old growth stands. After that time, the spacing and thinning program increases the average diameter by approximately 2.0 cm. The average diameter in the treated stands increases by approximately 20%, from 35 cm to 42 cm.

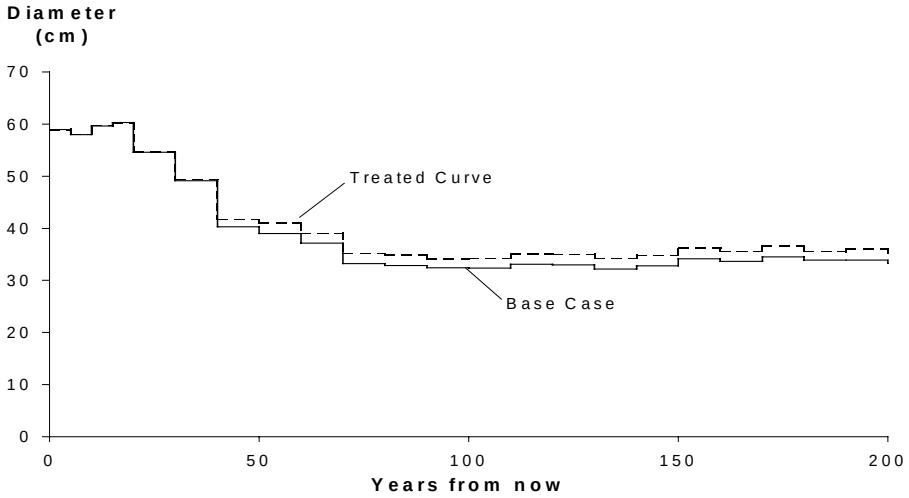


FIGURE 16. TFL 39 gain in average harvested diameters with a spacing and thinning program in all suitable stands.

8.1.1 Pole thinning and commercial thinning

Weyerhaeuser is developing expertise in the utilization of very small wood, and requested a test of opportunities for a pole thinning treatment in natural-origin Douglas-fir stands at approximately

40 years of age. The effect on sustainable harvest levels is almost nil. The volumes recovered in the pole thinning compensate for a small loss in clear-felled volume. Treated stands show gains of approximately 3 cm dbh, but when averaged over the complete harvest the diameter gain is less than 0.5 cm. This treatment is applied to approximately 200 ha/yr in the model, with yields of 100 – 150 m^3/yr (Appendix 2).

Stillwater Division (Block 1) also requested a test of opportunities for commercial thinning in Douglas-fir stands about 60 years of age. This test produced similar results to the pole thinning test, with a slightly (1.5%) depressed LTHL that was made up for by the volumes removed from the thinnings. Approximately the same diameter effect was produced as well, with negligible improvement overall, but gains of approximately 3 cm in the treated stands. . Both these regimes were modelled using custom-made Y-XENO yield tables.

8.2 Pruning for clear volume production

Government wants future timber harvests to supply a range of products similar to those presently harvested. However, forests managed on relatively short rotations do not have an opportunity to naturally shed understorey branches, occlude the stub, and grow a knot-free outer shell. To ensure a clearwood component in the product mix from future forests, pruning the lower branches from young trees is necessary.

Pruning occurs in two lifts totaling 5.5 m when trees are 10 – 18 years old. The pruning treatment produces a 16-foot butt log with a clearwood shell. Work by Forest Practices Branch using TASS and current market prices for clear and knotty lumber suggests that a pruned stand will be 40% at least more valuable than an unpruned stand at final harvest. Pruned butt logs presently sell for twice the price of similar sized unpruned logs in New Zealand

The discussions at the workshop recommended that pruning might be considered in Douglas-fir stands on high and good growing sites. Pruning is done in conjunction with juvenile spacing, to 400 or 800 sph, to accelerate diameter increment following the treatment. Pruned stands would be fertilized on a seven-year cycle.

The pruning regime was modelled for Blocks 1 and 2 only, since they contain most of the Douglas-fir stands in TFL 39. Figures 17 and 18 illustrate harvest level effects of the pruning regime for spacing to 400 and 800 sph, respectively. The lower density regime has a significant impact on the future volume harvested, due to lower site occupancy, as discussed in the preceding section. Figures 13 and 14 (Y-XENO diameter and volumes) illustrated the increased diameter and lowered volume response of the 400 and 800 sph regimes. Maintaining 800 sph depresses the LTHL less, and produces greater pruned log volume. Pruned log volume was estimated to be 30% of the treated stands volume at harvest.

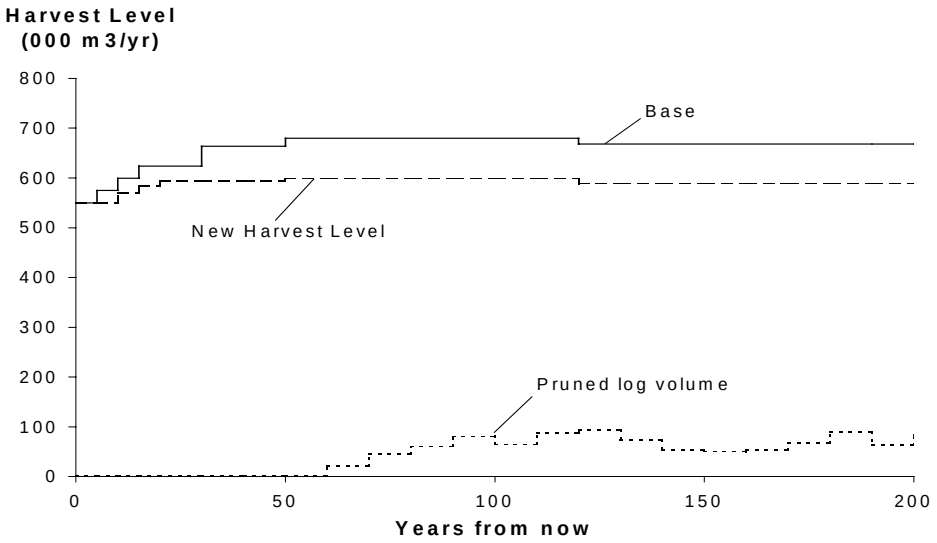


FIGURE 17. Block 1 harvest levels and pruned log volumes with a spacing, pruning and fertilization regime at 400 sph.

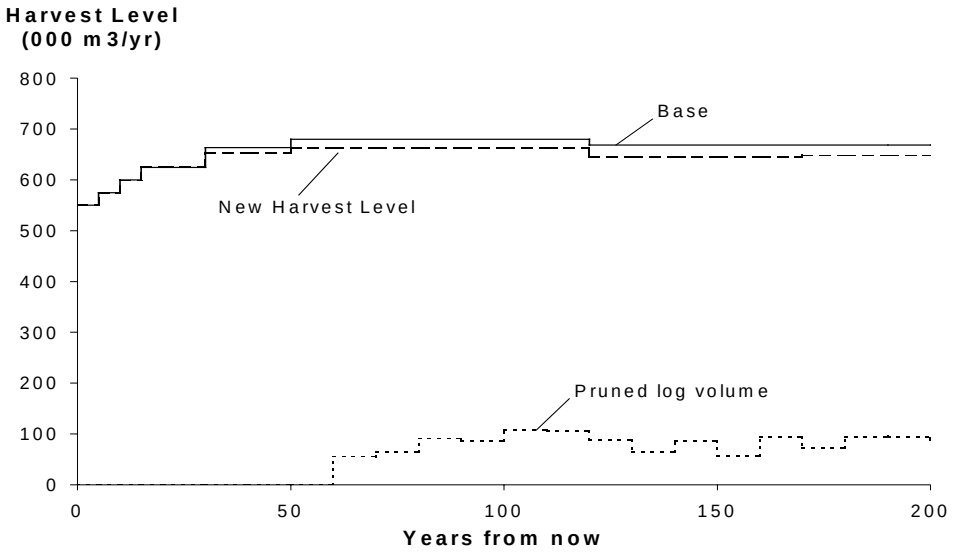


FIGURE 18. Block 1 harvest levels and pruned log volumes with a spacing, pruning and fertilization regime at 800 sph.

Pruning is the most labour-intensive and expensive treatment regime considered in this analysis. At a density of 400 sph, the pruning lifts cost $3913/ha, the spacing costs $2485/ha, and three aerial fertilizations with urea cost $693/ha. The result of this expenditure is a significantly reduced harvest level. Pruning 800 sph is estimated to cost an additional $3000/ha.

A pruning program in suitable stands would create approximately 18 full-time silviculture jobs for the 400 sph option in each of Blocks 1 and 2. However, the combined impact of the 400 sph regime on the LTHL is a reduction of 141,000 m^3/yr, or a loss of 197 future jobs in harvesting and processing. The 800 sph regime results in a loss of 48 long-term jobs.

8.3 Conversion of natural hemlock regeneration to planted Douglas-fir stands

A third activity identified at the workshops to improve the quality of future harvested timber is the conversion of naturally regenerated hemlock stands to become Douglas-fir leading stands. Douglas-fir timber is presently worth approximately 40% more than equivalent grades of hemlock timber.

To convert species, genetically improved Douglas-fir is planted, and fertilized at planting. Usually a brushing treatment is needed to help the fir become established on natural hemlock sites. At approximately 14 years of age, the plantation is juvenile spaced to remove the hemlock trees that have seeded in. Species conversion was modelled in Blocks 1 and 2. These are the most southerly blocks in TFL 39, located in a generally warmer and drier climate, conditions preferred by Douglas-fir.

Figure 19 illustrates the different volume development pathways for hemlock and Douglas-fir on good growing sites (site index 29) for each species. Hemlock grows faster initially, and then slows and is overtaken by Douglas-fir. Hemlock grown at lower densities (1500 or 3000 sph) shows the same, although lesser, bulge of early volume development relative to Douglas-fir. Figure 19 highlights the age when the species reaches 95% of culmination age. Short-rotation forestry will produce significantly greater volume growing high-density hemlock than growing Douglas-fir. However, on the same piece of ground Douglas-fir often grows at 2 – 4 m higher apparent site index, which would reduce but not eliminate the volume lead of hemlock in this example.

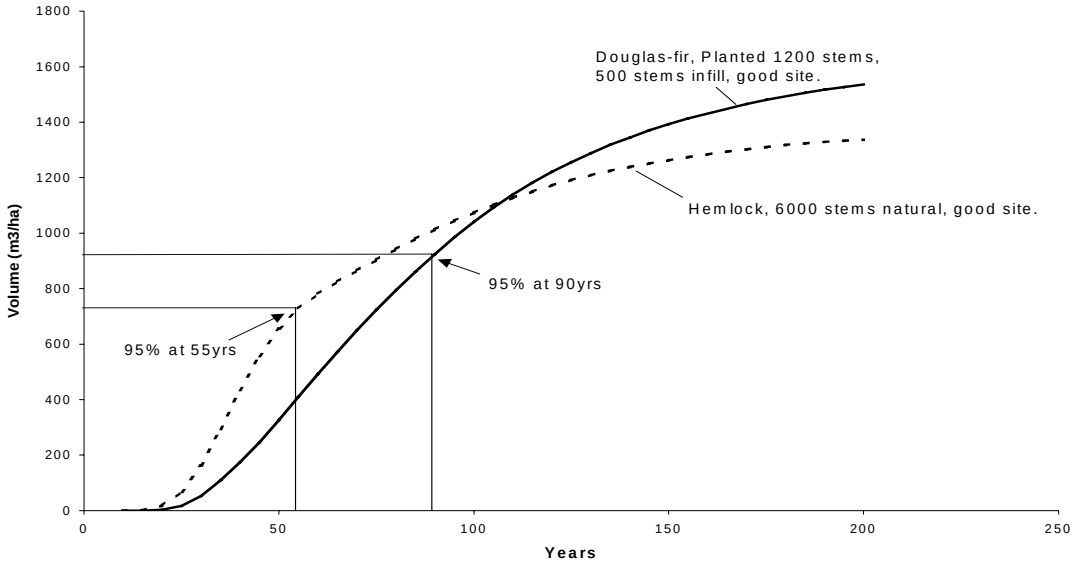


FIGURE 19. Hemlock versus Douglas-fir volume development on site index 29 for each species.

Modelling tested conversion to Douglas-fir of 50% of the high and good growing site stands expected to naturally regenerate to hemlock. Harvest levels in Blocks 1 and 2 were effected differently. In Block 1, the base case harvest levels were achieved for 90 years, followed by a 3.5% rise in the LTHL above the base case. In Block 2, shortfalls started in the second planning period and continuing until 40 years from now. After that time, the base case LTHL was achieved. The volume shortfall in Block 2 averaged 59,000 m³/yr (5% harvest level reduction) over the 35-year period.

The reason for the different responses in the model is that the TSR2 base case harvest flow for Block 1 does not push forest harvesting to the potential upper limit in the early periods. Figure 11 in the TSR2 report shows that the average age harvested over time from Block 1 is approximately 95 years, compared with approximately 75 years in Block 2. Thus Block 1 stands are harvested farther to the right in Figure 19, where Douglas-fir yields are rising above hemlock yields. In Block 2, a short-term lower-harvest adjustment period would be necessary to permit the new Douglas-fir stands to gain a bit more maturity.

Figures 20 and 21 illustrate the harvest flow, and the Douglas-fir component of the harvest for the test of species conversion for Blocks 1 and 2. In Block 1, converting half the candidate areas (areas that would naturally regenerate to hemlock and with site index greater than 27) to Douglas-fir will shift approximately 130,000 m³/yr (20% of the LTHL) from hemlock to Douglas-fir, and increase the overall value of timber harvested by 8%. In Block 2 the gain is approximately 275,000 m³/yr (25% of the LTHL) and an overall value gain of 10%.

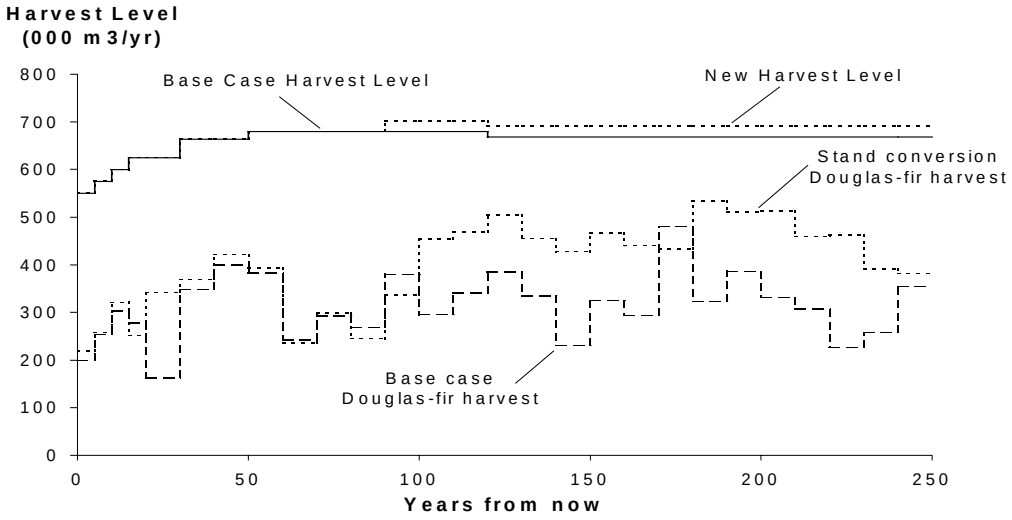


FIGURE 20. Block 1 long-term increase in Douglas-fir representation in the harvested profile.

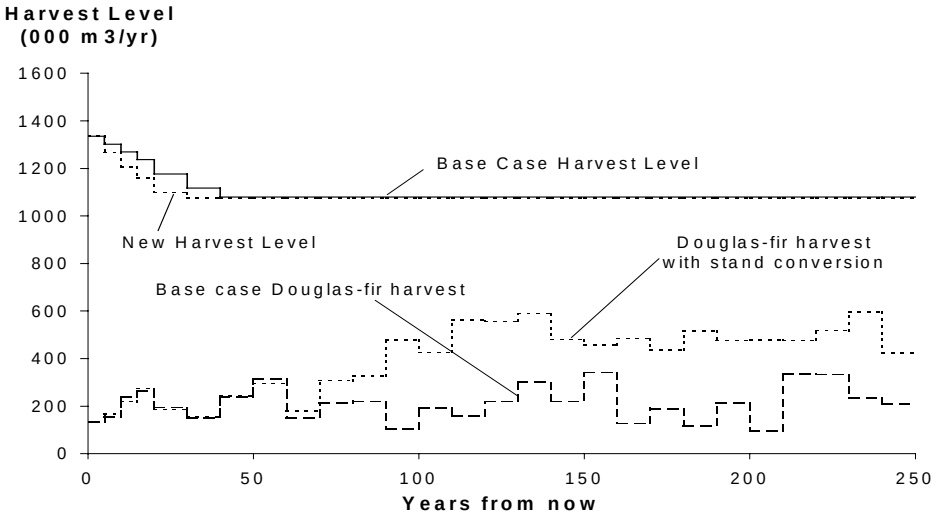


FIGURE 21. Block 2 long-term increase in Douglas-fir representation in the harvested profile.

Appendix 2 of the report Site Series Estimates by Site Series (B.C. Ministry of Forests 1997) lists site index conversions between hemlock and Douglas-fir. A hemlock SI 24 site would grow Douglas-fir at SI 27.1, and a hemlock SI 33 site would grow Douglas-fir at SI 37.1. The species conversion tested would therefore raise site index by 3–4 m.

The site index values used to generate Y-XENO volume tables were 29.0 and 35.5 for good and high site Douglas-fir, and 28.5 and 33.5 for good and high site hemlock, respectively. The results reported above thus include a site index lift of only 0.5 m for good sites and 2.0 m for high sites.

To test the impact of a larger site index lift on species conversion, half the treated good-site hemlock was converted to high-site Douglas-fir. This resulted in a LTHL 7.6% higher than the base case in Block 1, and 5.5% higher than the base case in Block 2. With this site index lift assumption, the species conversion raises the overall TFL 39 LTHL by 110,000 m^3/yr.

9. Preferred timber quality strategies

As discussed in Section 7, Weyerhaeuser's main emphasis is on volume production, relying on full stocking to achieve volume targets and to control timber quality. The company believes that as technology advances, present premiums for large log sizes will diminish.

Large scale programs of juvenile spacing to increase piece size are unattractive as treatment costs are high, volume losses may occur and gains in piece size tend to be offset by reduced wood quality (increased size of juvenile core, larger branches, and wider rings). Similarly, a large scale pruning program for clearwood is risky because it relies on premiums from clearwood to offset large up-front costs and reduced timber yields.

It is, however, recognized that treatments such as juvenile spacing and pruning may apply to specific sites. Examples include species conversion and the development of windfirm stand boundaries and specific habitat conditions.

The analysis uses broad assumptions to explore the potential gains from species conversion. Figure 22 illustrates the costs of converting half the candidate regenerating hemlock stands to Douglas-fir for Blocks 1 and 2. The modelling system used for this project, FSSIM, enabled only a one-time conversion of the species. By 100 years from now essentially all stands have been harvested and regenerated. The graph shows the first 100 years of the planning horizon for both blocks together.

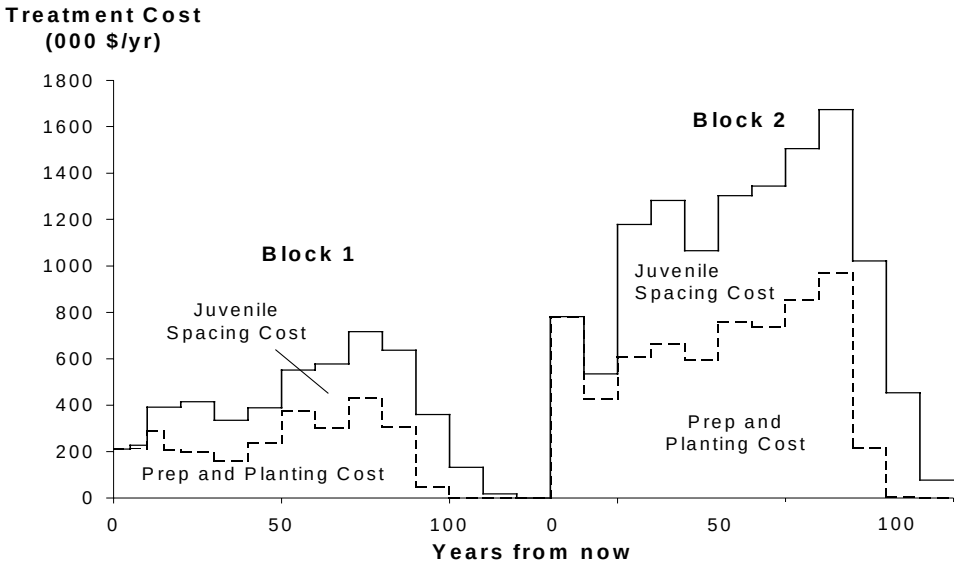


FIGURE 22. Species conversion costs for Blocks 1 and 2.

Block 2, which is larger than Block 1, has a higher percentage of hemlock in the natural forest so it can absorb a larger species conversion budget. Costs per hectare are held fixed over the planning horizon. The rise in expenditure reflects increasing area of species conversions over time, until all stands have been converted.

In the first 10 years, costs are approximately $205,000 in Block 1 and $780,000 in Block 2. In the mid term costs rise to $400,000 and $1.2 million respectively as stands develop and need the subsequent juvenile spacing treatment.

10. Returns to timber quality investments

Table 8 summarizes the modelling results for the three objectives of increased diameters, clearwood, and more valuable species. The budget is what is required on a sustained basis to treat all candidate stands within TFL 39. Changes in the long-term harvest level (LTHL) are expressed as a percentage of the base case LTHL. Silviculture jobs include commercial thinning for the spacing regime. Harvest and milling employment is estimated at one job per 1000 m^3/yr harvested and includes jobs from processing thinnings. Net employment is the sum of silviculture and harvest and milling jobs. Wood value is estimated using $80/$m^3$ for Douglas-fir and $50/$m^3$ for hemlock, $1.87/cm for increased diameter, and pruned logs worth double the value of un-pruned logs, The reported value is net of losses in the LTHL where applicable. Time to maturity is the time from the average of treatment ages until assumed final harvest of the stand. Investment return is the rate of interest earned on the budget over the time to maturity to create the wood value.

TABLE 8. Summary comparison of outputs for the three quality regimes.

Treatment Regime	Annual Budget ($ millions)	LTHL (+/- %)	Silviculture Employment (FTE jobs)	Harvest & Mill Employment (FTE jobs)	Net Employment created (FTE jobs)	Wood value created ($ millions)	Time to maturity (years)	Investment return (% interest)
Spacing for larger diameters	2.5	-9.3	103	-217	-114	-1.4	45	n/a
Pruning for clear wood (400 sph)	3.1	-4.2	36	-197	-161	-2.6	65	n/a
Pruning for clear wood (800 sph)	4.4	-1.0	53	-48	5	7.7	65	0.86
Conversion of hemlock to D-fir (without site index lift)	1.6	0.7	14	32	46	12.2	80	2.57
Conversion of hemlock to D-fir (with site index lift)	1.6	4.0	14	186	200	19.3	70	3.62

In Table 8 the value increases shown are gross timber values, and the picture may look different if harvesting costs were subtracted to arrive at net profit on the investment.

Net returns are negative for several treatment regimes in Table 8. Spacing for larger diameters increases the value of future harvests by $11.3 million/yr and provides $7.4 million/yr in small wood from thinnings. However, these gains are offset by reduced harvest levels, estimated at $20.1 million/yr of timber value foregone. Pruning 400 sph adds $8.6 million/yr future clear log value, but causes a harvest level loss of $11.1 million/yr.

Among the treatments with a positive return, pruning 800 sph adds $10.8 million/yr in clear log value, which is partially offset by $3.1 million/yr of foregone harvest level. Conversion of hemlock to Douglas-fir without lifting the site index creates value in two ways. Increased harvest levels add $1.5 million/yr and the more valuable species adds $10.7 million/yr. Including the site index lift assumption increases the harvest level gain by $7.1 million/yr.

The modelling system used in the analysis did not have the flexibility to seek subsets of the candidate stands, to test alternative budget levels for individual treatments. By treating all stands, the above results represent the average results to be expected in TFL 39. With budget limitations and alternative investment opportunities such as fertilization, only selected stands would be treated. Stand-level economic analysis will assist in selecting stands for treatment to provide returns that exceed the averages.

11. Wildlife habitat enhancement

Weyerhaeuser manages the forests of TFL 39 with due consideration for wildlife habitat now and into the future. Harvest rates and locations maintain large reserves of environmentally sensitive forest, riparian forest, and wildlife tree patches (Table 2). Additionally, Weyerhaeuser has zoned approximated 35% of the TFL 39 commercial forest as Habitat or Old Growth forests, with additional protection and mature tree retention. The new variable retention (VR) silviculture system reserves patches of trees in all harvest units. The base case includes incremental netdowns of 5%, 7.5% and 70% for Timber, Habitat and Old Growth zones, respectively. Figure 6 illustrated that harvest levels are significantly impacted by the VR silviculture system.

Recently, the company has considered the benefits of accelerating the development of old growth characteristics in second growth stands. Past harvesting has resulted in areas of dense hemlock regeneration along creeks and rivers, and in upland areas. Biologists and ecologists believe that opening up these stands will provide landscape diversity, and improve access and forage values for wildlife species. Treatments being considered include thinning stands to very low density, and creation of 0.1 – 0.4 ha openings in the second-growth stands. Treatments would mainly be targeted at reserved areas, particularly along riparian zones, although some consideration is also given to using the treatments in upland areas.

The stands considered for treatment are presently about 40 years old. The treatments would be a one-time entry, with the stands left to develop old-growth characteristics afterwards. Some small wood might be salvaged from the operations, providing a short-term gain in timber supply. As these stands subsequently develop, they are expected to contribute to meeting old seral forest cover requirements by, on average, 110 years of age, and potentially free some existing old growth stands for harvest.

Three aspects of the foregoing were tested in the models.

1. What would be the impact of reduced old seral forest cover constraints?
2. What is the short-term gain in timber supply from treatments in riparian areas?
3. What is the timber supply impact of treatments in natural-origin upland THLB stands?

These effects were tested in Blocks 1, 2, and 3|4. Results for Block 1 are illustrated in the following figures.

Figure 23 illustrates the timber supply gain of reduced old seral forest cover constraints. The percentage requirements are maintained as per the *Biodiversity Guidebook*, phased in over three 70-year rotations, but the age of old forest is assumed to be reduced from 250 years to 110

years. The LTHL for Block 1 rises by 2.5%. Results for the other blocks were a rise of 0.5% (Block 2) and 2.7% (Block 3|4). The increases result in a 1.5% rise in the LTHL for TFL 39.

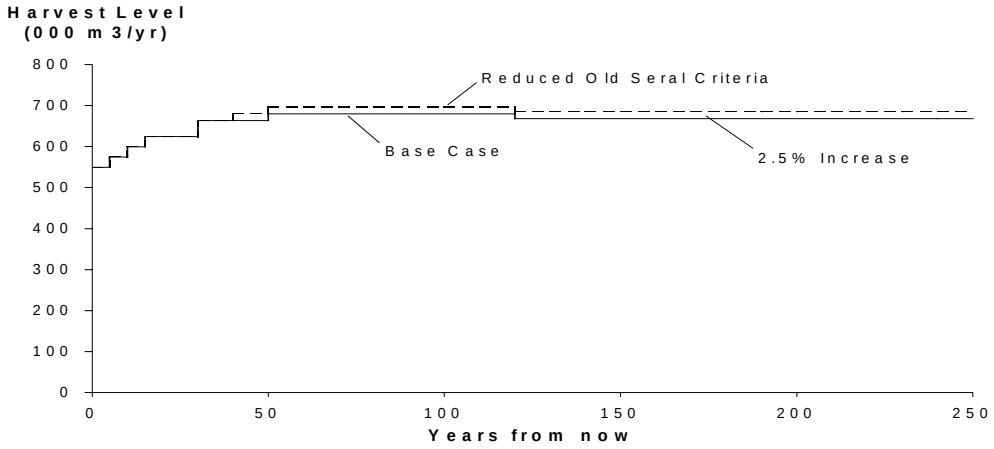


FIGURE 23. Block 1 harvest flow with the old seral age requirement reduced to 110 years

Figure 24 illustrates the effect on harvest levels of small-wood salvage from the variable density treatments in the riparian zones for Block 1. Blocks 2 and 3|4 show a similar increase in harvests 30 to 80 years from now. The total increase in the TFL 39 harvest level for the period is approximately 250,000 m^3/yr, or 8% of the base case harvest level. The modelling criteria were to maintain a short-term harvest level the same as the base case, and raise harvest levels to consume any excess growing stock that developed over the planning horizon relative to the base case. Figure 24 illustrates the upside potential; in reality, treatments would be selective as to location, and the gain may be only 10% – 20% of that shown.

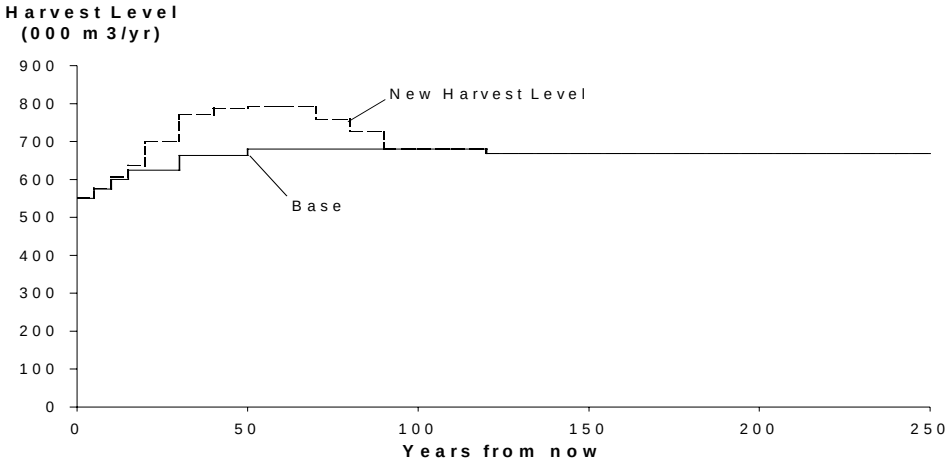


FIGURE 24. Block 1 increased short-term harvest level with variable density treatments in the riparian zone (outside the THLB).

Figure 25 illustrates for Block 1 the effect on harvest levels if variable density spacing, with small wood salvage, is undertaken in upland natural-origin stands within the THLB. In the base case, approximately 30% of stands are assumed to regenerate naturally. The wide and patchy spacing reduces stocking levels significantly, and therefore reduces the rate of volume production on treated lands. Within five years, harvest levels are below the base case, and remain there. Volumes extracted from treatments only partially compensate for the reduction in clear-felled harvest volumes.

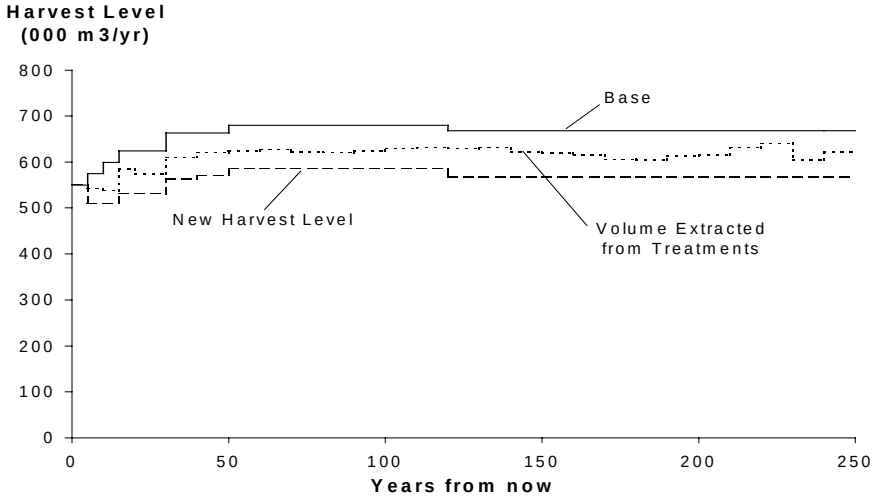


FIGURE 25. Block 1 reduced harvest levels with variable density spacing of 40 year old natural-origin stands within the THLB.

This brief analysis of habitat enhancement opportunities has three findings.

1. Old seral forest cover requirements are not overly constraining on timber supply.
2. Habitat enhancement with incremental silviculture in areas previously harvested but now excluded from the THLB may be beneficial for both wildlife and timber supply opportunities.
3. Habitat enhancement according to the proposed regime within the THLB would negatively affect timber supplies.

12. Working Targets

Timber supply analysis is a useful tool for assessing aggregate effects, over time, of incremental silviculture investments within a management unit. Stand-level analysis is also a helpful tool, used in conjunction with timber supply indications to focus investments into the most appropriate stands among the broad aggregations used in the timber supply model.

However, quantitative analysis techniques are limited by the assumption that current conditions will remain static into the future. Professional judgement, corporate preference and observation of trends in markets, technology, and climate all bear on the decision of where to best invest funds for very long time horizons.

In order to rationally select between investment opportunities, those opportunities need to be ranked on a common basis. The ranking needs to be based on a mix of the above-noted influences. Timber supply, financial return, short- and long-term employment, and corporate philosophy as conveyed by current budget allocations form the basis for the proposed ranking system developed in Table 9. Each treatment regime is assigned a high (H), medium (M) or low (L) rank for having relative merit within each response category. The rank n/a means that the regime would have negative value for the category. The aggregate ranking is developed by summing across the six categories, giving a point value of 3 for H, 2 for M, 1 for L, and -1 for n/a. Each response category is thus assigned equal weighting in the table. A user may wish to attach more importance to certain response categories, and increase the relative point scale for that category in determining the sum. The first two regimes in the table were not explicitly tested in the modelling. Both regimes result in prompt early stand growth, shown to be critically important for TFL 39 in tests of minimum harvest ages and VQO green-up in the MP#8 sensitivity analyses.

TABLE 9. Ranking of the incremental silviculture treatments.

Incremental silviculture treatment	Financial return	Short-term timber supply	LTHL timber supply	Short-term employment	Long-term employment	Current activity focus	Aggregate ranking
Brushing	M	M	M	M	M	H	13
Fertilize at planting	M	M	L	L	L	H	10
Fertilize pre-harvest	H	M	M	L	M	M	12
SCHIRP fertilization	M	M	M	L	L	M	10
Multiple spacing	n/a	n/a	n/a	H	n/a	L	0
Pole thinning	L	M	L	M	L	n/a	6
Commercial thinning	M	M	L	M	L	L	9
Space, prune & fert	n/a	L	n/a	H	n/a	n/a	0
Convert hemlock to D-fir	M	L	M	M	H	L	11
Riparian wide spacing	M	M	M	M	L	L	10
Upland wide spacing	L	n/a	n/a	M	n/a	n/a	-1

Three treatment regimes score over 10 points in Table 9. These are brushing, species conversion, and pre-harvest fertilization. A second tier of treatments, scoring 9 – 10 points, includes fertilization at planting, SCHIRP fertilization, commercial thinning and wide spacing in the riparian zone for habitat creation. With budget remaining after implementing the foregoing regimes, forest managers might consider pole thinning. The three treatments with negative financial return and/or negative timber supply effects rank at the bottom: multiple spacing, pruning, and wide spacing in upland THLB areas.

The next step in developing a rational investment strategy is to estimate the quantity of forest in appropriate condition to benefit from each treatment regime. Table 10 summarizes information provided earlier in this report and information drawn from the MP#8 report and its Appendices. The focus is on the first 10 years of the planning horizon. Cost estimates for individual treatments in each regime are included in Appendix 1.

TABLE 10. Areas suitable for treatment regimes, and cost of the regimes.

Incremental silviculture treatment	Candidate area (ha/yr)	Regime cost ($/ha)	Investment opportunity ($/yr)
Brushing	1,200	1,114	1,337,000
Fertilize at planting	840	180	151,000
Fertilize pre-harvest	1,243	231	287,000
SCHIRP fertilization	1,123	487	547,000
Multiple spacing	1,472	1,742	2,564,000
Pole thinning	1,000	625	625,000
Commercial thinning	450	-1,500	-675,000
Space, prune & fert	437	8,591	3,750,000
Convert hemlock to D-fir	858	1,924	1,650,000
Riparian wide spacing	650	2,800	1,820,000
Upland wide spacing	1,200	2,800	3,360,000
Total considered expenditure			16,091,000

The present incremental silviculture budget in TFL 39 is approximately $3 million/yr (Table 4). If all treatments discussed at the workshops were implemented on all sites modelled as suitable for treatment in the analysis, the potential expenditure would be four times the current budget level.

The modelling was focussed on identifying silviculture opportunities. The inventory information available did not provide precision in estimating areas operationally available for the different treatment options. For example, stand density, specific species information, and location will affect decisions on pre-harvest fertilization in Douglas-fir stands. Similarly, SCHIRP type stands were defined broadly as poor hemlock stands; this will include substantial areas that are not salal sites and will exclude some medium sites that are. It is necessary to incorporate an operational perspective in the proposed plan. Improved description of potential treatment sites may change the proposed treatment areas.

As discussed in Section 7, Weyerhaeuser's primary working target is to preserve, and if possible enhance, the flow of timber supply over time. TFL 39 is undergoing a smooth transition in harvest levels, underway for the past 15 years, to a long-term harvest level 9.1% lower than today.

The company is interested in incremental silviculture activities that reduce identified risks during the transition period. Risk is reduced by ensuring a reliable and ongoing flow of harvestable volume from second-growth stands. This is accomplished by activities that ensure prompt stand

establishment, rapid early growth, maintain full stocking, and increase stand volumes above what unmanaged stands would produce.

The company does not focus on log quality according to piece size (trees larger than 40 cm dbh). The cost of producing significantly higher volumes of a large tree size is high and the returns are often low and uncertain. Rather, the emphasis is on developing future timber supply and habitat opportunities in a more cost-effective manner, recognizing the timber quality benefits of maintaining full stocking.

13. Incremental Silviculture Program

This section outlines a recommended silviculture program. The program is 25% larger than the current program. The current program was developed without the benefit of a supporting timber supply analysis, however, it reflects company philosophy and an understanding of priority issues (stand establishment and rapid growth) that most impact timber supply. The recommended program continues some of the trends observed during the 1998 – 2000 period (Table 4), as more emphasis is on fertilization treatments and less on spacing and pruning.

The preceding section identified a ranking of incremental silviculture regimes, and a broad analytical view of the treatable area for each regime. Table 11 brings together the information derived in Tables 9 and 10 and operational input, and reorganizes the regimes in order of preference rank, to become a working table within which to allocate area and budget. A budget allocation estimate is proposed. This distribution of the budget is influenced by the preference rank, a desire to diversify the investments among a portfolio of treatments, consideration for habitat, and recognition of government employment objectives, as discussed in Section 7.

TABLE 11. Recommended silviculture program.

Incremental silviculture treatment	Aggregate ranking (points)	Treated area (ha)	Budget allocation ($000/yr)	Portion of the budget (%)	Silviculture employment (FTE jobs)
Brushing	13	600	668	17.8	7.3
Fertilize pre-harvest	12	1,600	370	9.9	1.2
Species conversion	11	300	523	13.9	7.2
Fertilize at planting	10	1,500	270	7.2	1.9
Riparian wide spacing	10	150	420	11.2	1.9
SCHIRP fertilization	10	800	390	10.4	1.1
Multiple spacing	0	200	349	9.3	4.1
Space, prune & fert	0	60	235	6.3	4.3
Surveys	n/a	9,500	380	10.1	4.5
Other	n/a		150	4.0	1.8
Total proposed budget			3,755	100.0	35.3

Commercial thinning (ranked 9 points) and pole thinning (ranked 6 points) treatments considered in the analysis have been dropped from Table 11, since commercial wood removal is involved in these treatments and they do not currently qualify for FRBC incremental silviculture funding. Similarly, the planting component of the species conversion treatment is excluded from the budget estimate, and only the juvenile spacing component is included. Employment estimates are only for jobs conducting the silviculture activities. Notes regarding treatments in Table 11 include:

Brushing: During the next few years there will be a transition from brushing pre-1987 stands to achieve free-growing, to vegetation management on higher sites as an incremental activity. Maintenance of this FRBC program beyond 5 years depends on implementing the incremental program.

Fertilization pre-harvest: Numbers are a preliminary estimate based on inventory and working up to a regime of three fertilization applications.

Species conversion: Modelling considered conversion of hemlock to Douglas-fir, redcedar may also be a favoured species.

Fertilization at planting: It is recommended that fertilization at time of planting is defined as an incremental treatment (as defined in silviculture prescription objectives). It is expected that the choice of sites for this treatment will be fine tuned and 1500 ha/yr is a current best estimate.

Riparian wide spacing: This program will largely depend on outcomes of the landscape unit planning process. It is an option for managing recruitment to meet old seral targets in variants that are currently short. It is expected that this program will be small (150 ha/yr) in the short-term.

SCHIRP fertilization: To date most of this activity has been in Block 4. There is also substantial potential in Block 6 and limited opportunities in Block 2.

Spacing: Spacing will be for a range of objectives including very high stand density, species choice (for example redcedar over hemlock, or against balsam in the transition zone for the balsam wooly adelgid), forage production, and development of windfirmness in specific areas.

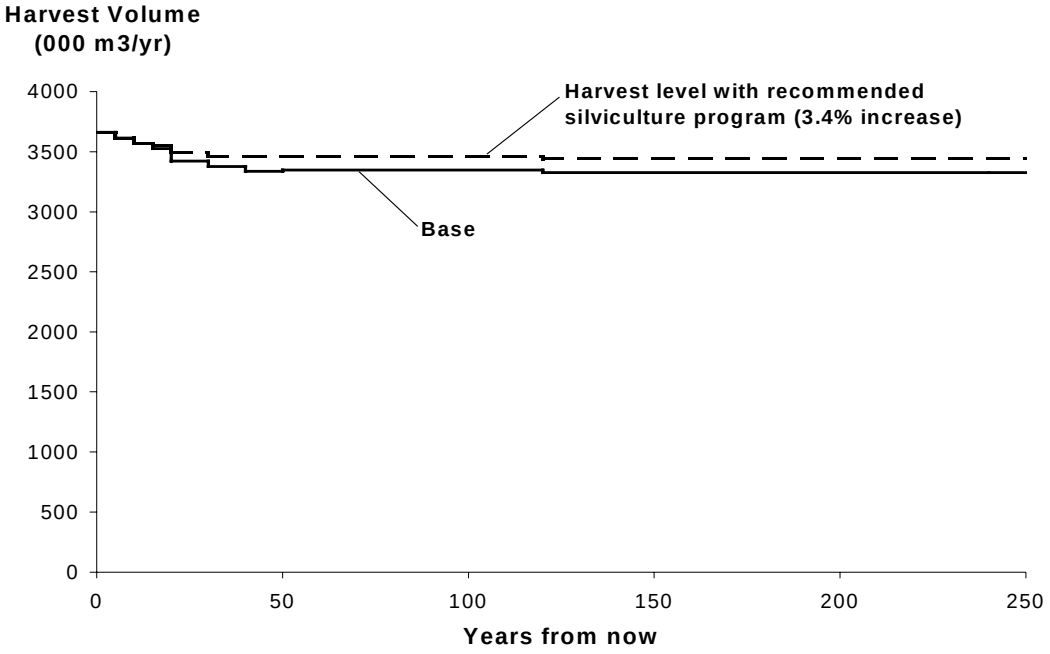
Surveys: These numbers are based on results for recent years.

Other: Includes treatments such as stand rehabilitation and planting of restored and rehabilitated areas.

The recommended silviculture program allocates 50% of the budget to treatments that result in more rapid stand establishment and early growth, and reduce the time to achieve green-up. This will improve harvesting flexibility in the short term, by reducing the impact of adjacency and visual quality forest cover constraints. These treatments will also reduce the time required for stands to achieve minimum merchantable volumes, and thereby shorten effective rotation ages.

Among treatments in the other 50% of the recommended silviculture program, pre-harvest fertilization will improve the overall harvest level. Additionally, the recommended silviculture program allocates approximately 15% of the budget to improve wildlife habitat conditions in TFL 39. By creating old seral attributes in regenerating stands, the program may release presently mature timber for earlier harvest. Treatments that are demonstrated in the analysis to negatively effect harvest levels, or to provide low financial returns, are undertaken in only small amounts for special circumstances.

Figure 26 illustrates the estimated overall effect of the recommended silviculture program on



TFL 39 harvest levels. The gain in the long-term harvest level is contributed from pre-harvest fertilization (1.3%), SCHIRP fertilization (0.9%), reduced time to achieve green-up in visually effective areas (0.5%), and reduced old seral forest cover requirements (0.7%). Reduced minimum harvest ages enable the planned short-term rate of reduction in harvest levels to be lessened and smoothly meet the increased long-term harvest level.

FIGURE 26. Effect of the recommended silviculture program on harvest levels.

14. Jobs, Income and Revenue

The benefits from the recommended silviculture program include creation of current employment undertaking the activities, creation of future harvest and milling employment due to increased future harvest levels, and government revenue from current and future taxation and stumpage fees.

Immediate employment creation in silviculture activities is estimated to create 35.3 full-time equivalent jobs. This will add harvestable volume in future years. Using a multiplier of 1.4 harvest and milling job per 1000 m^3 harvested, the harvest level increase will create approximately 70 jobs within 20 years, rising to 160 jobs by 40 years from now. Using standard economic multipliers of two indirect or induced jobs for each direct job, short-term employment creation would be on the order of 210 jobs, and long-term employment creation on the order of 480 jobs.

The direct jobs are well-paid. Assuming an income tax rate of $12,000 to $16,000 per direct job, and half that rate for indirect or induced jobs, the estimated government tax revenue from the silviculture program would be approximately $1.0 million in the first year. This would rise to $2.4 million by 20 years from now and to $4.2 million in the longer term.

Government stumpage revenue on the coast of British Columbia presently averages $27/$m^3$. At this rate, the increased harvest level will additionally create $1.4 million in government stumpage revenue within 20 years, and $3.1 million in the longer term. Thus the total expected government revenue return on the recommended silviculture budget of $3.8 million would be $4.8 million with a 20-year time horizon, or $7.3 million with a 40-year time horizon.

Additional benefits include the social stability contribution of increased, well-paid employment opportunities, the improved tourism opportunities with a greener visual condition, and the improved wildlife habitat that will exist across the landscape

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Appendix 1. Cost and Employment Assumptions

Silviculture Treatment	Cost ($/ha)	Revenue ($/m3)	Employment (days/ha)
Improved seed	0	0	0
Brushing	1,114	0	2.43
Fill Planting	900	0	1.20
Fertilize at Planting	180	0	0.25
SCHIRP	487	0	0.28
Juvenile spacing at age 14:			
to 1200 or 1700 SPH	1,744	0	4.14
to 800 SPH	2,115	0	5.40
to 400 SPH	2,485	0	6.96
Pole thinning at age 40 with wood removal:			
to 400 SPH	$55/m3	$50/m3	6.00
to 150 SPH	$50/m3	$55/m3	6.00
to low density for Objective 4	1,000	0	2.50
Commercial thinning	$55/m3	$65/m3	9.00
Aerial Fertilization	231		0.15
Pruning 2 lifts:			
first lift	1,800	0	6.53
second lift	2,113	0	7.67
Site preparation and planting:	2,000	0	3.25

Appendix 2. Volume (m^3/ha) recovered from thinning treatments

Block	Type	Pole Thinning age 40	Commercial Thinning age 60
1, 2	D-fir planted high-site	169	242
	D-fir planted good-site	90	122
	D-fir natural high-site	158	173
	D-fir natural good-site	91	119
3/4	D-fir natural high-site	158	173
	D-fir natural good-site	91	119
5	D-fir natural high-site	137	176
	D-fir natural good-site	109	138
6, 7	D-fir natural good-site	75	92

Appendix 3. Assumed old-growth average stand diameters

Site Class	Average Diameter (cm)
High	95
Good	80
Medium	65
Poor	50

Appendix 4. Data CD

Contents:

The September 2000 MP#8 timber supply analysis report
This Type 2 report
Graphical presentation of details for each block from the Type 2 analysis