Timber Supply Analysis Information Package
Tree Farm License 54

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Table of Contents

List of Tables

List of Figures

List of Maps

Appendices

1.0 INTRODUCTION

This information package has been prepared in support of the Timber Supply Analysis for Management Plan No. 4 for TFL 54. This document will be provided as an Appendix to the Timber Supply Analysis Report.

The timber supply analysis that will be conducted based on the data summarized here will be significantly different from previous analyses for TFL 54, and from analyses recently completed for nearby tenures. This difference is due primarily to three issues:

- the requirement that an area-based harvest level be determined as defined under the ABAAC Pilot Project Legislation and Regulations;
- the implementation of the Scientific Panel Recommendations that amongst many recommendations, suggest area based planning within Watershed Planning Units establishment of reserve networks; maintaining watershed rates of cut, and
- the widespread use of variable retention (VR), multi-entry silvicultural systems that leave between 15% and 70% of volume after the first pass.

The data summarized and methods presented in this document are the result of considerable collaboration between Interfor, the Ministry of Forests (MoF), J. S. Thrower and Associates (JST) and Timberline Forest Inventory Consultants (TFIC).

2.0 PROCESS

2.1 Overview

The data summarized in this document is the most current available. Any assumptions made for modelling and forecasting purposes are consistent with current forest management practices on the TFL.

The contents of this document will be reviewed with staff from Ministry of Forests – Forest Analysis Branch before starting any forest estate modelling.

This report will be included as Appendix 1 of the Timber Supply Analysis Report.

2.2 Growth and Yield

Although the area-based approach been taken to this harvest level determination does not use stand volume information directly, growth and yield forecasts continue to be a key requirement for strategic and operational planning. For this Timber Supply Analysis, minimum harvestable age and early stand height growth will be the key input parameters derived from G & Y information.

3.0 TIMBER SUPPLY FORECASTS / OPTIONS / SENSITIVITIES

Harvest forecasts that will be provided are summarized in this section. The set of assumptions pertaining to each option and sensitivity analysis is detailed in later sections.

3.1 Base Case

The base case forecast results from assumptions about the best estimate of current management performance at the time that this analysis is being completed. Major forest management considerations and issues incorporated into this base case analysis are:

- new Vegetation Resources Inventory (VRI);
- updated forest inventory database;
- current management regimes, especially variable retention prescriptions and standards;
- minimum harvestable ages based on forecast species and grade distributions;
- adherence to the recommendations of the Clayoquot Sound Scientific Panel Recommendations (1995);
- incorporation of reserve networks as dictated by approved and pending Watershed Plans;
- revisions to operability mapping in light of the new VRI, and with adjustments to include all logged areas or areas identified in FDPs that were previously mapped as inoperable;
- Forest Development Plans (FDPs);
- buffering of all roads in the road inventory;
- regeneration assumptions; and
- immature plantation history.

The base case is used as the baseline from which to assess risk associated with any of the assumptions in the sensitivity analysis.

3.2 Sensitivity Analysis

Sensitivity analysis provides a measure of the upper and lower bounds of the base case harvest forecast that reflects the uncertainty in the data and/or the management assumptions made in the base case. The magnitude of the increase and decrease in the sensitivity variable reflects the degree of uncertainty surrounding the assumption associated with that given variable. Table 3.1 summarises the sensitivity analyses that will be performed for the base case.

Table 3-1 Current management sensitivity analyses

Issue	Sensitivity analysis	Sensitivity level to be tested
Inventory	Inventory Volume Adjustment	Use unadjusted inventory volume
Landbase revisions	Change operability assumptions	THLB limit at 350m^3/ha
		THLB limit at 450 m^3/ha
		Exclude inoperable >200m from core THLB
		Exclude inoperable >100m from core THLB
	Marbled Murrelet	Remove draft reserves from THLB
Growth and yield	Increase Minimum Harvest Age	+10%, +20%, +30%
	Decrease Minimum Harvest Age	-10%
		IRM constraint on all primary basins
		5% / 5-year on all primary basins
	Visual Quality Objectives	+/- 10% maximum % removal
		+/- 2 metres VEG greenup height

3.3 Alternative Harvest Flows

The objective of area-based timber supply analysis is to determine a (strictly defined) even flow harvest level. As such, alternative harvest flows (that vary from period to period), of the sort normally examined during conventional, volume-based analyses, will not be considered or presented. However, model runs will be conducted using different harvest requests to demonstrate the robustness of the base case harvest level. The following harvest level variations will be presented:

- minus 10%
- plus 10%
- plus 20%

4.0 FOREST ESTATE MODEL

This timber supply analysis will be conducted with COMPLAN, a proprietary simulation model owned by Timberline. COMPLAN is a spatially explicit forest estate simulation model that schedules harvests at the cutblock or stand level subject to adjacency (green-up) and non-timber resource constraints (cover constraints). There is a great deal of flexibility built into the model so it is possible to realistically evaluate many scenarios. The most recent version of the model has been upgrade to allow for the area-based regulation of harvesting.

COMPLAN uses a hierarchical data structure that takes advantage of a compartmented approach to spatial data organization. Advantages of this approach include easy integration with GIS systems, adaptation to a wide variety of tenure administration structures, and integration of both strategic and operational planning.

COMPLAN offers a number of key features that make it ideally suited for both strategic and operational planning:

- Inventory and harvest are spatially located so that specific harvest units and forest stands used in the model can be identified on maps.
- Spatial location is defined by a hierarchical structure of compartments, subcompartments, and stands. In addition, spatially located cover constraints can be superimposed over compartments, subcompartments and stands.
- Adjacency is incorporated so that the harvest of certain units under given silvicultural regimes can render adjacent units to be unavailable for periods of time to allow for VEG green-up.
- Individual subcompartments can be aggregated into larger harvest units, subject to size and VEG green-up constraints.
- Periodic availability can be simulated for harvest at both the compartment and subcompartment levels. This may be used to incorporate operational feasibility (e.g. isolated blocks in the back of a drainage can be delayed to allow road access), additions or removals to the land base over time (e.g. additions due to technological advances), or to exclude permanent reserves.
- Individual stands within an otherwise available subcompartment can be designated as reserve areas that are permanently exempted from harvest. Typical examples would be low site or non-merchantable pockets within a subcompartment which are not harvested, but may contribute to cover constraint status.
- Non-forest areas (e.g. lakes) can be included in the data. Although these areas are not important for timber production or for cover, they may provide sources of important wildlife habitat.
- The capability for both even-aged and all-aged (selection) silvicultural systems is supported. Even-aged systems may consist of clearcutting or

multiple entry systems such as shelterwood and seed tree. Commercial thinning can also be simulated.

- The model is driven by yield tables. Harvests and yields for the various silvicultural systems are derived from yield tables developed outside the model. However, existing initial inventory volumes may be used as a starting point for the simulation and trended according to the shape of the yield table. If inventory volumes are not available, then the yield table volumes are used directly.
- An optional "approach to normality" is provided for growth of stands where the initial volume does not equal the predicted yield curve volume.
- Forest stands may shift from one yield class (i.e. treatment regime) to another at the time of harvest, or at other user-specified times subject to constraints on the maximum area allowed to shift.
- Harvest eligibility in any given period is controlled through the concept of absolute and desired minimum stand characteristics. A subcompartment is eligible for harvest if the area-weighted average value of a parameter is above the desired harvest minimum value. However, a subcompartment will not be harvested if any stand is below the absolute minimum value.
- Harvest priorities can be determined in five ways, including user-defined, oldest first, minimize volume loss, maximize conversion return, and minimize cost. In addition, provisions are made to allow harvesting of the full profile of timber on both an area or analysis unit basis.
- User-defined physical attributes (e.g. ecosystem, slope, etc.) can be assigned to individual stands or subcompartments. These attributes provide an additional basis for summaries of harvest, inventory, seral stages, etc.
- Cover constraints commonly encountered in integrated resource management can be simulated. These cover constraints take the form of proportions of areas that must be maintained with certain stand characteristics.
- Habitat and biodiversity calculations can be completed using the flexible physical stand attribute and yield table data structures.
- There are no artificial limitations on number of stands, subcompartments, yield curves or other model inputs; all data types are constrained only by the amount of available memory in the computer system.
- Simulations for harvest and inventory update are performed on a yearly or other user-defined basis. This allows accurate evaluation of adjacency constraints. All reporting is completed on a user-defined periodic basis.

5.0 CURRENT FOREST COVER INVENTORY

5.1 Overview

A Vegetation Resources Inventory (VRI) was conducted for Clayoquot Sound (including TFL 54) in 1996. However, this will be the first Timber Supply Analysis based on this inventory, as no analysis was conducted in support of Management Plan #3 in 1999.

5.2 History

The Phase I VRI was completed in 1996. No ratio adjustment (Phase II) analysis has been completed.

Interfor has converted the spatial and attribute data to FC1 format so to incorporate it into their existing information systems.

5.3 Updates

The inventory has been updated for depletion until the end of 2003; growth has been projected to the same date.

5.4 Inventory Adjustment

At the outset of the project, it was determined that the heights, site indices and volumes listed in the inventory were unrealistically low. Mature volumes were adjusted using historical inventory plots. Unfortunately, stand heights and site indices could not be adjusted using this data. The adjustment procedure will be described in detail in Appendix I of the Timber Supply Analysis Report.

6.0 DESCRIPTION OF LANDBASE

6.1 Overview

This section describes the methodology used to define the productive forest considered to contribute to, and be available for, long-term timber supply from within the total land base of TFL 54.

6.2 Timber Harvesting Landbase (THLB) Determination

Table 6-1 show the netdown process through which the timber harvesting landbase has been determined.

Table 6-1 Timber Harvesting Landbase Determination

		All TFL 54 (Ha)		
Classification	**Section**	**Total**	**Productive**	**Net**
Total TFL Landbase		49,298.0	48,121.0	
Non-forest	6.2.1	1,177.1		
Total Productive		48,121.0	48,121.0	48,121.0
Reductions				
Meares Island	6.2.2	3,813.4	3,795.7	3,795.7
Watershed Planning Reserves	6.2.3	14,183.1	13,345.3	13,345.3
Generated Reserves	6.2.4	1,237.7	1,190.7	1,190.7
Inoperable	6.2.5	10,276.7	9,333.4	5,187.1
Operable				**24, 602.2**
Non-commercial	6.2.6	2.4	2.4	-
Existing Roads	6.2.7	664.2	644.4	515.8
Operable Reductions				
Reduced Landbase				**24,086.4**
Future Changes				
Roads, Trails, Landings				
Net Long-term Landbase				**24,086.4**

6.2.1 Land Classified as Non-forest

Areas that do not support the growth of forests have been excluded from this analysis. The NPFORESTDESC field on the inventory file identifies these areas by category, as shown in Table 6-2.

Table 6-2 Exclusion of land classified as non-forest

Non-forest Classification	Total Area	Inside Clayoquot Sound	Outside Clayoquot Sound
Lake	774.9	766.6	8.3
NP	325.4	186.3	139.1
NPBR	26.4	26.4	-
NTA	11.1	0.7	10.4
Rock	14.8	3.3	11.5
Swamp	17.9	9.6	8.3
Other	6.6	6.6	-
Total	1,177.1	999.4	177.7

6.2.2 Meares Island

Although Meares Island remains within the TFL, timber harvesting is before the courts. It has been removed from the base case of this analysis in its entirety (3813.4 hectares). However, the foregone harvest resulting from its removal may be evaluated in a sensitivity analysis.

6.2.3 Watershed Planning Reserves

Most of the area of TFL falls within Clayoquot Sound and is therefore subject to the recommendations of the Scientific Panel. The Panel identified fifteen Watershed Planning Units; TFL 54 intersects nine of these, as shown in Table 6-3.

Table 6-3 Watershed Planning Unit Reserve Areas

Watershed Planning Unit	Total Area	Area Reserved	Productive Area Reserved
Beach	1,559.8	64.9	63.7
Bedingfield	3,773.2	1,508.0	1,495.3
Bedwell/Ursus/Bulson	71.4		
Cypre	5,921.4	2,120.7	2,084.9
Fortune Channel	3,278.7	1,281.0	1,269.8
Hesquiat	9,311.6	3,654.8	3,565.7
Kennedy Lake	5,847.6	1,369.3	1,340.1
Megin	53.9		
Sydney / Pretty Girl	11,704.0	4,093.9	3,451.1
None	351.8	90.5	74.0
Total	**41,873.3**	**14,183.1**	**13,345.3**

Watershed Plans have been completed for eight of these areas. Two (Bedingfield and Cypre) have been approved; the remaining six are still at the draft stage. An Interim Watershed Plan was available for only a portion of the Kennedy Lake basin.

The purpose of these Plans is to map and designate the areas set aside as reserves to protect a range of forest values as defined in the Scientific Panel Recommendations. They also map and designate the harvestable area – land that falls outside of reserves and on which sustainable forest harvesting can take place[1].

Under this planning process, reserves are selected to meet the following resource objectives:

- to protect hydroriparian resources
- to protect sensitive soils and unstable terrain
- to protect red- and blue-listed plant and animal species
- to protect forest-interior conditions in late successional forest
- to represent all ecosystems
- to ensure linkages among watershed-level planning areas
- to protect culturally significant areas

[1] Bedingfield Watershed Plan

These reserves replace reserves for wildlife habitat, ESA's, OGMA's and FPC riparian buffers.

6.2.4 Generated Reserves

Some portions of TFL 54 are not within the Clayoquot Sound Land Use Decision area and, therefore, are not subject to the Watershed Planning process. Also, portions of the Kennedy Lake basin do not yet have Interim Watershed Plans or Watershed Plans completed. For these areas, a GIS process was used to generate reserves based in the following input coverages:

- riparian buffers
- terrain stability
- environmentally sensitive areas
- operability

These areas would have been netted out in any conventional timber supply analysis; they are been converted to reserves here for consistency with the remainder of the TFL. The area of each resource concern is shown in Table 6-4.

Table 6-4 Generated Reserve Input Coverage Areas

Resource Concern	Area Reserved (ha)	Productive Area Reserved (ha)
Riparian Buffers	657.1	625.6
Terrain Class V	458.8	457.5
ESA - Recreation	26.8	25.8
ESA - Soils	360.2	336.0
Inoperable	172.8	152.5
Total	**1,237.6**	**1,190.7**
Total Area (outside Clayoquot)		**3630.4**
Total Harvestable Landbase (outside Clayoquot)		**2416.6**

(Individual areas do not sum to the total shown due to overlap between resource concerns.)

6.2.5 Land classified as inoperable

Operability codes describe the presence or absence of physical barriers or limitations to harvesting. Operability mapping, including both economic and physical operability, was completed for the TFL in 1992 and was accepted by the South Island Forest District in 1993. Of the area that remains of the TFL, a total of 17,240 hectares, including low-productivity sites, are considered inoperable. This coverage was the starting point for a re-evaluation of operability in light of changes to economic conditions and a new forest inventory. The adjustment to the VRI is described in Section 8.

Based on the adjusted inventory volume, previously inoperable stands were considered to be operable it they had a volume of greater than 400 m3/ha, had a slope of less than 60%, and were not Terrain Class V. Also, any stand that was recently logged, or will be logged in the near future (according to the current FDP) was also considered to be operable. Finally, any mature, previously operable areas that do not have a volume of at least 400 m^3/ha were made inoperable and removed from the THLB. Table 6-5 shows the progression of these calculations.

Table 6-5 Operability Revisions

	Total area (ha)	Productive area (ha)	Net area removed (outside reserves) (ha)
Initial Inoperable	17,240.2	16,292.1	10,311.3
minus:			
Inoperable >400m3, <60% slope, not Terrain V	7,554.8	7,554.8	5,276.0
Inoperable in FDP Blocks	531.5	526.7	472.7
plus:			
Operable <400m3/ha, >120 years old	1,161.5	1,141.1	606.9
Revised Inoperable	**10,276.7**	**9,333.4**	**5,187.1**

Checkplots of these operability changes were reviewed by field staff familiar with the area. The net impact on the operable landbase is a gain of 5,124.2 hectares (10,311.3 ha. minus 5,187.1 ha.).

All of the area recovered is assigned a (high retention) P6 VR prescription[2], which limits harvest to 30% of the stand volume. Figure 6-1 shows the area distribution (by VR prescription) of the initial and revised THLB's.

[2] Variable retention prescriptions are discussed in Section 8.3.7.

Figure 6-1. THLB Area Distribution – Before and After Operability Revision

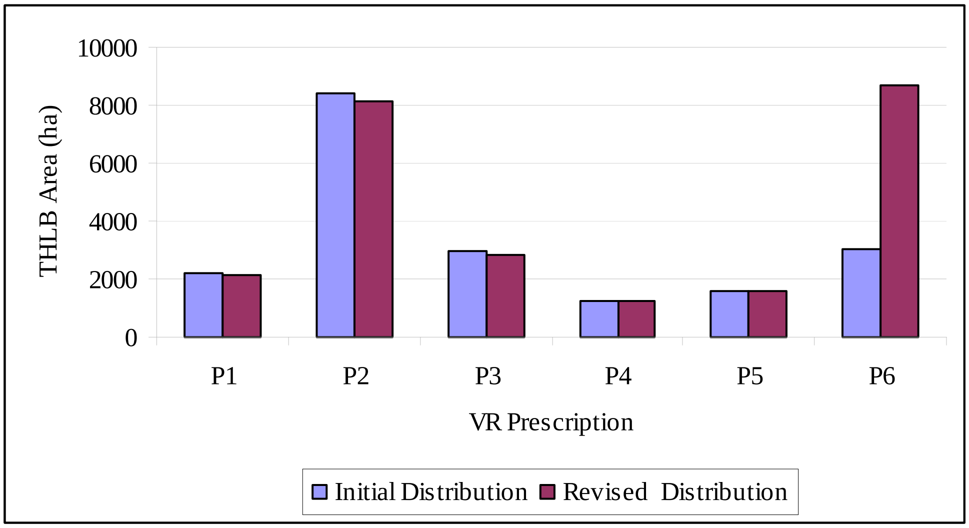
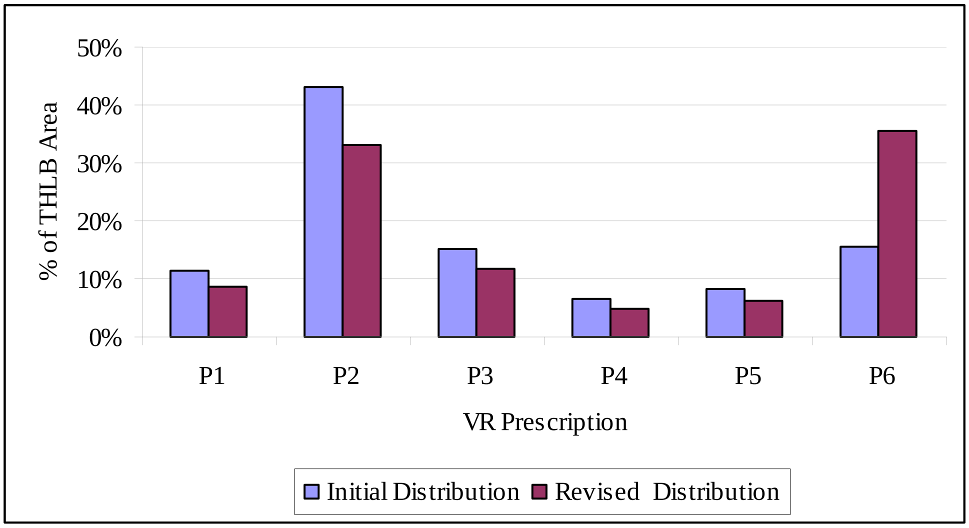


Figure 6-2 shows the same distribution expressed as a percent of THLB area.

Figure 6-2. THLB % Distribution – Before and After Operability Revision



6.2.6 Land classified as non-commercial forest types

Only 2.4 hectares was netted out of the THLB because it was non-commercial. These were areas occupied by non-commercial brush species. 172 hectares of red alder leading stands were retained in the THLB, on the basis that they can be managed operationally to contribute to variable retention requirements. No deciduous species other than alder forms a major component of any stand in the THLB.

6.2.7 Land classified as non-contributing due to roads, trails and landings

Existing roads, trails and landings reductions are applied to the current productive forest. Future roads, trails and landings reductions are applied as a netdown on the future yield curves.

Existing roads are described as line features in the road inventory. Reductions are based on a 5 metre buffer applied to either side of all roads. This represents an average for roads, trails and landings. The buffered area is removed from the polygons in which it occurs. Table 6-6 shows reductions to the THLB due to present roads, trails and landings.

Table 6-6 Present roads, trails and landings and reductions to the THLB

Description	Total area (ha)	Productive area (ha)	Net area removed (ha)
Existing roads, trails and landings	664.2	644.4	515.8

6.2.8 Other Potential Alienations

In past analyses, netdowns would have been applied for the one or more of the following reasons:

- Land classified as low growing potential
- Land classified as non-contributing due to wildlife habitat
- Land classified as non-contributing due to cultural heritage resources
- Land classified as non-contributing due to riparian reserves and management zones

No netdown of stands with low timber growing potential has been applied here because:

- The VRI significantly underestimated height and site index, and therefore cannot be used to accurately identify low productivity areas; and
- In past analyses, areas of low productivity were considered to have been sufficiently excluded by the netdown for operability. A review of the SIA results show that most low productivity areas fall inside reserves areas; only 80 hectares of the THLB has a SIA site index of 15 or less. These areas will be managed operationally through retention prescriptions.

As noted previously, wildlife habitat, cultural heritage resources and riparian reserves are all adequately accounted for by Watershed Planning Unit Reserves.

7.0 FOREST INVENTORY ORGANIZATION

In order to reduce the complexity of the forest description for the purposes of timber supply analysis simulation, aggregation of individual forest stands may be necessary. However, it is critical that this aggregation does not obscure either the biological differences in forest stand productivity or differences in management objectives and prescriptions. It is important to note that in these analyses, aggregation of the landbase will be consistent in all options and sensitivity analyses. This is to ensure that differences in results reflect differences in management decisions and not inventory aggregation.

7.1 Watershed Planning Units

Watershed Planning Units are a fundamental to forest management in Clayoquot Sound. Watershed Reserves Networks are identified in Watershed Plans, which must be prepared in accordance with the Clayoquot Sound Land Use Decision. Old seral requirements are specified at the Watershed level; in this sense they are similar to Landscape Units that have been defined for much of the remainder of the province. However, Watershed Plans go further, and explicitly identify "Harvestable Area". Table 7-1 shows the area of TFL 54 in each of the watersheds that it overlaps.

Table 7-1 Area by Watershed Planning Unit

Watershed Planning Unit	Total Area (ha)	Productive Area (ha)	Net area (ha)
Beach	2,537	2,513	1,932
Bedingfield	3,773	3,749	1,900
Bedwell/Ursus/Bulson	71	70	23
Cypre	5,921	5,854	2,972
Fortune Channel	3,279	3,263	1,857
Hesquiat	9,314	9,220	4,644
Kennedy Lake	5,900	5,834	3,542
Meares	3,772	3,754	
Megin	54	53	24
Sydney / Pretty Girl	11,704	11,053	5,394
None	2,972	2,756	1,797
Total	49,298	48,121	24,086

7.2 Analysis Unit Definitions

If possible, yield curves will not be aggregated into analysis units. This will depend largely on the number of unique yield curves that are produced, and the limitations of COMPLAN.

Should it become necessary to aggregate yield curves into analysis units for technical reasons, the following criteria will be used:

- VR prescription;
- minimum harvest age; and possibly
- years to 8 metres stand height.

This is the greatest degree of aggregation that would be possible without adversely affecting area-based AAC computations.

7.3 Age Class Distributions

The age class distribution for TFL 54 is given in Table 7-2.

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Table 7-2 Area by age class

Age Class	Productive Area	Net Area
0	80.5	44.3
1	3,891.4	2,751.5
2	4,548.3	2,841.9
3	983.0	587.8
4	97.5	27.7
5	120.3	45.9
6	173.5	79.5
7	377.9	102.4
8	11,305.1	4,129.1
9	26,543.5	13,476.5
Grand Total	48,121.0	24,086.4

8.0 GROWTH AND YIELD

8.1 Overview

The site productivity, yield, and other growth and yield (G&Y) information for this analysis was developed by J. S. Thrower & Associates Ltd. (JST). This was done in conjunction with Interfor, the MOF Research Branch and Forest Analysis Branch, and Timberline. This section describes the approaches used in developing G&Y information for:

- Yield estimates for natural stands;
- Yield estimates for managed stands; and
- Estimating minimum harvest age (MHA).

8.2 Natural Stands

Most natural stands on the TFL are in the older age classes (8 and 9) where the net volume is not expected to increase over time. Therefore, the approach for all natural stands was to assume that the volume given in the inventory will remain constant and not change over time (or "flat-lining" the yield curves). Younger mature stands (age classes 4-7) will increase in volume over time; however, they account for only a small portion of the TFL and thus the assumption of no volume growth for all natural stands is conservative for these younger mature stands.

8.3 Managed Stands

8.3.1 Modeling

All G&Y estimates for existing and future managed stands were developed using the MOF TIPSY model. This model is used to generate the estimates of yield for most TFLs and TSAs in the province. A unique yield table was developed for each stand (forest cover polygon) in the TFL based on:

1. Species composition and stand density.
2. Silviculture regimes developed by Interfor staff to reflect silviculture and management history on the TFL.
3. Site index estimates localized to the TFL.
4. Volume reductions to account for the G&Y impacts of VR.

8.3.2 Silviculture Eras

Interfor developed unique inputs to TIPSY to reflect four different eras of silviculture history on the TFL (Table 8 1). These eras impact G&Y because each era resulted in different regenerated stand conditions and thus in different inputs to the TIPSY and the associated different yield estimates.

All stands harvested and regenerated prior to 1960 were regenerated naturally. From 1960 to 1969 (era 1), sites were burned following harvest and planted with Fd. This practice continued through era 2 when Cw (and some Ba) was introduced to the planting program. By 1986 (era 3), the practice of burning was phased out and Cw became the primary planted species following harvest.

TFL 54 was transferred to Interfor in December 30, 1991. The licence was obtained by an assignment of the former west coast portion of TFL 46 held by Fletcher Challenge Canada Limited. In 1995, Interfor revised their silviculture regimes to be consistent with the Clayoquot Sound Scientific Panel. Areas of the TFL inside the Clayoquot Sound Science Panel came under VR prescriptions and all sites were planted with genetically improved Cw or wild Ba and Yc stock. This silviculture regime was implemented to 2004 and is the prescription that Interfor intends to apply to all stands in future. A small part of the TFL is outside the Clayoquot Sound Scientific Panel area and the silviculture practice is to clearcut and plant genetically improved Cw.

Table 8-1 The four silviculture eras used in the managed stand yield tables

Era 1	1960-1969	CC, Burn, Plant Fd
Era 2	1970 to 1985	CC, Burn, Plant Fd, Cw, (Ba)
Era 3	1986 to 1994	CC, Plant Cw (Ba)
Era 4	1995 to Present and Future	CC or VR, Plant genetically improved Cw (Ba or Yc)

8.3.3 Stand Density & Species Composition

As discussed, Interfor staff developed silviculture regimes for all managed (since 1960) and future stands. For era's 1 to 3 (non-VR era's), separate regimes were developed for each inventory type group (ITG) in the VRI. Because there are approximately 20 to 25 different ITGs in each non-VR era, the most common regime modeled in each non-VR era is presented in Table 8-2 .

Table 8-2 Average species composition and density modeled in TIPSY for era's 1 to 3.

	Species Mix	Planted density (stems/ha)	Natural Ingress (stems/ha)	Free-to-grow density (stems/ha)
Era 1	FdHw	600	1500	2100
Era 2	CwHw	900	2100	3000
Era 3	CwHw	900	2100	3000

Three separate silviculture regimes were developed for era 4 to reflect the different silviculture regimes under VR prescription. These prescriptions were applied by VRI ITG and are shown in Table 8-3.

Table 8-3 Species composition and density modeled in TIPSY for era 4.

ITG	Species Mix	Planted density (stems/ha)	Natural Ingress (stems/ha)	Free-to-grow density (stems/ha)
CH	CH	1200	800	2000
HBC	HBC	1000	4000	5000
HBY	HBY	1000	2500	3500

8.3.4 NSR Areas

Areas classified in the inventory as Not Satisfactorily Restocked (NSR) are considered part of the working forest and were regenerated as managed stands. This assumption applies to existing managed stands only.

8.3.5 Genetic gain

Following a review of Interfor's planting program, we applied a volume increase of 2% for stands planted with Cw since 1995 and to future managed stands planted with Cw to account for the improved G&Y expected from planting improved Cw seed. Interfor plants Class A seed, but chose not to apply the expected gains of 5% from Class A Cw seed in the yield tables because it is not always available for purchase. Genetic gain was not applied to any other species.

8.3.6 Site Index

The site index for existing and future managed stands was estimated using the results of the Site Index Adjustment (SIA) project completed for the CWH biogeoclimatic zone on the TFL in 2004. The SIA results showed that the forest inventory underestimated the site index of managed stands by approximately 11 m and 8 m for Hw and Cw stands respectively. The average Hw site index was 17 m in the old-growth based inventory compared to 28 m in managed stands. The average Cw inventory site index was about 15 m compared to 23 m in managed stands. These results are similar to projects completed by the MOF and other forest licensees throughout the coastal and interior regions of BC.

8.3.7 VR Impacts

We estimated the G&Y impacts of VR using the MOF Tree and Stand Simulator (TASS) model. VR harvesting is expected to result in reduced G&Y of regenerated stands because of the competition from the retained trees on the younger regenerating trees. The process was to estimate the impact of 18 different VR regimes and then reduce the TIPSY generated yield tables by the estimated amount for each regime (know as the VR adjustment factor [VRAF]).

The 18 VR regimes were defined by Interfor as combinations of:

1. One or two pass harvesting;
2. VR levels of 15%, 40%, and 70%; and
3. VR patterns including dispersed single trees, trees aggregated into groups, and combinations of dispersed and aggregate retention.

The TASS simulations were completed by the MOF Research Branch. The simulations included all combinations of:

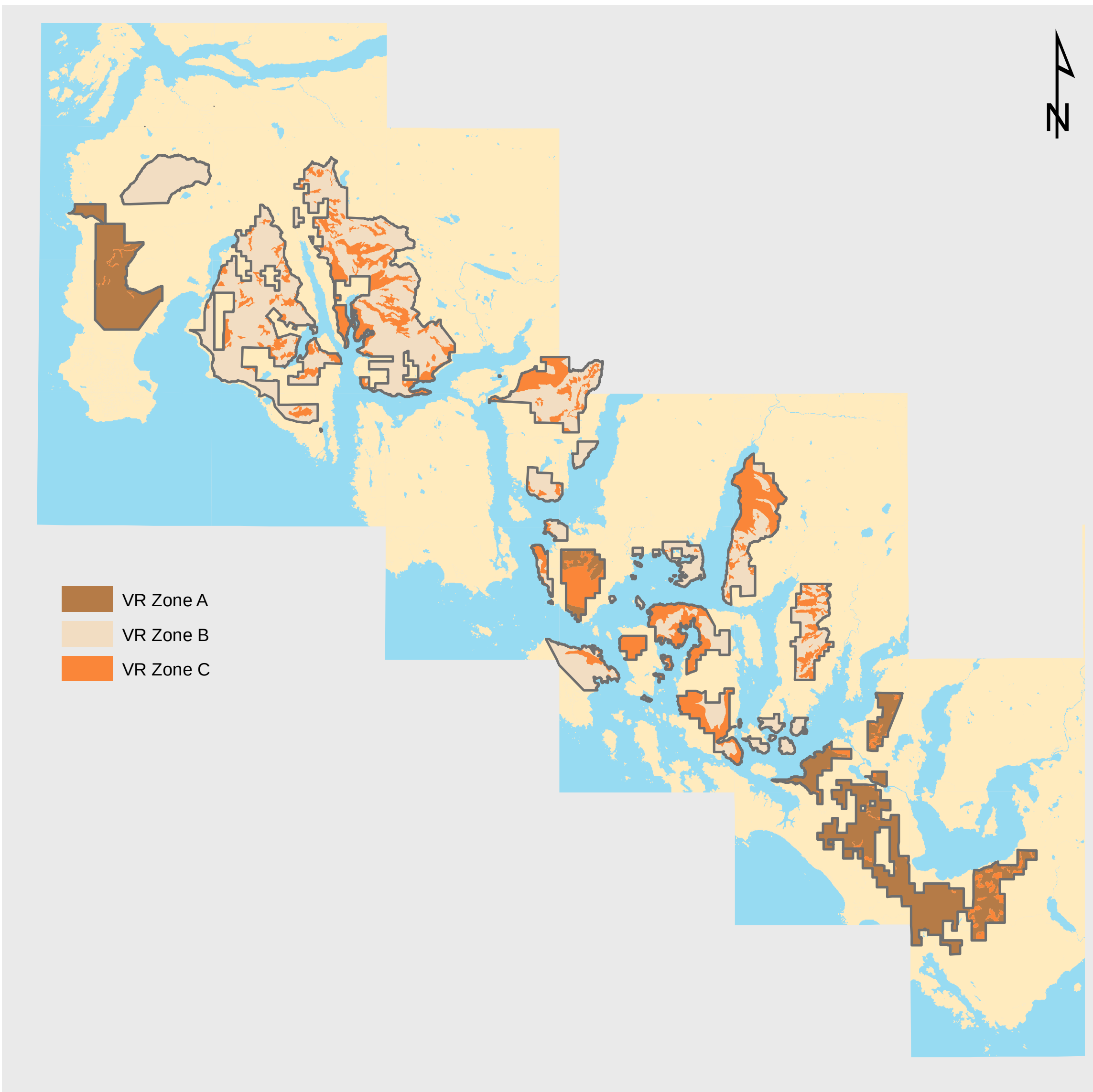
4. The 18 VR regimes.
5. Site index 15 m, 20 m, 25 m, 30 m, and 35 m.
6. Planting densities of 1,000 Hw trees/ha with natural ingress of 4,000 Hw trees/ha.

The G&Y impacts were estimated as the volume difference from the growth that would be achieved in an open (clearcut) condition where regenerating trees were not subjected to competition from residual mature trees (e.g., competition for light, moisture, and nutrients). This growth difference was then used as a proportional adjustment to reduce the G&Y estimates from TIPSY.

The VR prescription for each resultant polygon in the TFL stand was assigned by dividing the TFL into three operating zones (Table 8-4, Map 8-1). A VR regime was then assigned to each stand using the process shown in Figure 8-1.

Table 8-4 Operating Zones for VR Prescriptions

VR Zone	Zone Name	Source
Zone A	High Intensity	From Interfor hardcopy map – developed and accessible corridors Kennedy and Stewardson
Zone C	Limited Availability	Visual 'Natural Appearing' within 5km of Coast
Zone B	Conventional Operations	Remainder



Map 8-1 Zones for VR Prescription Assignment

Figure 8-1. Variable Retention Prescription Logic

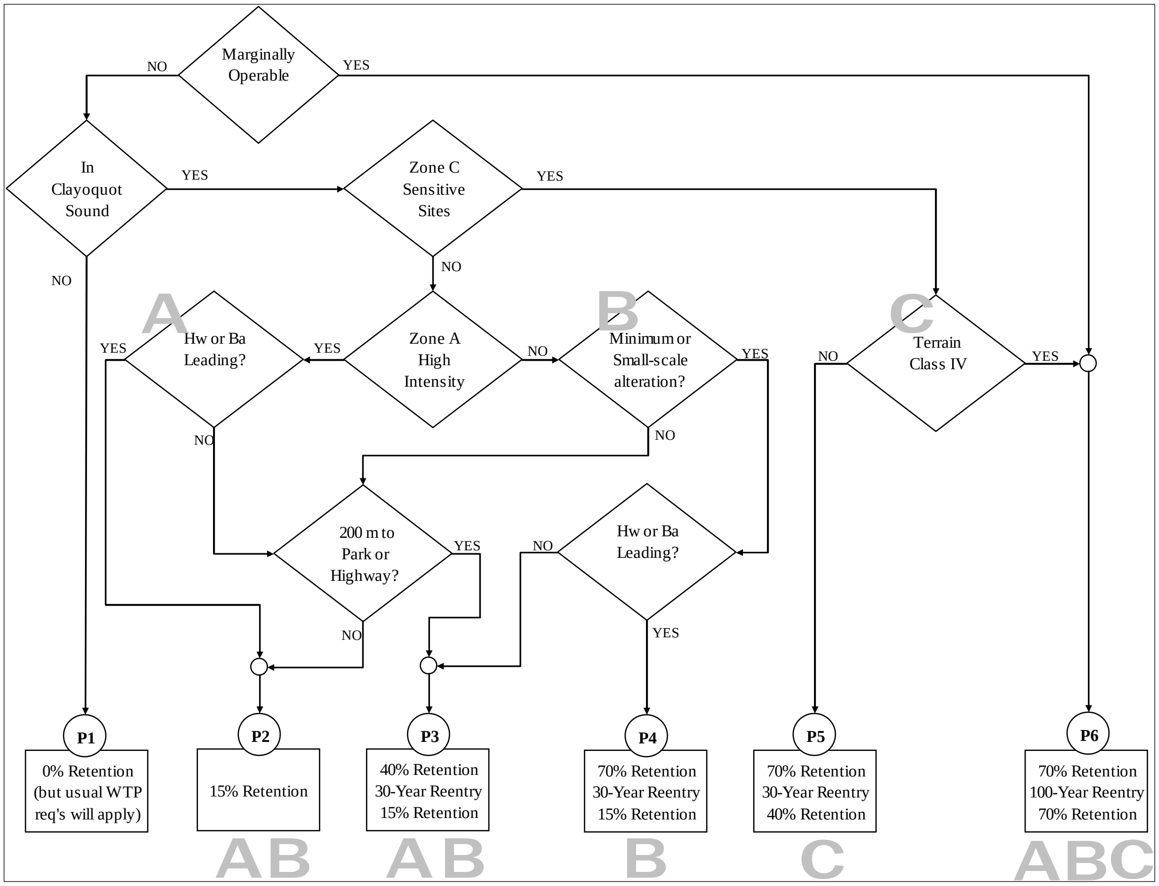
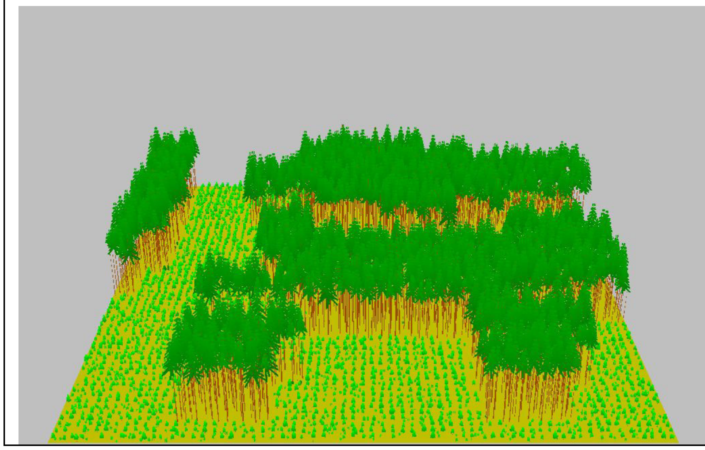


Figure 8-2 gives an example of the G&Y results generated with TASS to define the VRAF for the various VR levels. This is Hw-leading, site index 30 m with a planted density of 1,000 stems/ha and 1,000 stems/ha of natural ingress.

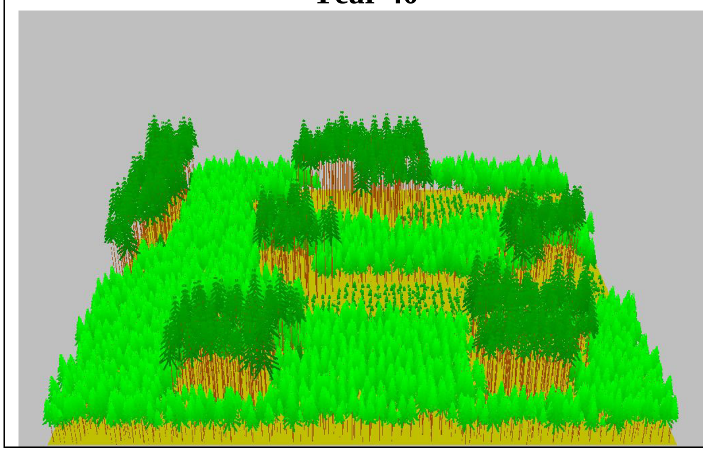
This example shows a P3 VR regime at 10, 40, and 100 years after initial harvest. At initial harvest, 40% of the area is harvested in the first pass; 30 years later the stand is revisited and 45 of the remaining 60% of the area is harvested in the second pass.

Year 10



Understory stand characteristics:
1st pass cohort
Merch. volume = 0 m^3/ha
Top height = 3.4 m

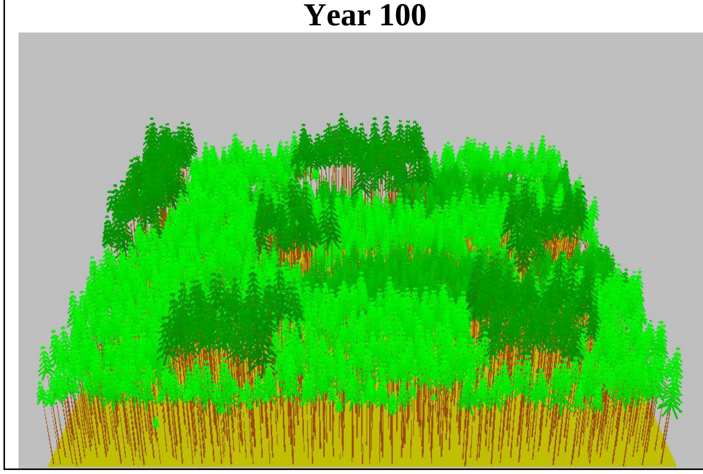
Year 40



Understory stand characteristics:
1st pass cohort
Merch. volume = 166 m^3/ha
Top height = 20.9 m

2nd pass cohort
Merch. volume = 0 m^3/ha
Top height = 3.4 m

Year 100



Understory stand characteristics:
1st pass cohort
Merch. volume = 604 m^3/ha
Top height = 40.4 m

2nd pass cohort
Merch. volume = 167 m^3/ha
Top height = 32.9 m

VRAF= (604+167)/1,129[3] = 0.68

Figure 8-2. Visualization of TASS simulation of a P3 VR regime

[3] In this example, 1,129m^3/ha is the total volume on site (regenerating volume plus existing natural volume).

8.4 Minimum Harvest Age (MHA)

8.4.1 Overview

We used economic criteria to define the minimum harvest age (MHA) for this analysis. A stand cannot be harvested in COMPLAN until it reaches this minimum age. The MHA is not necessarily the age at which stands are selected for harvesting in the model, but rather is the earliest age that a given stand is considered for including in the harvest queue. MHA is often defined in timber supply analyses using physical or biological features such as minimum piece size, species, stand age, or culmination of mean annual volume increment (MAI). However, we believe that MHA based on economic criteria is a more realistic representation of how stands will be selected for harvesting in the future.

In this analysis, MHA is achieved when a stand is estimated to be profitable to harvest. This is where the estimated stand value exceeds the cost of harvesting and reforestation. The process for determining MHAs is described below.

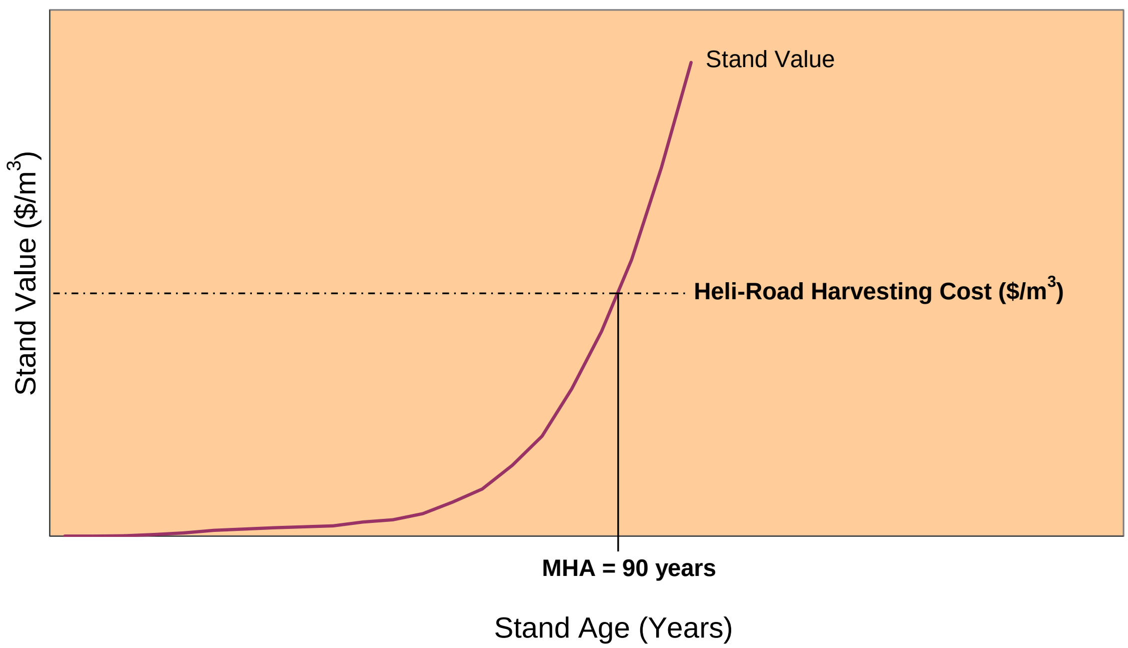


Figure 8-3 Minimum Harvest Age (MHA) for Idealized Stand Harvesting Method: Heli-Road Harvesting

8.4.2 Future Stand Value

Stand value was estimated for each existing and future managed stand on the TFL based on:

7. Volume yield estimated from TIPSY (developed as previously described).
8. Grade distribution as defined by an end-use sort matrix (developed by Interfor to reflect local grades and conditions).
9. Log prices for each end-use sort (developed by Interfor to estimate a long-tem average selling price in 2004 dollars) (Table 8-5).

Table 8-5 End-use sort pricing matrix to derive economic MHA

Fd	**$/m^3**	**Cw**	**$/m^3**	**Hw**	**$/m^3**	**Ba**	**$/m^3**	**Ss**	**$/m^3**	**Dr**	**$/m^3**
Select	$120										
Sawlog	$105	Merch	$140	Std	$60	Std	$60	Std	$ 60	Sawlog	$75
Gang	$ 85	Gang	$145	Gang	$55	Gang	$55	Gang	$ 55		
Peewee	$ 55	Peewee	$ 80	Peewee	$45	Peewee	$45	Peewee	$ 45		
		Shingle	$ 80								
Pulp	$ 25	Pulp	$ 30	Pulp	$40	Pulp	$40	Pulp	$ 40	Pulp	$15

8.4.3 Future Harvest Costs

Projected future harvest costs were developed by Interfor to reflect the average costs of harvesting and reforesting areas on the TFL. These costs assume that roads to access blocks in the first pass are there in future, but will require some maintenance and reconstruction costs.

These costs include total engineering overhead costs, road reconstruction, logging, and basic silviculture (excluding stumpage costs). The land base is divided into Kennedy Flats and other areas to reflect logical cost differences. Conventional harvest methods (only) are to be used in the Kennedy Flats area – conventional harvest costs will apply. The area outside Kennedy Flats is further divided into conventional logging, helicopter and dump on the road, and helicopter and dump in the ocean (Table 8-6).

Table 8-6 Estimated future harvesting costs of areas outside of Kennedy Flats

Area / Type	Harvest Cost ($/m^3)
Conventional	$53.50
Heli Road	$64.50
Heli Ocean	$59.50

8.4.4 Existing Stand MHA

The economic MHAs were calculated for all existing managed stands. (Existing natural stands are all age class 8 and 9 and assumed to be above MHA now.) This was set as the earliest point at which stand timber value exceeded (by a value of $0.01) the appropriate logging method costs. The results for existing managed stands are shown in Figure 8-4.

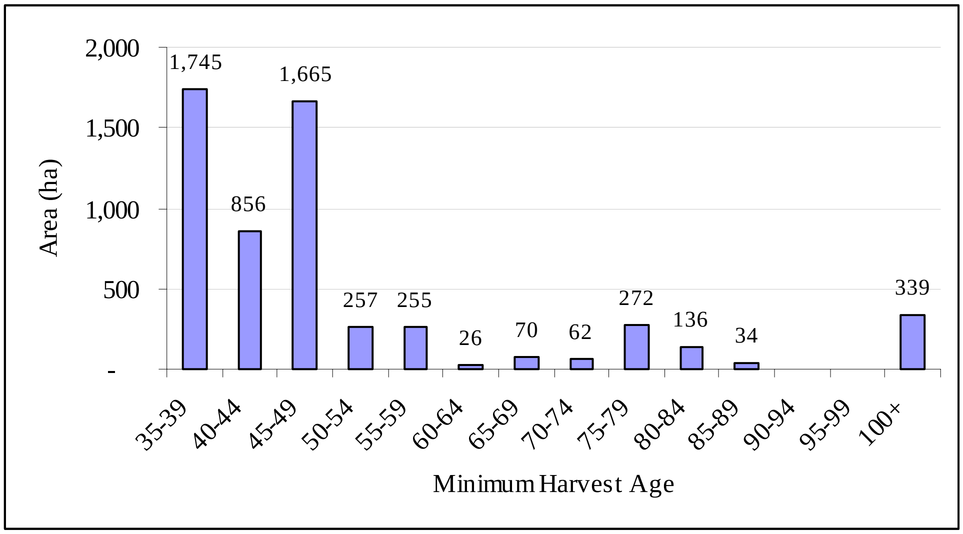


Figure 8-4. Existing managed stand MHA

For the timber supply analysis, all MHAs will be capped at 100 years.

8.4.5 Future Stand MHA

MHAs were calculated for future managed stands in the same manner – the youngest age at which stands become profitable to log using the appropriate harvesting method. Figure 8-5 summarizes the MHA results for future stands.

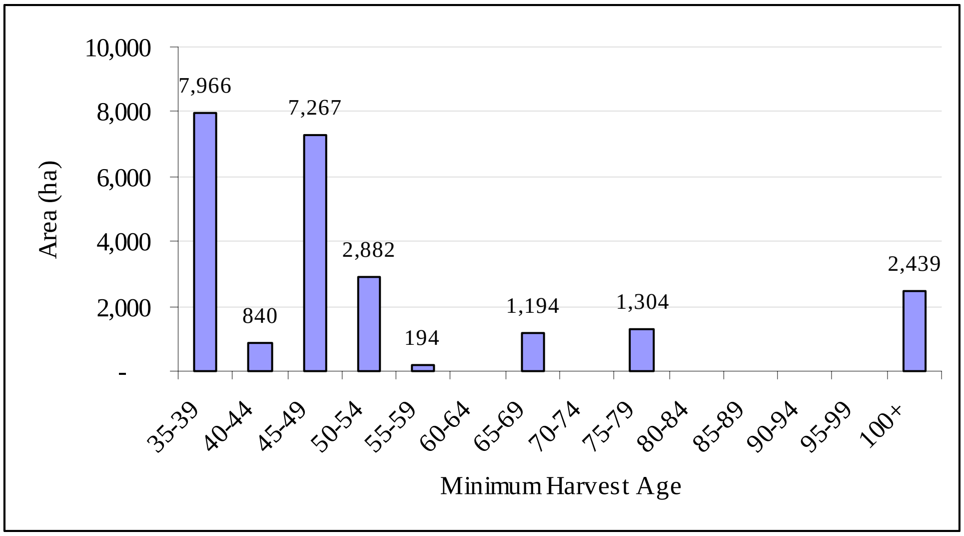


Figure 8-5. Future stand MHA

9.0 NON RECOVERABLE LOSSES

An area-based approach to AAC calculation negates the need for estimates of endemic, non-recoverable losses which area usually dealt with through OAF's and yield curve netdowns in conventional analyses.

10.0 INTEGRATED RESOURCE MANAGEMENT

This section provides details on how modelling methodology will address non-timber resource requirements.

10.1 Forest Resource Inventories

Table 10-1 lists the sources of spatial data that are used to create the timber supply analysis resultant.

Table 10-1 Non-timber resource inventory status

Inventory category	Data source	Mapping Scale	Completion	Update
Forest cover – VRI (Converted to FC1 by TFIC)	MSRM	1:20000	1996	2003
TFL54 Boundary	Interfor			2004
Watershed Plan Reserves	Interfor	Digital	Ongoing	2004
Watershed Plan Reserves	MSRM	Digital	Ongoing	2004
Scenic Corridors	MSRM	1:20000	1998	1998
TEM (Interfor unioned from various sources)	Various	1:20000	Various	
Clayoquot Boundary	MSRM			2002
FDP Blocks / Roads	Interfor	1:20000		2004
FEN (ESA,MA,OPER,VMA,VQO – outside Clayoquot)	Interfor		1995?	
Landscape Units (Outside Clayoquot)	MSRM	1:20000	1996	1996
Operability[4]	Interfor		1992	1992
Parks	MSRM		1999	2001
Terrain (TFIC unioned from various sources)	Interfor/MSRM	1:20000	Various	

10.2 Forest Cover Requirements

Cover constraints will be applied in the forest estate model to:

- limit the rate of cut in some basins to the level specified by the Scientific Panel
- ensure that visually integrity of designated sensitive areas is maintained
- model the impact of block adjacency restrictions for areas outside of Clayoquot Sound

Table 10-2 summarizes the approach that will be taken to modelling each of these.

[4] For TSR, modifications were made as described in Section 6.2.5

Table 10-2 Forest Cover Requirements

Resource Issue	Limiting Criteria	Threshold	Subject Area
Watershed Rate of Cut			
5% in 5 years	age less than 5 years	5%	Basins
10% in 10 years	age less than 10 years	10%	
Visual Quality			
Natural Appearing	height less than 8 metres	20%	Scenic Inventory Polygons
Small Scale Alteration	height less than 7 metres	30%	
Minimal Alteration	height less than 6 metres	40%	
IRM	height less than 3 metres	25%	Hesquiat/Escalante and Kennedy/Beach
Old Seral	age greater than 120 years	40%	Watershed Planning Unit

10.2.1 Watershed Rate of Cut

With respect to watershed-rate-of-cut, the Scientific Panel made the following recommendations:

- Limit the area cut in any watershed larger than 500 ha in total area to no more than 5% of the watershed area within a five-year period.
- In primary watershed of 200-500 ha in total area, limit the area cut to no more than 10% of the watershed area within a 10-year period. (This prescription provides flexibility for harvesting within small watersheds.)
- In any watershed larger than 500 ha in total area, and primary watersheds of 200-500 ha in total area in which harvest has exceeded 20% of the watershed area in the most recent 10 years, allow no further harvest until the watershed conforms with the specified rate-of-cut.
- In any watershed specified in the previous recommendations and in which the recent harvest is greater than 5% in the last five years, but less than 20% in the last 10 years, allow no further cutting until a watershed sensitivity analysis and stream channel audit have been completed. If these assessments indicate significant hydrological disturbance, substantial or chronic increase in sediment yield, or significant deterioration in aquatic habitat, cease harvesting until undesirable conditions are relieved. Otherwise, harvest may continue at a rate which will bring the drainage unit within the recommended rate -of-cut limits within five years.
- In any watershed larger than 500 ha in total area (and primary watersheds of 200 - 500 ha in total area) in which harvest has occurred, require a watershed sensitivity analysis and stream channel audit once every five years. Where such assessments identify hydrological disturbance, substantial increase in sediment yield, or significant deterioration in aquatic habitat, cease harvesting until these conditions are relieved. If such conditions are

recognized at any other time, sensitivity analysis and/or stream channel audit shall be undertaken immediately.

- In watersheds where the harvestable area is less than 30% of the total area, allow resource managers to use professional judgment to vary these standards without changing the intent to regulate rate of harvest to minimize hydrological change.

The application of these rules to the resultant data set has led to the basin rate of cut restrictions listed in Appendix II (for primary basins) and Appendix III (for secondary, tertiary and quaternary basins). Interfor is currently reviewing the recommendations as per the Scientific Panel "adaptive management" process and will be proposing an alternative methodology in the Management Plan text that could provide greater operational flexibility. However this TSR applies the current rate of cut recommendations and is therefore conservative in its approach.

10.2.2 Visual Quality

The inventory of scenic resources that was completed for Clayoquot Sound differs from the visual inventories that have been completed for the rest of the province in two significant ways:

- the categories used to classify visually sensitive area are unique to the Clayoquot; and
- while the assigned levels of acceptable landscape alteration provide much qualitative guidance to operational planners, they do not provide the quantitative rules needed for strategic planning.

It was necessary to deal with these issues so that scenic resources will be appropriately considered in the timber supply modeling. The Clayoquot Sound visual classes were first translated into the established provincial classes as follows:

- Natural Appearing translated to Retention
- Minimal Alteration translated to Partial Retention
- Small Scale Alteration translated to Partial Retention

These translations were based on a comparison of Table 4.1 in the Bedingfield Watershed plan and Table 1 of the Visual Impact Assessment Guidebook. Table 10-3 shows the area that falls within each of these categories.

Table 10-3 Visual Landscape Classification

Clayoquot Sound Visual Class	Provincial Class	Total Area (ha)	Productive Area (ha)	Net area (ha)
Small Scale Alteration	Partial Retention	6,263.3	6,238.4	3,136.4

Minimal Alteration	Partial Retention	10,348.0	10,249.8	5,403.0
Natural Appearing	Retention	8,058.7	7,992.9	2,571.0

Once these classes were translated, it was possible to deal with the second issue by determining a system of quantitative rules to be used in the modeling process. These rules have two components. First of all, a threshold alteration limit for the individual visual landscape polygon was decided on by consulting Table 4 of the Visual Impact Assessment Guidebook. An average residual stand height of 30 metres was assumed for the entire area. Although, the table specifies the maximum amount of volume that can be removed for a given visual class, this will be equated to a maximum proportion of area for the analysis. The following thresholds were determined:

- Natural Appearing: 20%
- Minimal Alteration: 30%
- Small Scale Alteration: 40%

Secondly a visually effective greenup height for each visual classification was established through discussions with Interfor and MoF, a review of the approach taken by others and consultation of Berris' Draft Recommendations. The following visually effective greenup heights were decided on:

- Natural Appearing: 8 metres
- Minimal Alteration: 7 metres
- Small Scale Alteration: 6 metres

These two components will be applied together in the timber supply analysis. Within each visual polygon, height growth will be tracked on a stand by stand basis. The height and equivalent area of the youngest stand cohort will be used to compile the area of each visual polygon that is within the cover constraint.

10.2.3 Integrated Resource Management

For the portions of the TFL within Clayoquot Sound, no green-up constraints apply between adjacent cutblocks on the basis of the Variable Retention prescription. Consequently, no integrated resource management (IRM) constraint will be applied to these areas. However, the areas outside of Clayoquot are subject to adjacency constraints. A cover constraint (maximum of 25% less than three metres tall) will be applied to these areas. This constraint is usually applied at the landscape unit level, but that would not be practical in this case, as only small areas are involved. Instead, the constraint will be applied separately to the blocks to the north of Clayoquot Sound (Hesquiat and Escalante) and those to the south (Kennedy and Beach).

10.2.4 Stand Level Biodiversity

The practice of leaving WTPs for the areas of TFL 54 outside Clayoquot will be modelled in the current management option by reducing the average volume per hectare that is harvested.

The stand level biodiversity requirement will account for both wildlife trees (WT) and tree patches (WTP) by reducing the average volume per hectare that is harvested, to account for trees which must be left within cutblocks.

10.3 Timber Harvesting

10.3.1 Utilization levels and merchantability

Utilization levels and merchantability are only important for the impact that they have on MHA. This discussion can be found in section 8.4

11.0 REFERENCES

B.C. Ministry of Forests. 2001. Provincial Guide For The Submission Of Timber Supply Analysis Information Packages for Tree Farm Licences. Version 4. Victoria, BC. 60 p.

The Scientific Panel for Sustainable Forest Practices in Clayoquot Sound. 1995. Report 5 – Sustainable Ecosystem Management in Clayoquot Sound: Planning and Practices. Victoria, BC. 296 p.

Clayoquot Sound Technical Planning Committee. 2003. Bedingfield Watershed Plan. Nanaimo, BC. 133 p.

Clayoquot Sound Technical Planning Committee. 2003. Cypre Watershed Plan. Nanaimo, BC. 136 p.

International Forest Products Limited. 1999. Proposed Management Plan No. 3 for Tree Farm Licence 54. Vancouver, BC. 97 p.

Friesen Rea & Company and Nemus Consulting. 2002. Area-based Allowable Annual Cut Determination: Recommended Information Requirements for Tree Farm .Licences. Victoria, BC. 18 p.

Appendices

Appendix I

Inventory Adjustment Procedure

Memo

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CERTIFIED ISO 9001:2000

To: Albert Nussbaum RPF, Dave McGregor RPF, Gerry Sommers RPF, Jerry Miehm RPF
From: Guillaume Thérien, PhD
cc: Hamish Robertson RPF, Alec Orr-Ewing ATE
Date: November 23, 2004
Project: IFV-022
File: \\Madrid\clients\Interfor\Vancouver\IFV-022\Documents\Inventory_Adjustment_Memo_2004NOV25.doc
Re: TFL 54 Inventory Adjustment

This memo summarizes the assumptions made during the inventory adjustment of International Forest Products' (Interfor) Tree Farm Licence (TFL) 54. Preliminary work done by Timberline Forest Inventory Consultants Ltd. (TFIC) and J.S. Thrower & Associates Ltd. (JST) showed that the existing Vegetation Resources Inventory (VRI) Phase I severely underestimated polygon-level volumes. The area-based pilot agreement between Interfor and the BC Ministry of Forests allows Interfor to use procedures outside of provincial standards to derive input information into the timber supply analysis. We have used expert opinion to derive appropriate volume estimates for this analysis. The project team included Alec Orr-Ewing, Guillaume Thérien, and Hamish Robertson of JST and Gerry Sommers, Dave MacGregor, and Don MacMillan of Interfor and Jerry Miehm of TFIC. It is important to note that volume estimates for existing mature polygons are important to help define the minimum volume thresholds for the operable land base; otherwise, volume of mature stands does not impact the area-based timber supply analysis.

1. Unadjusted Population

- TFIC provided the TFL 54 VRI Phase I population. The total area of TFL 54 was 61,467 ha.
- Phase I inventory was projected to 2003.
- Phase I volume was estimated using VDYP 6.6d and a utilization level of 17.5 cm+.

2. Ground Plots

- Ground plots came from the ground inventory collected by BC Forest Products (BCFP) on what is now TFL 54 in the early 1970's. There were a total of 2,436 ground plots and 21,792 measured trees. Alec Orr-Ewing installed many of these plots.
- Data included basal area factor (BAF), and for each tree in the prism plot: species, height and DBH. Age was not available. There were no site index (SI) trees but there was a plot-level SI available (probably transcribed from the map).
- Tree gross whole-stem and merchantable volumes were computed using the VRI compiler with Kozak's 1994 taper equations.
- Decay, waste, and breakage (dwb) was estimated using the following algorithm:
  IF spp NOT IN ('B', 'C', 'H', 'Y') THEN dwb=10%
  ELSE IF spp IN ('B', 'H') AND elevation <= 700 m THEN dwb=10%
  ELSE IF spp IN ('B', 'H') AND elevation > 700 m THEN dwb=25%
  ELSE dwb = 30% - ((SI – 5) * (20% / 30)).
- SI was capped at a minimum of 5 m if the indicated site index was below 5 m (31 trees). The maximum SI was 34.8 m.

The dwb distribution by species group and 5-m SI class was as follow:

Spp Group	Statistic	5-m SI Class 5	10	15	20	25	30	35	Total
B-H	n	50	1,736	6,564	661	250	52	40	9,353
	dwb	12%	13%	11%	10%	10%	10%	10%	11%
C-Y	n	116	2,732	8,240	435	162	26	23	11,734
	dwb	29%	26%	23%	20%	17%	13%	10%	24%
Others	n	17	188	430	42	18	9	1	705
	dwb	10%	10%	10%	10%	10%	10%	10%	10%
Total	*n*	*183*	*4,656*	*15,234*	*1,138*	*430*	*87*	*64*	*21,792*
	dwb	***23%***	***21%***	***18%***	***14%***	***13%***	***11%***	***10%***	***18%***

The dwb algorithm was derived using the project teams collective expert knowledge. Several dwb scenarios were tested including MOF loss factors, provincial VRI loss factors, and expert opinion. We determined that the provincial VRI loss factors (average 10% for plots 121 years and older) were conservative and understated the expected decay on the TFL. Conversely, recent cruise information[1] from TFL 54 (64 blocks) using MOF loss factors showed an average dwb of 34% and likely overstates expected decay. We used expert opinion to derive an overall average dwb of 18%, weighted by species and site index class.

3. Ground Locations

- Plot locations were located on BCFP mylars. Each location was digitized and the Phase I forest polygon number associated with the location was identified.
- 1,699 plots contained both ground data and a ground location. 479 plots were previously removed because they lacked ground locations (most were outside the current definition of the TFL and some locations were misidentified) and 731 plots lacked associated ground data (the plot was not located on the mylar or was misidentified on the mylar).

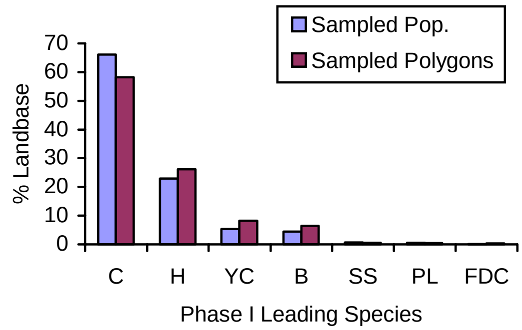
4. Net Down

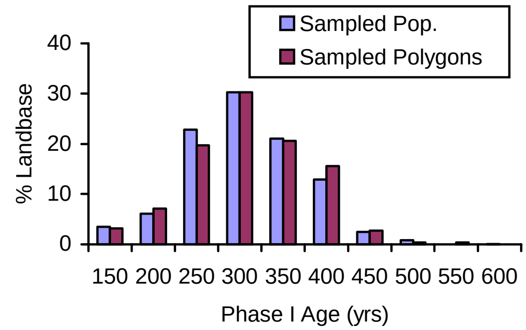
- We assumed that the ground plots represented a sample representative of a certain, undefined, sampled population. The definition of the sampled population was unknown and had to be estimated. We assessed the plot distribution across different attributes and eliminated areas that were under-sampled.
- We considered the following attributes: spatial distribution, ownership, forest productivity, age class, elevation, and operability. This removed 591 ground plots and 38,333 ha. The net-down is as follow:

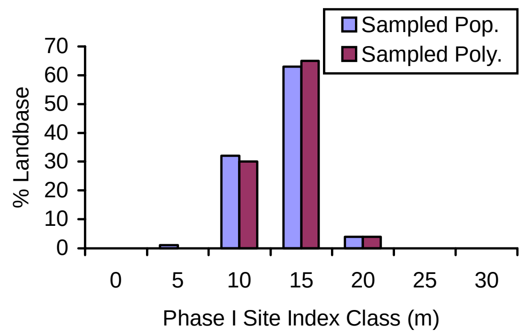
Net Down	No. Plots	Area (ha)
Vargas Island and Hesquiat Peninsula	50	12,362
Non-Productive	9	1,256
Less than 120 years old	199	9,805
Above 1000m	0	199
Inoperable	333	14,711
Total	*591*	*38,333*

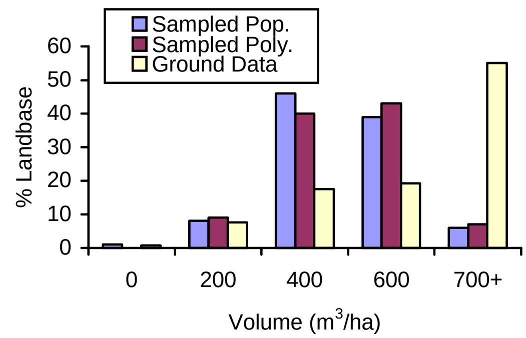
[1] The population represented in the cruise data set was assumed to be different from the TFL 54 population in general.

- Following net down, there were 1,108 plots covering 23,145 ha left for adjustment. The sample was representative of the sampled population in terms of leading species distribution, site index, volume, and age.









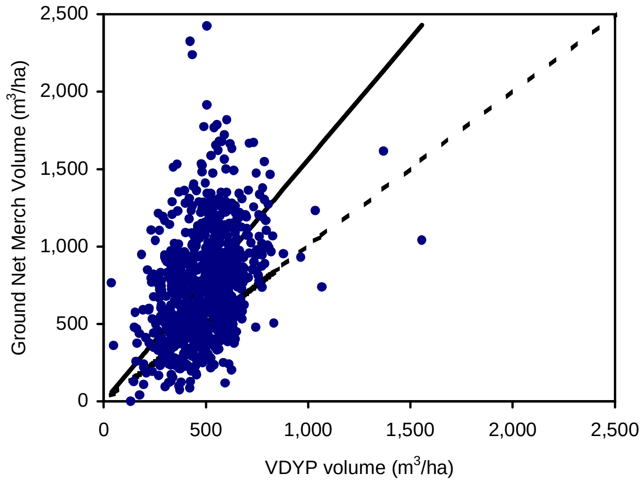
5. Compilation

- Net merchantable volume/ha was compiled for each plot using tree volume, plot BAF, and tree DBH.
- Net merchantable volume was then averaged by forest cover polygon.
- There were 802 sampled polygons (and 5,690 polygons) in the population.

6. Volume Adjustment

- A ratio of means was estimated between the ground and VDYP volumes.
- Each sampled polygon was weighted according to the area it represented within a volume class.
- The adjustment ratio was 1.561 with a sampling error of ±3.2%.
- The average volume for the adjusted population was 753 m^3/ha.
- The statistics and scatter plot for the adjustment were:

Sample Size	Pop Phase I Average (m^3/ha)	Sample Phase I Average (m^3/ha)	Sample Ground Average (m^3/ha)	Ratio	Adjusted Phase I Average (m^3/ha)	Sampling Error %
802	482.3	484.5	756.5	1.561	753.0	3.2



We looked at the ratio of means following different post-stratification strategies and computed the 95% confidence interval as if the data came from a random sample.[1] In most cases, the stratum ratio is not different from 1.561. The overall ratio underestimates the ratio computed for H-leading stands (23% of the leading species) and areas with site index less than 12.5 m (33% of the site index classes). In polygons with unadjusted Phase I volume between 500 and 700 m^3/ha (39% of the volume classes), the ratio of 1.561 slightly overestimated the stratum ratio. We would expect an underestimation in low-volume polygons (or younger stands or low site index stands) since plots are more likely to incorporate denser rather than less dense stands. The opposite is true for high-volume polygons (or older stands or high site stands); a plot is more likely to be located in a hole than in an area denser than the average for the polygon. Therefore, the areas where the ratio did not perform as expected was in the H leading polygons. It is therefore possible that the volume adjustment under-estimated the true volume in H leading polygons.

Ldg .Spp.	Area (%)	n	ROM	95% CI
B	5%	47	1.458	[1.301, 1.616]
C	67%	480	1.514	[1.456, 1.571]
H	23%	210	1.689	[1.575, 1.804]
Y	5%	65	1.578	[1.276, 1.879]

SI (m)	Area (%)	n	ROM	95% CI
10	33%	262	1.770	[1.653, 1.887]
15	63%	509	1.518	[1.462, 1.574]
20	4%	31	1.223	[1.079, 1.368]

Age (yrs)	Area (%)	n	ROM	95% CI
150	3%	28	2.366	[1.867, 2.865]
200	6%	60	2.228	[1.876, 2.580]
250	23%	173	1.614	[1.493, 1.735]
300	30%	242	1.494	[1.410, 1.578]
350	21%	151	1.555	[1.466, 1.644]
400	13%	119	1.445	[1.328, 1.562]
450	3%	29	1.213	[1.019, 1.407]

Volume (m^3/ha)	Area (%)	n	ROM	95% CI
200	9%	73	2.260	[1.968, 2.551]
400	46%	346	1.640	[1.553, 1.727]
600	39%	336	1.477	[1.412, 1.542]
800	6%	47	1.328	[1.214, 1.443]

[1] 95% confidence interval can only be computed from a random sample. Therefore, the 95% confidence intervals presented here should be considered as rough estimates that cannot be verified.

7. Species Composition

- We considered adjusting species composition but abandoned the idea because too many polygons had an adjusted volume higher than what we considered to be biologically unacceptable.
- Most species had a similar adjustment ratio except for balsam, which was slightly higher than the other species. Balsam is probably under-estimated in lower volume polygons while other species are probably slightly over-estimated. We could not test this hypothesis because we did not have the right data.

8. Ratio Application

- The ratio of 1.561 was applied to the Phase I volume of all polygons in the sampled population (23,145 ha).
- Polygons with a Phase I volume larger than 864.8 m^3/ha (163 ha) were capped at an adjusted volume of 1,350 m^3/ha.
- We assumed that the ratio observed where there were ground plots could apply to similar areas where there were no ground plots. Therefore, the volume adjustment ratio of 1.561 was applied to the portion of the TFL 54 population below 1,000 m, productive, older than 120 years and with a Phase I volume greater than 0 where no ground plot was available (26,230 ha).
- Polygons with a Phase I volume larger than 864.8 m^3/ha (163 ha) were also capped at an adjusted volume of 1,350 m^3/ha.
- Other areas (13,003 ha) were left unadjusted.

9. Adjusted Volume

- The overall average volume for the entire TFL increased from 343 to 527 m^3/ha (54%) after adjustment. The team of experts determined that an average polygon volume of 527 m^3/ha is a reasonable average polygon-level estimate.

	Ground	Area	Phase I Volume (m^3/ha)				Adjusted Volume (m^3/ha)			
Adjusted	Data	(ha)	Avg.	Min.	Max.	SD	Avg.	Min.	Max.	SD
Adjusted	With Data	23,135	482	0	1,556	73	752	0	1,350	112
	Without Data	26,229	346	0	1,179	80	539	0	1,350	122
	Total	49,364	410	0	1,556	84	639	0	1,350	130
Unadjusted	Without Data	5,439	161	0	822	76	161	0	822	76
Zero Volume	Without Data	6,664	0	0	0	0	0	0	0	0
Total	*Total*	*61,467*	*343*	*0*	*1,556*	*105*	*527*	*0*	*1,350*	*164*

Appendix II
TFL 54 Site Index Adjustment Final Report

TFL 54 Site Index Adjustment

Final Report

Prepared for

Gerry Sommers, RPF
International Forest Products Ltd.
Vancouver, BC

Project: IFV-018

March 31, 2004

J.S. Thrower & Associates Ltd. *Consulting Foresters*
Vancouver – Kamloops, BC

Executive Summary

International Forest Products Ltd. (Interfor) completed a Site Index Adjustment (SIA) project on TFL 54 to improve the productivity estimates for second growth stands. Like all areas of coastal BC, the site index estimates in the standard forest cover inventory were developed from old-growth stands. Many research and operational studies over the last 15 years have shown that these old-growth site indices underestimate the actual growth of second growth stands.

The results of the SIA process showed that the existing inventory significantly underestimates the site index of second growth stands. The overall average site index for second growth stands of western hemlock (Hw) in the CWH biogeoclimatic zone was about 28 m compared to about 17 m in the forest inventory. Estimates for western redcedar (Cw) increased from 15.1 to 22.6 m.

The results of this SIA project are similar and are consistent with other productivity projects completed in coastal BC. However, the variability in this SIA project was higher than has been observed elsewhere. Therefore, we recommend that Interfor use these site index estimates as the most reliable estimates of second growth stand productivity, but that subsequent analyses examine the potential impact of this variation. In addition, a growth and yield monitoring program would ensure that the site indices and associated volume yield estimates continue to reflect actual growth on the TFL.

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Table of Contents

List of Tables

List of Figures

1. INTRODUCTION

1.1 Background

Growth and yield practitioners in BC generally accept that site indexes estimated from old-growth stands underestimate the growth of managed stands growing on the same sites. This trend has been repeatedly confirmed in projects completed by the Ministry of Forests (MOF) and forest licensees throughout BC.[1,2,3,4] The old-growth site indexes represent current stand conditions reflecting historical events (suppression, height growth damage, partial cutting regimes); however, when old-growth site indexes are applied to future managed stands in timber supply modeling, the growth and yield of managed stands is generally underestimated. Ultimately, this can have a significant negative impact on the forecasted timber supply, especially on areas such as TFL 54 where most area is in older age classes (Appendix I).

1.2 Problem Statement

The allowable annual cut (AAC) on International Forest Products Limited's (Interfor) Tree Farm License (TFL) 54 has been reduced by the MOF by 58% since 1991. Interfor believes that this reduced AAC is lower than the potential long-term sustainable harvest level. A strategic growth and yield report also suggested that the current inventory site indexes underestimate the potential growth of managed stands (Figure 1).[5] Interfor thus initiated a Site Index Adjustment (SIA) project to improve the estimated growth of second growth stands on the TFL.

Figure 1. Cw and Hw inventory site index by age class in the CWHvm1 and CWHvh1.

1.3 Objectives

The objective of this project was to develop reliable estimates of potential site index (PSI) for second growth stands of western hemlock (Hw) and western redcedar (Cw) on TFL 54. Interfor intends to use the improved site indexes to build managed stand yield tables to support the proposed area-based timber supply analysis for Management Plan (MP) 4.

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[1] JST has completed Site Index Adjustment projects for TFLs 5, 6, 8, 15, 18, 30, 35, 37, 38, 45, 46, 47, 52, 53, the Merritt, Adams Lake, Hope, and Okanagan IFPA areas, and the Fraser TSA.

[2] Nussbaum, A.F. 1998. Site index adjustments for old-growth stands based on paired plots. Working paper 37. Ministry of Forests Research Program. Victoria, BC. 21 pp.

[3] B.C. Min. For. 1997. Site index estimates by site series for coniferous tree species in British Columbia. Site Productivity Working Group, B.C. Min. For. and Forest Renewal BC. 265 pp.

[4] Second approximation MOF SIBEC estimates are approved for timber supply analysis: www.for.gov.bc.ca/hre/sibec/index.htm

[5] J.S. Thrower & Associates Ltd. 2003. Strategic recommendations for a growth & yield program for Interfor's TFL 54. Contract report for International Forest Products Ltd., Ucluelet, BC. March 31, 2003. 31 pp.

1.4 TERMS OF REFERENCE

This project was completed by J.S. Thrower and Associates Ltd. (JST) for Gerry Sommers, *RPF* and Don McMillan, *RPF* of Interfor. The JST team was Hamish Robertson, *RPF* (project manager), Guillaume Thérien, *PhD* (senior biometrician), and Tara McCormick, *BSc* (technical support).

This report was prepared for Interfor, and will be submitted to the MOF Forest Analysis Branch for review and approval for use in timber supply analysis. Interfor completed this project with funds allocated from the Forest Investment Account (FIA).

2. METHODS

2.1 SIA Overview

This SIA project was completed in three steps:

1. **Preliminary PSI Estimates** – were developed for Hw and Cw for the ecosystems in the operable area on TFL 54.
2. **Site Index Sampling** – was completed across the operable area of the TFL to measure actual tree growth.
3. **Statistical Adjustment** – was done using the ground samples to remove bias in the preliminary PSI estimates and to better reflect the average conditions of the TFL.

2.2 Target & Sample Populations

The target population was 41,205 ha and included all stands in the Coastal Western Hemlock (CWH) biogeoclimatic (BGC) zone in the timber harvesting landbase (THLB) and Reserve Zones (Table 1).[6] This is the area where the adjusted PSI estimates will be applied for subsequent use in timber supply analysis. This area is located in the CWHvh1 (35%), CWHvm1 (51%), and CWHvm2 (14%) (Appendix I).

Table 1. Area distribution of THLB and Reserve Zones by leading species and age class.

Leading Species	Age Class									*Area*	
	1	2	3	4	5	6	7	8	9	*(ha)*	
Cw	1,686	637	242	11	11	44	59	5,144	12,907	*20,740*	*50%*
Hw	1,566	1,897	449	57	28	93	166	1,415	5,522	*11,194*	*27%*
Yc	3	4	1			9		2,176	2,602	*4,795*	*12%*
Fdc	46	1,390	65			2		48	32	*1,583*	*4%*
Ba	199	5	59	10	42		36	82	1,034	*1,466*	*4%*
Other	181	257	93	10	32	4	58	642	148	*1,426*	*3%*
Total (ha)	*3,680*	*4,189*	*910*	*88*	*113*	*153*	*320*	*9,508*	*22,246*	*41,205*	*100%*
	9%	*10%*	*2%*	*0%*	*0%*	*0%*	*1%*	*23%*	*54%*	*100%*	

The sample population was a subset of the target population where reliable PSI estimates could be estimated from field measurements. The main commercial tree species are Hw and Cw (about 78% of the target population); however, due to sampling limitations for Cw,[7] as discussed in the MOF-approved sample plan,[8] random sampling was only completed for Hw.[9]

[6] Data received from Timberline Forest Inventory Consultants on July 30, 2003 with THLB and reserves defined.

[7] Cw is often not found in the codominant tree canopy making it very difficult and costly to sample Cw PSI through random sampling.

[8] J.S. Thrower & Associates Ltd. 2003. Tree Farm Licence 54 Site Index Adjustment. Sample Plan. Contract report for International Forest Products Ltd. Vancouver, BC. August 26, 2003. 11 pp.

[9] A localized site index conversion equation was developed for Cw from Hw (Section 3.2).

The Hw sample population included stands 15 to 100 years total age where Hw was leading or was at least 30% of stand volume. The Hw sample population included 5,093 ha (12% of the target population) (Table 2).[8]

Table 2. Area (ha) of Hw sample population.

Age Class	Hw Ldg	Not Cw or Hw Ldg Hw ≥30%	Cw Ldg Hw ≥30%	*Total (ha)*
1	818	108	368	*1,294*
2	1,897	646	372	*2,915*
3	449	107	205	*761*
4	57	9	5	*71*
5	28	14	9	*51*
Total	*3,249*	*885*	*959*	*5,093*

2.3 Hw Sample

Fifty (50) points were randomly selected from the Hw sample population. The distribution of site series in the Hw sample population did not represent well the target population.[8] To correct this, the Hw sample was selected using a weight multiplier computed as the total area of the leading site series in the target population divided by the area of the leading site series in the Hw sample population. The corrected sample polygon area was therefore the product of the polygon area and the weight multiplier. This resulted in a Hw sample that represented the target population.

Sample polygons were then systematically selected (with a random start) proportional to weighted area from the list of Hw sample population polygons sorted by subzone and leading site series. A random location was selected in each eco-polygon using a 5 m grid in a Geographic Information System (GIS). All statistics were thus based on appropriate sampling weights.

Table 3. Preliminary Hw PSI estimates.

Site Series	Subzone CWHvh1	CWHvm1	CWHvm2
01	24	28	26
02	12	12	12
03	23	24	21
04	28	24	23
05	29	30	27
06	30	26	26
07	30	31	29
08	30	31	29
09	24	31	18
10	--	--	12
11	20	--	22
12	12	20	--
13	22	12	--
14	14	24	--
15	25	--	--

2.4 Preliminary PSI Estimates

Preliminary PSI estimates were developed for Hw for the forested biogeoclimatic ecosystem classification (BEC) site series on TFL 54 as delineated in the Clayoquot Sound TEM (Table 3) (Appendix I).[10]

Estimates were developed by Tara McCormick (JST) and Bob Green, *MSc RPF RPBio* (B.A. Blackwell & Associates Ltd.) to reflect the potential productivity, expressed as site index, of managed stands growing on TFL 54. Preliminary PSIs were based on SIBEC estimates but were modified to reflect the local conditions on TFL 54 and the expected trends in productivity among site series.

[10] Madrone Consultants Ltd. 2002. Terrestrial Ecosystem Mapping for the Clayoquot Sound area. Year Four. Contract report for the Ministry of Sustainable Resource Management. Nanaimo Forest District. 366 pp.

Application of the preliminary PSIs to the target population resulted in an overall average of 25.0 m and ranged from 12 m to 31 m (Table 4).

Table 4. Preliminary PSI statistics for the TFL 54 target population.

Subzone	Area[a] (ha)	PSI (m) Avg	Min	Max	SD	Elevation (m) Avg	Min	Max	SD
CWHvh1	13,972	22.8	12.0	30.0	3.3	70	5	287	45
CWHvm1	20,705	26.5	12.0	31.0	2.9	347	10	785	149
CWHvm2	5,476	24.5	12.0	29.0	2.5	691	472	915	44
Total	*40,153*	*25.0*	*12.0*	*31.0*	*3.5*	*298*	*5*	*915*	*230*

[a] PSI estimates are not applied to non-forested site series.

2.5 HW RANDOM SAMPLING

Field sampling was completed between Aug. 29 and Sept. 25, 2004 by JST field crews, following methods described in the MOF-approved sample plan.[8] Each sample was a 400-m^2 plot (11.28 m radius) where site index was estimated from measurements of breast-height (BH) age and total height from suitable Hw site trees in the four 100-m^2 quadrants. Site tree selection followed MOF SIBEC standards,[11] thus suitable site trees included the largest diameter dominant or co-dominant Hw tree in each quadrant that were at least 10 years old at BH, live, standing, and without damage or suppression affecting more than five percent of height growth. Site trees could not be veterans or residuals from a previous stand.

Forty (40) of the 50 selected samples resulted in site index observations for Hw. Sixty-two (62) Hw trees were sampled with an average of 1.5 trees/plot (Table 5). The average field Hw site index was 26.6 m and ranged from 14.1 to 40.6 m (Table 6). Site index was sampled over a range of 19 to 771 m in elevation. The average age of sample trees was 33 years at BH. Ten (10) of the 50 selected samples were rejected due to unsuitability for site index sampling (Appendix II).

Table 5. Number of trees per plot.

No. Trees Per Plot	No. Plots	*%*
1	25	*63*
2	9	*23*
3	5	*13*
4	1	*3*
All	40	*100*

Table 6. Field sample statistics.

Spp	Subzone	n	Site Index (m) Avg	Min	Max	SD	Elevation (m) Avg	Min	Max	SD	BH Age (yrs) Avg	Min	Max	SD
Hw	CWHvh1	16	22.9	16.8	40.6	7.3	73	19	203	55	51	13	83	22
Hw	CWHvm1	18	30.3	14.1	37.5	5.9	402	59	501	79	18	12	84	10
Hw	CWHvm2	6	25.3	19.0	27.5	2.6	652	624	771	47	19	18	25	2
Hw	*All*	*40*	*26.6*	*14.1*	*40.6*	*7.3*	*270*	*19*	*771*	*204*	*33*	*12*	*84*	*23*

2.6 COMPARISON OF FIELD SAMPLE & TARGET POPULATION

Weighting of the field sample resulted in the sample population better representing the target population in subzone, preliminary PSI class, and site series (Figure 2 and Figure 3). The 800 m elevation class was slightly under represented in the sample compared to the target population (Figure 4). This has little impact on the overall adjustment, as it is the ratio between the preliminary PSIs and ground estimates that is important in the SIA process rather than the average site index of the sample.

[11] Province of British Columbia. 2000. SIBEC Sampling and Data Standards version 5.0. BC Ministry of Forests Site Productivity Working Group. Victoria, BC.

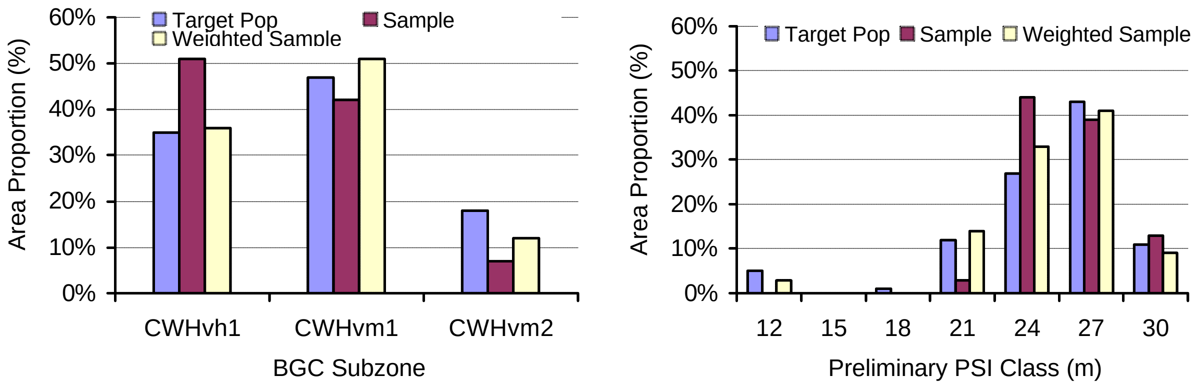

Figure 2. Area distribution of target population, sample population, and weighted sample by BGC subzone and preliminary PSI class.

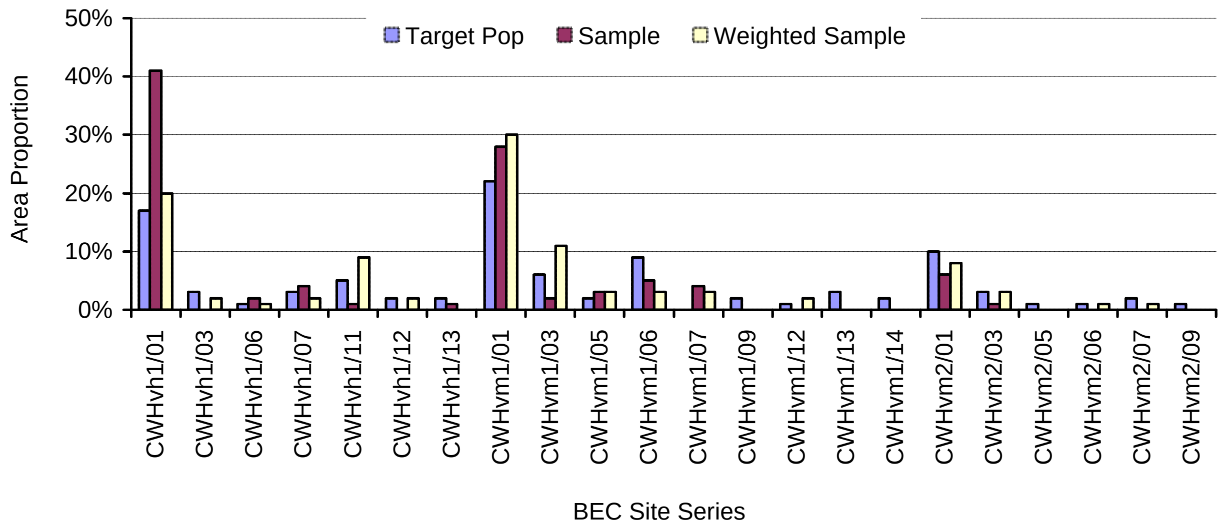

Figure 3. Area distribution of target population, sample population, and weighted sample by BEC site series.

2.7 Subjective Cw Sampling

Cw is Interfor's most important management species on the TFL;[12] it has been the dominant planted species over the past 10 years and has been planted exclusively in recent years. Because Cw is not often found in the codominant tree canopy, it is very expensive to sample using the conventional random SIA method. Instead, we used subjective sampling to establish site pairs of Cw and Hw to develop localized site index conversion equations for TFL 54. Cw site trees were selected in proximity to Hw site trees to collect site index data for pairs growing on the same

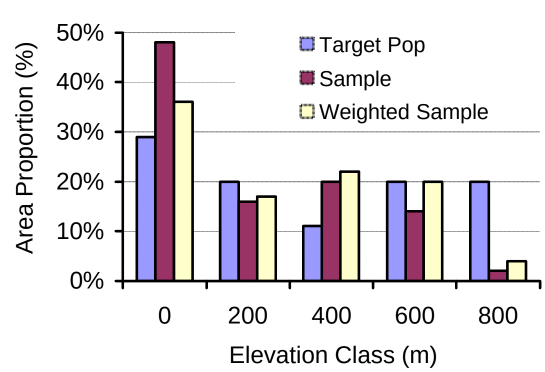

Figure 4. Area distribution of target population, sample population, and weighted sample by elevation class.

[12] Personal comm. with Dave MacGregor, *RPF* TFL 54 Silviculture Forester.

sites (same soil moisture and nutrient regimes). Site tree selection for the pair analysis also followed MOF SIBEC standards.[11]

Twenty-six (26) site pairs were located during the SIA field-sampling phase (Table 7). The average field site index was 24.6 m for Hw (range of 14.3 to 34.3 m) and 21.3 m for Cw (range of 13.3 to 30.1 m). Sixty-nine (69) percent of the pairs were collected in the CWHvh1.

Table 7. Site index statistics of Cw-Hw site pairs.

Subzone	Site Series	No. Pairs	Hw SI			Cw SI		
			Avg	Min	Max	Avg	Min	Max
CWHvh1	CWHvh1/01	14	25.8	17.4	34.3	21.0	14.9	28.5
	CWHvh1/05	1	32.3	32.3	32.3	27.8	27.8	27.8
	CWHvh1/06	1	18.8	18.8	18.8	14.3	14.3	14.3
	CWHvh1/11	2	22.0	17.4	26.6	18.6	15.4	21.8
	All	*18*	*25.3*	*17.4*	*34.3*	*20.8*	*14.3*	*28.5*
CWHvm1	CWHvm1/01	3	16.4	14.3	19.1	18.9	13.3	22.5
	CWHvm1/03	3	26.9	25.6	28.7	26.4	22.2	30.1
	CWHvm1/07	2	27.3	21.3	33.2	21.8	15.0	28.6
	All	*8*	23.1	14.3	33.2	*22.5*	*13.3*	*30.1*
Total		*26*	*24.6*	*14.3*	*34.3*	*21.3*	*13.3*	*30.1*

2.8 Quality Assurance

Quality assurance (QA) of the field measurements was completed by an independent auditor to ensure the appropriate standards were achieved. Kelly Sherman, *RPF* of Timberline Forest Inventory Consultants (TFIC) completed a random 10% audit of the field data on Nov. 19-20, 2003. The audit showed that the plot location, site tree selection, height and age measurements, and site index conversion pair selection completed by the JST crews met all specified standards (Appendix III).

2.9 Analysis

The preliminary Hw PSI estimates were statistically adjusted to remove the bias in the predicted estimates. The adjustment ratio was computed using the average field PSI and preliminary Hw PSI estimates. Separate ratios were computed for the CWHvh1 and the CWHvm group (vm1 and vm2). The ratios were then applied to the eco-polygon preliminary Hw PSI estimates to compute the adjusted PSI estimates.

The site index conversion equation was developed using the 26 pairs of Cw and Hw site indexes. The equation also used the ratio of means (ROM) and was compared to the MOF Cw-Hw equation.[13]

[13] Nigh, G.D. and G. Kayahara. 2000. Site index conversion equations for western redcedar and western hemlock. Northwest Science 74(2): 146-150.

3. RESULTS

3.1 Hw Statistical Adjustment

The ROM adjustment equation showed that the preliminary Hw PSI estimates over-predicted the average field PSI by 7.3% in the CWHvh1 and under-predicted the average field PSI by 13.9% in the CWHvm group (Table 8, Figure 5). The targeted sampling error of ±1.5 m was not achieved in either group because of higher than expected variation (discussed in Section 4).

Table 8. Hw adjustment statistics.

	Subzone Group	
	CWHvh1	CWHvm
No. of samples	16	24
Sample mean prelim PSI (m)	24.7	26.0
Sample mean field PSI (m)	22.9	29.7
ROM	0.927	1.139
R-squared	10%	0%
% Sampling Error of ROM	17.9	8.6
Population prelim PSI (m)	22.8	26.1
Population adjusted PSI (m)	21.1	29.7
95% Sampling Error (m)	4.1	2.2
95% Confidence Interval (m)	[17.0, 25.2]	[27.5, 31.9]

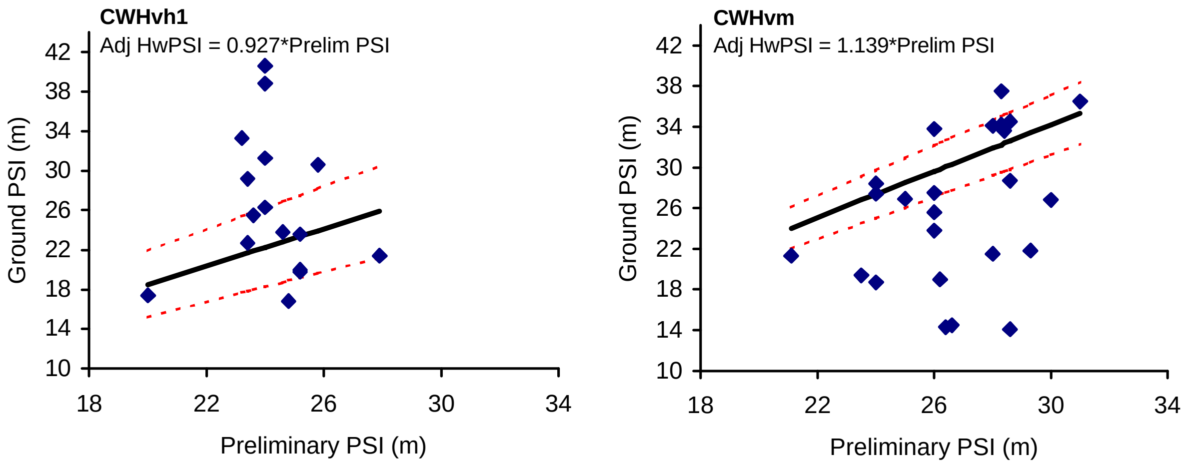

Figure 5. Relationship between average ground PSI and average predicted PSI for the Hw sample. (The thick black line shows the average PSI for a polygon of a given predicted PSI. The narrow red line shows the 95% confidence interval for the average. Sampling weights are not illustrated).

The adjusted preliminary PSI estimates resulted in an average Hw site index of 21.1 m in the CWHvh1 and 29.7 m in the CWHvm (Table 8). The range of predicted PSI for the CWHvh1 sample was about 20 to 28 m, compared to the range of field PSI of 17 to 41 m. In the CWHvm, the range of predicted PSI for the sample was about 21 to 31 m compared to the range of field PSI of about 14 to 38 m.

The CWHvh1 adjustment resulted in a downward shift to the distribution of preliminary Hw PSI by one 3-m PSI class (Figure 6). In the CWHvm, the majority of the area shifted from the 27 to 30 and 33 m PSI classes.

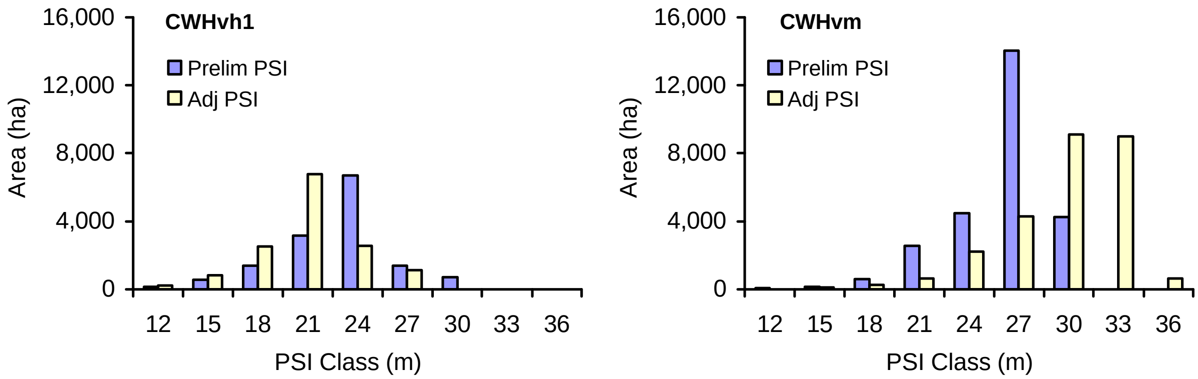

Figure 6. Area distribution of preliminary and adjusted PSI by subzone group.

3.2 CW PSI ESTIMATES

A localized site index conversion equation was developed for Cw using the ROM method to express the relationship between Cw and Hw site tree pairs. The equation is:

*Cw PSI = 0.865 * Hw PSI* *[Equation 1]*

with a sampling error of 0.056 (6%). This equation is similar to the MOF provincial Cw-Hw equation (Figure 7), but the MOF equation predicts higher (6%) Cw estimates at higher Hw site indexes. The MOF equation is:

*SI(Cw) = -1.199 + 0.9545 * SI(Hw)* *[Equation 2]*

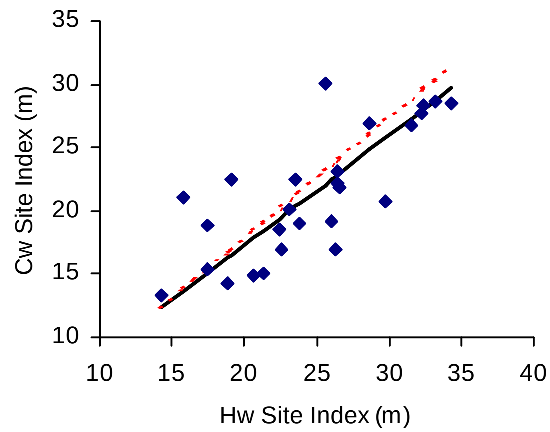

Figure 7. Relationship between Cw and Hw PSI (thick black line is local site index conversion equation and thin red line is the MOF equation).

Cw site index can be estimated using either equation with the adjusted Hw estimates. Cw PSI estimates for each site series were obtained by applying the Cw-Hw equation to the adjusted Hw PSI estimate for the corresponding site series. The TFL 54 site index conversion equation gave an average PSI for Cw of 18.2 m in the CWHvh1 and 25.7 m in the CWHvm, compared to 18.9 m and 27.1 m, respectively, using the MOF equation.

There are two sources of sampling error associated with the average Cw PSI estimate: the sampling error associated with the average adjusted Hw PSI estimate and the sampling error associated with the site index conversion equation. The total sampling error for the Cw PSI estimate was ± 3.7 m in the CWHvh1 (20%) and ± 2.5 m in the CWHvm (10%).

3.3 APPLICATION OF RESULTS

Area-weighted average adjusted PSI estimates can be calculated for the forest cover polygons in the target population based on their component eco-polygons. Interfor should use the forest cover polygon level PSI estimates for existing and future managed stands in the yield table process.

4. DISCUSSION

4.1 VARIATION BETWEEN PREDICTED & GROUND PSI

There was significant variation between predicted and field PSI estimates (Figure 5). The variation between the predicted and field PSIs in the CWHvh1, as measured by the root mean square error (RMSE) was larger than anticipated and larger than observed in other coastal SIA projects (Table 9).

Table 9. Hw RMSE for coastal SIA projects.

Landbase	RMSE (m)
TFL 37	4.8
TFL 38	4.5
TFL 46	5.5
TFL 47	5.9
TFL 54 – CWHvm	5.2
TFL 54 – CWHvh1	7.7

We attempted to reduce the variation between the predicted and field estimates by improving the preliminary PSI estimates. Applying SIBEC estimates as the preliminary PSI estimates appeared to improve the predictive ability (R^2 = 57%) and slightly reduced the sampling error in the CWHvh1 (Table 10); however, the average adjusted population estimate was similar to the SIA adjusted average. Conversely, SIBEC estimates increased the sampling error in the CWHvm group compared to the SIA preliminary estimates, and resulted in a higher (8%) overall adjusted average than SIA. Therefore, using SIBEC estimates did not significantly improve the results.

Table 10. Comparison of SIBEC and SIA values as preliminary PSI estimates.

	SIBEC Prelim PSI		SIA Prelim PSI	
	CWHvh1	CWHvm	CWHvh1	CWHvm
No. observations	16	24	16	24
Sample mean prelim PSI (m)	17.7	22.3	24.7	26.0
Sample mean field PSI (m)	22.9	29.7	22.9	29.7
ROM	1.293	1.330	0.927	1.139
R-squared	57%	2%	10%	0%
% sampling error of ROM	20.4	12.0	17.9	8.6
Population prelim PSI (m)	16.8	24.1	22.8	26.1
Population adjusted PSI (m)	21.7	32.1	21.1	29.7
Sampling error (m)	3.4	2.9	4.1	2.2
95% Confidence Interval	[18.3, 25.1]	[29.2, 35.0]	[17.0, 25.2]	[27.5, 31.9]

We believe that a large portion of the observed variation can be explained by the high natural within-polygon and within-site series variation of PSI on zonal sites (Table 11, Table 12). Field PSI estimates were based on 1.5 trees/plot on average and almost two-thirds of the estimates were based on a single tree (Table 5). This increased the variability of the plot-level PSI estimates as there is a greater likelihood that the estimated field PSIs reflected individual micro-sites rather than average plot productivity. Using a smaller number of trees in the average field PSI estimate for a plot increases the measurement error. This measurement error is only one component of the unexplained variation.

The TEM report noted that zonal sites have greater variation than adjacent ecosystems.[9] For example, the CWHvm1/01 is found on shallow or deep soil, at low or high elevation, on steep or gentle slopes. In the CWHvh1, the 01 site series can be found on shallow or deep soils, on hummocky terrain (mixed with other site series), and on steep or gentle slopes. These variations have a major impact on site index.

This within-site series ecological and environmental variation is accentuated on the CWHvh1/01 when the TEM-based site series is used instead of the field-observed site series (Table 11 and Table 12). The larger variation on the TEM zonal sites can be explained by the inherent mapping error and mapping limitations on this landbase.

In previous SIA projects, the BEC system has provided a reasonable framework for predicting site productivity; however, the BEC classification alone does not appear to be an adequate predictor of site index on TFL 54 (R^2 of 0-10%, Table 8). The data suggests there are ecological processes that are significantly impacting the site productivity on this landbase. Therefore, we considered other site factors to try to improve the resolution of the site-series based predicted PSI estimates. With the assistance of Bob Green *MScF RPF,*[14] we modeled the impact of drainage and water table on site productivity in the subdued terrain of the CWHvh1 and CWHvm1 using available biophysical information such as slope, elevation, site series complexes, and site series modifiers.

The CWHvh1 is highly variable because of subdued terrain and rolling topography, resulting in a mosaic of drainages. While the CWHvh1 and CWHvm1 are climatically similar, they have different drainage characteristics. Water excess can occur on flatter ground in the CWHvh1, decreasing productivity, but on well-drained, steeper slopes the productivity of the CWHvh1 and CWHvm1 are comparable. Conversely, the CWHvm1 is usually located on valley walls, but on TFL 54 the CWHvm1 is also found on subdued rolling terrain where drainage can limit tree growth. The resolution of the available biophysical data (slope, elevation, site series complexes and modifiers) was too coarse to allow us to accurately model the significant impact of drainage. We were unable to differentiate high and low sites in the CWHvh1 (where drainage was or was not a problem) and low sites in the CWHvm1 (where drainage was a problem). Therefore, given the available data this exercise did not reduce the variation between predicted and field PSI. More work is needed to study the impact of drainage in the CWHvh1 and CWHvm1 variants, especially on zonal sites.

Table 11. Range of field PSI by TEM leading site series.

TEM	Field Site Index (m)				
Site Series	n	Avg	Min	Max	SD
CWHvh1/01	11	23.0	16.8	40.6	9.5
CWHvh1/11	3	20.9	17.4	29.2	1.9
CWHvm1/01	11	31.8	14.1	37.5	6.2
CWHvm1/03	3	28.1	18.6	28.4	2.3
CWHvm2/01	4	26.4	19.0	27.5	1.2

Note: Only site series with more than one observation are included.

Table 12. Range of field PSI by field leading site series.

Field	Field Site Index (m)				
Site Series	n	Avg	Min	Max	SD
CWHvh1/01	9	28.6	20.0	40.6	4.4
CWHvh1/11	3	17.0	16.8	29.2	2.7
CWHvh1/12	2	18.7	17.4	19.8	0.8
CWHvm1/01	13	29.9	14.1	36.5	6.3
CWHvm1/05	4	34.4	26.8	37.5	1.7
CWHvm2/01	5	18.1	14.5	27.5	2.5

Note: Only site series with more than one observation are included.

[14] Bob Green is considered one of BC's leading coastal forest ecologists.

4.2 Comparison of Adjusted PSI & Inventory Site Index

Application of the adjusted PSI estimates to the target population results in a 20-98% increase over the inventory site index (Table 13). The largest increase was in Hw-leading stands in the CWHvm1 and CWHvm2, with lowest increases in the CWHvh1 for both Hw- and Cw-leading stands. The magnitude of increase over inventory site index, the overall average PSI (28.2 m for Hw and 22.6 for Cw), and the averages by subzone are consistent with other coastal TFLs and seem reasonable for this landbase.

Table 13. Comparison of inventory and adjusted site index for Hw and Cw.

Ldg Spp	Subzone	Area (ha)	Site Index (m) Inventory	Site Index (m) Adj PSI	Difference (m)	Difference (%)
Hw	CWHvh1	3,098	18.6	22.5	+3.9	+21%
	CWHvm1	5,657	16.4	31.2	+14.8	+90%
	CWHvm2	2,030	14.4	28.5	+14.1	+98%
	Hw Total	*10,785*	*16.7*	*28.2*	*+11.5*	*+69%*
Cw	CWHvh1	8,620	15.1	18.1	+3.0	+20%
	CWHvm1	10,512	15.2	26.0	+10.8	+71%
	CWHvm2	1,580	14.7	24.2	+9.5	+65%
	Cw Total	*20,713*	*15.1*	*22.6*	*+7.4*	*+49%*

4.3 Risks & Uncertainty for Timber Supply

Interfor is pilot-testing an area-based timber supply analysis for MP 4 on the TFL. The results of this SIA project show significant increases in site index for Hw (+11.5 m) and Cw (+7.4 m) that will improve the timber supply forecast. However, the level of uncertainty around the final site index estimates impacts the confidence in the minimum harvest age estimates, green-up and adjacency constraints, as well as volume increment.

The adjusted PSI estimates are unbiased estimates of site productivity, which in itself is a significant improvement over the inventory site indexes (for which no accuracy measure exists). In the CWHvm, the bias (the average difference between the adjusted PSI and the inventory site index estimates) was generally greater than 10 m (Table 13). Therefore, while less precise than anticipated, the PSI estimates provide a more accurate estimate of site productivity than inventory site index since PSI estimates are unbiased. The uncertainty around the average PSI estimate is estimated as ± 2.2 m for Hw and ± 2.5 m for Cw.

The sampling error in the CWHvh1 is about the same magnitude as the bias. This indicates that at the lower end of the 95% confidence interval, the PSI estimates are approximately the same on average as the inventory site index. Thus, the inventory site indexes could be interpreted as the lower bound of the PSI estimates. Interfor should consider completing a sensitivity analysis (± 2 and ± 4 m for the CWHvm and CWHvh1, respectively) to determine the potential impact of the errors in the estimates.

The best method to ensure that PSI estimates obtained from the SIA project adequately measure the site productivity on TFL 54 is to undertake a growth and yield (G&Y) monitoring program. In a G&Y monitoring program, randomly located permanent sample plots are established and re-measured in targeted stands with a known frequency, such as 5 or 10 years. The monitoring program provides an early warning system if the observed site index estimates deviate from the SIA PSI estimates used in the timber supply analysis. The results of this program could be useful to further justify assumptions around minimum harvest age, green-up, and adjacency in the area-based timber supply analysis.

5. RECOMMENDATIONS

From the results of this project, we recommend that Interfor:

1. Use these estimates of site index in the upcoming timber supply analysis.
2. Complete a sensitivity analysis to estimate the impact of potential errors in these estimates. We suggest using ± 2 m for site index in the CWHvm and ± 4 m in the CWHvh1.
3. More work is needed to explain the differences in site productivity on zonal sites in the CWHvh1 and CWHvm1 (Interfor could either improve the resolution of the TEM or complete a different type of mapping).
4. Establish a growth & yield monitoring program on the TFL.

APPENDIX I – STUDY AREA

TFL 54 is located on the west side of Vancouver Island and is adjacent to the towns of Ucluelet and Tofino. The TFL is almost completely (93%) within the area covered by the provincial government's Clayoquot Sound Land Use Decision (CSLUD). Management of the portion of the TFL inside the CSLUD area follows the recommendations of the scientific panel.

The TFL landscape is dominated by old-growth forests comprised primarily of Cw, Hw and Pacific silver fir (Ba). The TFL is located in the windward island mountains eco-section in the CWH and Mountain Hemlock BGC zones.

The TFL spans 49,317 ha (including 3,813 ha for Meares Island). The target population covers 41,205 ha (Table 14), of which 27,438 ha are in the THLB and 13,767 ha are in the Reserve zones.

Interfor manages their TFL operations from Ucluelet and the TFL is administered by the MOF Port Alberni District office. Most of the wood harvested from the TFL is processed in Interfor's mills in Vancouver.

Table 14. Area distribution of THLB and Reserve Zone by subzone, leading species, and age class.

	Ldg.	Age Class									*Total*	
Subzone	Spp.	1	2	3	4	5	6	7	8	9	*(ha)*	*(%)*
CWHvh1	Cw	699	440	219	9	3	30	22	2,836	4,373	*8,632*	*21*
	Hw	342	772	394	19	8	13	11	349	1,201	*3,110*	*8*
	Yc								657	171	*828*	*2*
	Fdc	8	619	65			2		8	0	*702*	*2*
	Ba	1	1	47		2				85	*136*	*0*
	Other	89	143	60	10	29	4	58	549	114	*1,057*	*3*
CWHvh1 Subtotal		*1,138*	*1,975*	*785*	*38*	*43*	*49*	*91*	*4,399*	*5,946*	*14,465*	*35*
CWHvm1	Cw	883	192	22	2	7	14	27	2,078	7,303	*10,529*	*26*
	Hw	1,014	882	54	37	19	52	127	720	2,841	*5,746*	*14*
	Yc	3	1						1,279	1,525	*2,807*	*7*
	Fdc	35	697						41	31	*804*	*2*
	Ba	148	3	7	9	19		21	48	622	*877*	*2*
	Other	91	113	34		2			94	34	*368*	*1*
CWHvm1 Subtotal		*2,174*	*1,888*	*117*	*48*	*48*	*66*	*175*	*4,258*	*12,356*	*21,130*	*51*
CWHvm2	Cw	104	4	1		1	0	10	229	1,231	*1,580*	*4*
	Hw	209	244	1	1	1	28	28	347	1,480	*2,339*	*6*
	Yc	0	3	1			9		240	906	*1,160*	*3*
	Fdc	3	74							0	*77*	*0*
	Ba	50	1	4	1	20		16	34	326	*452*	*1*
	Other	1	0						0		*1*	*0*
CWHvm2 Subtotal		*368*	*326*	*8*	*1*	*23*	*37*	*53*	*850*	*3,943*	*5,610*	*14*
All	Cw	1,686	637	242	11	11	44	59	5,144	12,907	*20,740*	*50*
	Hw	1,566	1,897	449	57	28	93	166	1,415	5,522	*11,194*	*27*
	Yc	3	4	1	0	0	9	0	2,176	2,602	*4,795*	*12*
	Fdc	46	1,390	65	0	0	2	0	48	32	*1,583*	*4*
	Ba	199	5	59	10	42	0	36	82	1,034	*1,466*	*4*
	Other	181	257	93	10	32	4	58	642	148	*1,426*	*3*
Total		*3,680*	*4,189*	*910*	*88*	*113*	*153*	*320*	*9,508*	*22,246*	*41,205*	*100*
(%)		*9*	*10*	*2*	*0*	*0*	*0*	*1*	*23*	*54*	*100*	

The most important site series in the target population are the three zonal sites, the CWHvh1/11, and the CWHvm1/03 (Table 15).

Table 15. Area distribution of THLB and Reserve Zone by BEC site series based on the TEM.

Site	CWHvh1		CWHvm1		CWHvm2	
Series	(ha)	(%)	(ha)	(%)	(ha)	(%)
NP[a]	493	1	401	1	134	0
01	6,887	17	10,783	26	3,115	8
02	123	0	679	2	75	0
03	1,013	2	3,960	10	1,393	3
04	8	0	11	0	12	0
05	34	0	1,251	3	185	0
06	405	1	1,240	3	223	1
07	1,167	3	1,618	4	345	1
08	129	0	6	0	0	0
09	0	0	93	0	101	0
10	0	0	0	0	26	0
11	2,950	7	24	0	2	0
12	959	2	841	2	0	0
13	190	0	147	0	0	0
14	55	0	75	0	0	0
15	52	0	0	0	0	0
Total	*14,465*	*35*	*21,130*	*51*	*5,610*	*14*

APPENDIX II – LIST OF REJECTED SAMPLES

Plot No.	Subzone	Site Series	Mapsheet/ Polygon	Ldg. Spp.	Inv.SI (m)	Inv.Age (yrs)	Reason for Rejection
4	CWHvm1	01	092F012 762	Hw	23.9	19	Stand too young (<10 yrs at BH)
6	CWHvm1	07	092F021 946	Hw	16.9	97	Stand too old (>100 yrs at BH)
8	CWHvh1	07	092C093 85	Hw	26.5	57	Alder leading, no codominant Hw
11	CWHvm1	01	092E058 2345	Hw	25.1	23	Suppression in advance regeneration Hw
18	CWHvm1	03	092E050 9	Cw	22.0	37	Vets
28	CWHvm1	03	092F003 36	Hw	21.1	17	Windthrow with vets and residuals
33	CWHvh1	11	092F003 331	Hw	20.1	82	Suppression in advance regeneration Hw
44	CWHvm1	01	092C093 2015	Hw	26.0	24	No Hw present
45	CWHvm1	01	092F003 2004	Hw	22.0	31	Safety issues, steep cliff
48	CWHvm1	03	092E039 565	Hw	14.9	17	Vets

APPENDIX III – RESULTS OF QUALITY ASSURANCE

Data Type	Tolerance	Results
Site tree selection	No error	No error
Height to DBH	actual ± 5cm	All within tolerance
DBH	actual ± 0.1cm	We rationalized a few diameters, but none impacted tree selection
Total tree height	actual ± 20 cm or 2%	Some discrepancies with HW droop, but all within reason
BH age	if age < 50 no error, otherwise 1year	Did not QC as they were office verified
Notes	must have notes on acceptable damaged sample trees	Very diligent with notes
Subzone	No error, includes notes on transition	Found one error. Notes inappropriately identified as transition.
Site Series	± site series	All within tolerance
Elevation	± 50 m	Used GIS
Slope	within 10 %	All within tolerance
Aspect	± 15 degree from actual	All within tolerance
Meso slope	± one class	All within tolerance
Soil nutrient regime	± one class (especially important for Cw/Hw pairs)	All within tolerance
Soil moisture regime	± one class (especially important for Cw/Hw pairs)	All within tolerance

Appendix III
Primary Basin Rate of Cut

Basin Name	Rate-of-Cut Rule	Basin Area(ha)	TFL Basin Area(ha)	Rate-of-Cut (ha/5-or10-year Period)
1	5-Year	2,068	1,007	70.0
2	5-Year	1,699	254	55.5
3	5-Year	3,060	1,620	86.8
4	5-Year	47,751	4,283	228.7
5	None	87	13	-
12	10-Year	224	74	7.4
13	None	196	62	-
14	None	128	54	-
16	10-Year	378	181	18.1
17	10-Year	229	142	14.2
18	5-Year	504	477	23.8
19	None	161	71	-
22	5-Year	882	27	1.4
23	None	142	21	-
24	None	199	140	-
25	None	144	144	-
26	None	133	133	-
27	None	114	114	-
28	5-Year	569	569	28.5
29	10-Year	385	385	38.5
30	10-Year	306	306	30.6
32	5-Year	21,682	484	24.2
37	None	167	92	-
38	None	159	121	-
39	None	112	20	-
40	10-Year	224	186	18.6
41	10-Year	440	21	2.1
42	10-Year	498	152	15.2
44	10-Year	218	127	12.7
45	None	143	44	-
46	None	167	130	-
47	None	134	91	-
48	10-Year	239	10	1.0
49	None	156	156	-
50	None	152	152	-
51	None	150	43	-
52	None	113	113	-
54	5-Year	538	364	26.9
55	10-Year	270	128	27.0
56	5-Year	609	390	19.5
57	10-Year	219	118	11.8

Basin Name	Rate-of-Cut Rule	Basin Area(ha)	TFL Basin Area(ha)	Rate-of-Cut (ha/5-or10-year Period)
58	5-Year	511	244	12.2
67	10-Year	249	84	8.4
68	10-Year	323	29	2.9
69	5-Year	2,741	1,531	76.5
70	5-Year	790	527	26.3
71	10-Year	404	336	40.4
72	None	165	120	-
73	5-Year	1,406	438	23.1
77	5-Year	24,204	78	45.3
79	10-Year	283	283	28.3
80	10-Year	436	299	29.9
95	None	172	47	-
96	10-Year	248	128	12.8
97	5-Year	1,541	1,351	67.6
98	5-Year	533	533	26.7
99	5-Year	3,580	3,370	169.0
100	10-Year	335	213	21.3
102	5-Year	5,593	1,785	93.8
103	10-Year	421	338	33.8
104	None	137	81	-
105	10-Year	343	165	16.5
106	5-Year	566	182	9.1
107	10-Year	275	164	27.5
108	None	103	40	-
109	None	141	79	-
110	5-Year	1,052	299	15.8
111	None	139	61	-
112	5-Year	1,767	1,531	76.6
113	None	162	162	-
114	10-Year	296	216	21.6
115	5-Year	551	403	20.2
116	5-Year	5,689	2,798	141.6
118	10-Year	255	110	11.0
119	10-Year	227	132	18.8
120	5-Year	673	274	15.5
121	5-Year	984	418	46.1
125	5-Year	829	328	41.5
126	10-Year	308	218	30.8
127	10-Year	385	121	38.5
128	5-Year	1,047	609	34.0
129	5-Year	676	484	27.1

Basin Name	Rate-of-Cut Rule	Basin Area(ha)	TFL Basin Area(ha)	Rate-of-Cut (ha/5-or10-year Period)
130	5-Year	676	120	6.0

Appendix IV
Secondary / Tertiary Quaternary Basin Rate of Cut

Basin Name	Basin Type	Rate-of-Cut Rule	Basin Area (ha)	TFL Basin Area (ha)	Rate-of-Cut (ha per 5- or 10-year Period)
2.1	Secondary	5-Year	516	59	10.6
3.1	Secondary	None	498	274	0.0
3.2	Secondary	5-Year	968	475	23.7
4.1	Secondary	5-Year	1283	140	7.2
4.13	Secondary	5-Year	1403	877	56.8
4.2	Secondary	5-Year	2063	1131	56.5
4.3	Secondary	5-Year	11765	20	1.3
4.4	Secondary	5-Year	522	323	17.7
4.5	Secondary	5-Year	1097	827	42.1
4.6	Secondary	None	243	153	0.0
4.7	Secondary	None	254	202	0.0
32.1	Secondary	5-Year	1320	484	24.2
69.1	Secondary	5-Year	636	108	5.4
73.1	Secondary	None	396	326	0.0
73.2	Secondary	5-Year	981	112	5.8
77.2	Secondary	5-Year	770	28	38.5
77.3	Secondary	5-Year	7329	50	225.9
99.1	Secondary	5-Year	2430	2254	113.2
99.2	Secondary	5-Year	1150	1116	55.8
102.1	Secondary	5-Year	1706	1314	65.7
102.2	Secondary	None	454	251	0.0
110.1	Secondary	None	164	26	0.0
112.1	Secondary	None	292	239	0.0
112.2	Secondary	None	192	124	0.0
112.3	Secondary	None	327	280	0.0
116.1	Secondary	None	234	102	0.0
116.2	Secondary	5-Year	2607	2122	106.6
116.3	Secondary	5-Year	1519	330	16.5
121.A	Secondary	5-Year	688	178	34.4
4.13.5	Tertiary	None	56	42	0.0
4.13.6	Tertiary	5-Year	639	460	28.2
4.13.7	Tertiary	None	112	28	0.0
4.13.8	Tertiary	None	41	26	0.0
4.13.9	Tertiary	None	378	322	0.0
4.2.1	Tertiary	5-Year	762	537	26.9
4.2.2	Tertiary	5-Year	667	278	13.9
77.3.3	Tertiary	5-Year	1323	50	40.8
99.1.1	Tertiary	5-Year	1812	1801	90.6
102.1.1	Tertiary	None	451	278	0.0
102.1.2	Tertiary	5-Year	1179	1006	50.3
116.2.1	Tertiary	5-Year	753	741	37.7
116.2.2	Tertiary	None	497	463	0.0

116.2.3	Tertiary	5-Year	834	645	32.3
77.3.3.1	Quaternary	5-Year	545	50	27.2
99.1.1.1	Quaternary	5-Year	700	688	35.0