The Importance of Silviculture in Timber Supply Analysis, a Coastal Perspective

Silviculture Working Group,
Coast Region FRPA Implementation Team

May, 2018
# Table of Content

Acknowledgements.................................................................................................................. 4

1 INTRODUCTION .................................................................................................................. 6

2 BACKGROUND ..................................................................................................................... 7
   2.1 Timber Supply and Timber Supply Review ................................................................. 7
   2.2 Timber Harvesting Land Base ..................................................................................... 8
   2.3 Net-Downs .................................................................................................................. 9
   2.4 Analysis Unit ............................................................................................................. 9
   2.5 Yield Tables ............................................................................................................. 10
   2.6 Base Case ................................................................................................................ 12
   2.7 Reporting Silviculture Updates and Land Status Tracking System (RESULTS) ........ 14

3 SILVICULTURAL FACTORS THAT INFLUENCE TIMBER SUPPLY ANALYSIS ............. 14
   3.1 Species Composition ............................................................................................... 14
      3.1.1 Silviculture and Inventory Labels ........................................................................ 14
   3.2 Stand-level Retention ............................................................................................. 18
   3.3 Density .................................................................................................................... 22
   3.4 Site Index ............................................................................................................... 23
      3.4.1 Site Index and the Provincial Site Productivity Layer ........................................... 23
      3.4.2 Determination of Years to Breast Height ............................................................ 25
      3.4.3 Importance of Site Index ................................................................................... 27
   3.5 Regeneration Method and Stem Distribution ............................................................. 27
   3.6 Regeneration Delay ............................................................................................... 29
   3.7 Operational Adjustment Factors ............................................................................. 30
   3.8 Genetic Worth by Species ...................................................................................... 32
   3.9 Forest Management Activities ............................................................................... 32
      3.9.1 Density Management: Juvenile Spacing ............................................................ 32
      3.9.2 Competition Management ................................................................................. 34
      3.9.3 Fertilization ..................................................................................................... 36
   3.10 Climate Change ..................................................................................................... 38

4 CONCLUSION/RECOMMENDATIONS .......................................................................... 39

APPENDIX 1: Land Base Area Netdown Summary ................................................................ 41

APPENDIX 2: Background Information ............................................................................. 42
Acknowledgements

This discussion paper is a collaborative work prepared by members of the Coast Region FRPA Implementation (CRIT) Silviculture Working Group (SWG). The following working group members contributed to this paper:

- Craig Wickland RPF, Coast Area, Chair SWG,
- Graham Hues RPF, Western Forest Products, SWG member (retired)
- Paul Bavis RPF, Western Forest Products, SWG member
- Paul Barolet RPF, North Island-Central Coast Natural Resource District, SWG member
- Shannon Pearce, RPF, North Area, SWG member
- Rick Monchak RPF, TimberWest Forest Corp., SWG member
- Joe LeBlanc RPF Interfor Corporation, SWG member
- Jack Sweeten RPF, Chilliwack Natural Resource District, SWG member
- Rod Negrave PhD, RPF, Coast Area, SWG member
- Mark Palmer RPF, South Island Natural Resource District, SWG member
- Ellery Tetz RPF, BCTS Skeena Timber Sales Office, SWG member

This discussion paper is dedicated to the memory of Rod Negrave who passed away in 2016.
1 INTRODUCTION

Silviculture has the potential to have a significant positive impact on timber supply. Historically, timber supply modelling has relied on assumptions for most silviculture related inputs. Today, in many cases, these assumptions are still used. When an effort is made to understand actual silviculture performance, rather than relying on assumptions, the impact to timber supply is often positive.

Achieving a timber supply forecast that is modelled on actual silviculture performance is a tremendous opportunity. During the timber supply review process, if not before, an effort needs to be made to understand actual silviculture performance. Data that exists in the Reporting Silviculture Updates and Land Tracking Status System (RESULTS) and silviculture surveys can be modified to capture actual performance attributes that are necessary to inform timber supply modeling assumptions. Therefore, an improved understanding by forest professionals of the silvicultural factors that influence timber supply and the role they play in affecting these factors is critical. This paper attempts to provide that understanding.

This paper has two objectives:

- To demonstrate the importance of silviculture in timber supply analysis by examining the various silviculture related inputs that influence timber supply and how silviculture practices can impact these factors, and
- To provide resource professionals with an understanding of the importance of their role in determining, delivering, and monitoring silviculture practices and the effect this will have on timber supply analysis.

Photo 1: Even aged management is the basis for most TSR assumptions.
2 BACKGROUND

2.1 Timber Supply and Timber Supply Review

Timber supply is the volume of merchantable wood that is forecasted to be available for harvesting over a specified time period under a particular management regime. It is the result of: the condition of the existing forest, the rate of growth of the unmanaged and managed forest, how the forest is being managed for timber and other resource values (e.g., visuals, wildlife, and watersheds) as further described below. An example of a condition impacting overall growth rate could be higher levels of treed retention.

Timber Supply Review (TSR) consists of a timber supply analysis, first nation consultation and public review. This process is to be performed on each timber supply area (TSA) and tree farm license (TFL) every 10 years to support the Chief Forester’s allowable annual cut (AAC) determination. The AAC determination is a dynamic process that reflects current forest management practices including their potential impact on short and long term timber supply. It is supported by the best available information across a wide range of environmental, social and economic factors as outlined in Section 8 of the Forest Act. These factors include abnormal insect and disease infestations, and the rate of timber production that may be sustained on an area giving consideration to species composition, rate of growth, regeneration delay and silvicultural treatments applied to the area.

Photo 2: Forest professionals need to link silviculture practices to the timber supply at the landscape scale.
2.2 Timber Harvesting Land Base

The Timber Harvesting Land Base (THLB) can be described as the residual area of a management unit (e.g., timber supply area, tree farm licence) that is available and suitable for growing timber after all non-timber values have been accommodated. It is the productive forest land\(^1\) that is expected to support long term, commercial timber production within the management unit. The THLB for a management unit is derived by a process of delineating the categories of land that are not expected to contribute to current or future timber production. Land is considered non-THLB where no harvesting is expected. Areas within a management unit that are unavailable for timber harvest due to management for other non-timber resource values, such as old growth management areas (OGMA), conservancies, wildlife habitat areas, riparian reserve zones, known archaeological sites and other protected areas, are excluded from the THLB.

\[\text{Photo 3: An example of current and well planned variable retention (VR) including riparian reserve zone. Introduced in 1995, VR has been implemented on the landscape in some management units due to changing societal values.}\]

Some areas managed for non-timber resource values are not fully excluded from the THLB but rather are subject to additional rate-of-cut and forest cover retention requirements. Examples include: management for visual quality objectives, protection of water quality within community watersheds, maintaining ecological function of upland streams, riparian management areas, forest cover adjacency, or where harvest is limited by a general wildlife measure. There are also situations, albeit infrequent where management activities may increase the THLB of a management unit: for example management activities which improve productivity or operability (e.g., reforestation of land classified as non-commercial brush, or through the acquisition of productive forest land (e.g., timber licence reversions). It is important to note that the AAC across the coast has declined 29 %\(^2\) (7 million m\(^3\)) since the peak in 1984. This decline is primarily due to reduction in THLB to accommodate changing trends in societal values (e.g., establishment of:

\[1\text{ E.g., sites with a site index greater than 10 meters and capable of producing 300 cubic meters per hectare}\]
\[2\text{ Coast Allowable Annual Cut Verification and Key Driver Review and Analysis (1975-2012)}\]
2.3 Net-Downs

The following are examples, but not a complete list, of the additional types of productive land base often excluded from the THLB (i.e., either as spatially-explicit or non-spatial net downs):

- Sites with known unstable terrain (i.e. often supported by reconnaissance level mapping of terrain stability by a qualified professional)
- Legally established recreation sites, trails and interpretive forests
- A portion of the forested area having potential karst features in management units subject to a Government Action Regulation (GAR) order for karst
- Ungulate winter range (UWR) where the approved general management measure usually prohibits timber harvesting
- Wildlife Habitat Areas (WHA) where general wildlife measures specify no harvesting or silviculture
- All or a portion of a wildlife tree patch percentage specified in the landscape unit planning guidebook for stand level biodiversity retention
- First Nations’ cultural heritage resource values
- Area associated with managing for specific higher level plan objectives (e.g., Ecosystem Based Management (EBM) objective for red and blue listed plant communities)
- A percentage reduction for existing and future roads, trails and landings
- In some management units a percentage of broadleaf leading stands where there is excessive decadence or operability constraints
- Commercially uneconomic and inoperable areas
- Private land, woodlot licences, community forest agreements and land tenures

2.4 Analysis Unit

For modelling purposes, the forest inventory is aggregated into analysis units to capture biological and productive similarities that form the THLB. An analysis unit (AU) is comprised of areas with similar tree species composition, timber growing potential or site index, management regime and in some instances location (i.e., specific portion of a management unit where practices differ). The definition of the analysis units can be defined or modified by management unit.
**Figure 1:** Examples of even aged analysis units for future managed stands which can be redefined using RESULTS and forest cover data.

The following are examples of new analysis units for future managed stands to capture management practices that have changes since the previous TSR:

- New aspen/cottonwood (Ac) analysis unit, to incorporate all Ac leading stands in the inventory.
- New Fdc planted zone, used to convert existing analysis units to a future regime planted to Fdc.
- New marginal cedar and hemlock analysis units added to separate low site conditions.

Analysis units are further broken down to reflect whether they are natural stands or managed stands. Typically each analysis unit is assigned a separate, distinct timber volume projection or yield table as shown in Figure 1. Assumptions for silvicultural regimes (e.g., regeneration delay, planted or natural, densities, and site index adjustments) will vary among analysis units for managed stands. For the most part, timber supply analysis units have been primarily based on even-aged management regimes for managed stands and natural stand yield tables for existing stands that have been inventoried.

### 2.5 Yield Tables

Stand growth projections, as illustrated through yield tables are derived through yield prediction systems or models which estimate the characteristics of timber yield from the average stand
given information on initial conditions. Two types of models are typically used in developing yield tables, individual tree models and whole stand models.

**Individual tree (managed stand) models:** The Tree and Stand Simulator Model (TASS) is a spatially explicit individual tree model designed to produce growth and yield information for even-aged managed stands. TASS is calibrated for four coastal species (Douglas-fir, Western hemlock, Sitka spruce, Western redcedar) and four interior tree species (Lodgepole pine, White spruce, Douglas-fir, Western hemlock). The growth and yield information (i.e., yield table data base) for use by the Table Interpolation Program for Stand Yields (TIPSY) is generated by the TASS. Yield tables for existing managed stands and future managed stands are derived using TIPSY. Existing managed stands are usually defined as part of the TSR data package (e.g., stands less than a certain age with some level of active management). Site productivity is determined through the provincial site productivity layer estimates of site index for timber supply areas. Data obtained from measurements of permanent sample plots in both managed and natural stands provides validation for treatment response, growth and mortality.

**Whole stand (natural stand) models:** Yield tables for natural stands are usually defined within the TSR data package and are derived using the Variable Density Yield Prediction (VDYP) system version 7, an empirical growth and yield prediction system based upon temporary inventory sample and permanent growth sample data. As VDYP 7 uses basal area for density calculations, volume predictions should more closely approximate actual changes in volume across the density range. With VDYP 7 volume projections are more likely to decrease in the long term since the height of stands tend to flatten and the basal area may also decline in old stands. Driven by inventory stand composition and site index estimates, the VDYP system estimates stand heights, volume, basal area and diameters at different utilization levels and ages.

---

3 TASS managed stand yield table for coastal Douglas-fir planted to 1110 stems per ha – Growth and Yield Prediction Systems Special Report Series 7
**Photo 4:** VDYP 7 can model the growth of stands with retained basal area such as this one that will have a portion of even aged understory cohort of new regeneration in the gaps. The residual basal area can contribute to future timber supply when reported to RESULTS as part of the Forest Cover Inventory.

### 2.6 Base Case

From a range of possible timber supply forecasts, attempts are made to avoid both excessive changes from decade to decade and significant timber shortages in the future to ensure the long-term productivity of forest lands. This is known as the base case forecast, as illustrated in figure 3, and forms the basis for comparison when assessing uncertainty with respect to future timber supply. The majority of data used to define current practices within the base case is obtained from RESULTS.

The base case represents current practices across the land-base; it characterizes the timber supply resulting from natural and managed stands assuming current management practices continue. The term natural stands refers to old growth and younger stands of natural origin that have received minimal or no silvicultural treatment. A managed stand refers to second growth forest cover where at least basic silviculture is occurring or the site was previously harvested.

The base case is designed to represent only one out of a number of theoretical forecasts. It reflects current practices and knowledge and may include some future uncertainty. As such the resulting AAC determination may or may not match the base case forecast.
Figure 3: Example of a base case harvest level over time.

Assessing uncertainty is done through a sensitivity analysis that changes assumptions or parameters associated with one or more analysis units to determine the upward (+) or downward pressure (-) on timber supply when compared to the base case. Downward pressures on timber supply may result from different silvicultural practices specific to managing for new objectives (e.g., Land Use Order, visuals, species at risk, new retention requirements). Upward pressure on timber supply may result from enhanced growth performance through intensive silviculture treatments (e.g., late rotational fertilization of Coastal Douglas-fir stands, increased planting densities, or use of select seed with genetic gains).

Figure 4: Data input from RESULTS and field surveys used for a high and low sensitivity run comparing the base line (base case) to varying levels of treed retention within a management unit.
2.7 Reporting Silviculture Updates and Land Status Tracking System (RESULTS)

The RESULTS application tracks silviculture information to generate statistics. Data (e.g., forest cover information, silvicultural treatments, and planted tree species) is submitted to RESULTS through the Electronic Submissions Framework (ESF) or similar tenure holder software. Data is extracted and used as inputs to silviculture factors and analysis units used in timber supply reviews as follows:

- Data for analysis units and the base case
- Development of managed stand yield tables
- Regeneration delay data
- Silvicultural systems applied
- Retention levels for Wildlife Tree Retention Areas (WTRA's) and aggregate reserves
- Basal area reported with the forest cover inventory
- Net area to reforest per year within a management unit
- Planting densities by hectares and species
- Amount of area with natural regeneration
- Seedlots, seed use, and genetic worth
- Fertilization treatments, brushing treatments
- Pre-commercial thinning treatments
- Area denuded by fire

RESULTS is integral to the timber supply process for the data and statistics it provides for inputs to silviculture factors.

3 SILVICULTURAL FACTORS THAT INFLUENCE TIMBER SUPPLY ANALYSIS

3.1 Species Composition

3.1.1 Silviculture and Inventory Labels

Common practice for describing species composition within an opening uses the silviculture and inventory labels based on data collected during silviculture surveys. The silviculture label is the standardized method for describing the well-spaced or free growing crop tree component in order to demonstrate compliance with approved stocking standards. As part of the process to adjudicate whether free-growing conditions are met, a silviculture label is created for all standards units and reported to RESULTS. The inventory label is the standardized method for describing all (planted and/or natural) commercial tree species growing in an opening based on density determined from plot data and an ocular estimate of species composition at every fourth plot. The inventory label created is required for reporting purposes (RESULTS).

Historically, species composition for managed stand yield tables and timber supply forecasting has been informed by inventory labels. It is important to note the following points if using the inventory label to inform timber supply analysis:
• The inventory label at free growing measures all commercial trees and does not consider that many trees may not survive or maintain their canopy position within the stand for the full rotation.
• The inventory label may be dominated by natural ingress species of lower site index compared to the density of planted tree species of higher site index and/or genetic gain.

Due to general concerns that relying solely on the inventory label for species composition would skew towards natural ingress, the timber supply forecasting approach has recently been modified by Forest Analysis and Inventory Branch (FAIB). Using TASS II, both planted trees and the natural stand component are modelled concurrently. The inventory label is used to inform the model of density (total stems/ha) and the species composition of the natural ingress component. Data from RESULTS is used to provide the model with planting information (e.g., species, planting density, genetic gain). TASS II is used to model the dynamics of the competition between the planted stems (including genetic worth) and the natural ingress component based on stocking and site indices of each species. The natural ingress component is calculated and modelled in TASS by phasing it in over time. This approach will allow the model (TASS II) to derive a final stand species composition at harvest based on the effects of competition between the planted and natural ingress components. This Provincial approach allows the FAIB to consistently model stand volumes with TASS II using the best available data from RESULTS.

Using FAIB’s current approach for the site in photo 5 and 6, the planted stems, and natural ingress component from the inventory label would be modelled using TASS II. Consider the planted cut block in photos 5 and 6.

Photo 5: Plantation with browse protectors for cedar, Sitka spruce, and balsam.
Photo 6: The same free growing plantation is now a hemlock leading monoculture despite planting efforts.

In this example planting information alone (density, species, genetic gain) may not be a reliable predictor of future crop trees and species composition. Photo 6 illustrates that at the time of free-growing the planted trees have an intermediate or supressed canopy position and the future crop at rotation will likely be dominated by natural ingress.

These considerations generally support the notion that solely using the inventory species composition and or planting information may not be the best data for reflecting merchantable species composition at rotation. An alternative is to apply the free-growing silviculture label, rather than the inventory label, to better inform the current species composition for modelling purposes. This approach better reflects species composition of the future stand as it will capture actual stand conditions based on the canopy position of dominant crop trees at free-growing.

The potential benefits of using silviculture label information when aggregating species composition for use in analysis units and modeling becomes obvious when analysis units accurately reflect the dominant trees on site. To further illustrate the benefit of this approach, consider openings planted to coastal Douglas-fir (Fdc) of higher site index compared to natural ingress of Western hemlock (Hw) of lower site index for the same site.

For example:
- Silviculture label: Fdc70Hw30 @ 1,000/ha
- Inventory label: Hw70Fdc30 @ 2,500/ha

In this Douglas-fir example the silviculture label species composition better reflects the species composition at free-growing to rotation. The inventory label reflects a higher component of natural hemlock ingress that will not become dominant crop trees, outcompeted by the dominant planted Douglas-fir. Using the silviculture label to capture the species composition in this example combined with appropriate planting information increases the contribution of Douglas-fir that is being modeled for the analysis unit.

This approach provides the basis for using the silviculture label for determination of species composition for the timber supply review process under Management Plan (MP) #4 for TFL 47.

<table>
<thead>
<tr>
<th>BGC</th>
<th>Subzone</th>
<th>Site Series</th>
<th>Fd</th>
<th>Hw</th>
<th>Cw</th>
<th>Ba</th>
<th>Yc</th>
<th>Bg</th>
<th>Ss</th>
<th>Dr</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWH</td>
<td>xm</td>
<td>01</td>
<td>P T/ha(^4)</td>
<td>840</td>
<td>0</td>
<td>140</td>
<td>10</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N T/ha(^5)</td>
<td>0</td>
<td>2200</td>
<td>50</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Crop %</td>
<td>62</td>
<td>29</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 5: CWH xm 01 analysis unit for MP#4.

For MP #4, the AUs are based on site series derived from Terrestrial Ecosystem Mapping. Each site series or group of similar site series is an AU. The data used to inform the species composition (crop %) for each AU comes from free growing surveys – the silviculture label including total crop stems/ha. Planting information also provides the genetic gain for planted stems to be applied to AUs.

Going forward the following conditions must be met to ensure this approach is successful:

- The surveys must be done correctly and consistently across the plan area.
- The surveys must be able to be aggregated by AU. In the above example, since the AUs are based on site series and surveys are done by standards units which are also based on site series, the aggregation is straightforward.
- The aggregate must be of a sufficient size in order to average out the variation of one year to the next or one operating area to the next. A minimum of 5 years of surveys is recommended.

\(^4\) Planted trees per hectare often with genetic gain (e.g., Douglas-fir, cedar)
\(^5\) Natural trees per hectare
Additional points for consideration if using the silviculture label and planting information as the means to inform timber supply include:

- For all sites, and especially where crop trees are slower to express dominance, delaying the free growing survey and declaration to the latter part of the free growing window would improve silviculture label quality and TSR analysis value.
- Consideration should be given to limiting the silviculture label to target (M value), not M+ (the M-value represents maximum allowable number of well-spaced or free growing trees that may be recorded in a single plot). Going beyond the target stocking (TSS) will likely introduce non crop trees into the species composition (e.g., in the case of the above AU example more Hw) that may be less desirable.

Shifting the modeling focus from the species composition of the inventory label to the species composition of the silviculture label should be cost neutral, as existing processes could be easily adapted. In situations where there is a significant amount of stand level retention, the silviculture and inventory label will need to be accompanied by a volume adjustment factor and a description of the retained basal area (m$^2$/ha).

Key to the success of the silviculture label approach is placing greater reliance on the completed silviculture surveys, in particular the free-growing survey. Surveyors and signing forest professionals must be aware of the linkage to timber supply analysis and ensure that the most probable crop trees in each survey plot are selected. Crop trees need to be selected based on the surveyor’s judgment that they are the most likely to form part of the future crop (i.e., dominant or codominant trees with good vigour). Preferred species of lesser dominance that are intermediate crown position or suppressed or slowing growing should not be selected as free growing crop trees unless there are compelling reasons to do so (i.e. forest health/tallest crop tree is unacceptable).

In summary, utilizing the silviculture label species composition to inform the analysis units for timber supply may be beneficial provided the crop tree data can be consistently captured across a management unit. This approach also provides opportunities for professionals to review crop tree performance, allow for adjustments to practices that improve stand level decision making and management, and to develop a better understanding of the linkages between the free growing stand and timber supply modelling. These are all convincing reasons to use the silviculture label to inform timber supply models, when better data is available.

### 3.2 Stand-level Retention

On the coast, silviculture practices have evolved from the large clear-cuts of the past with no residual retention, to variable retention at the landscape level and the retention silvicultural system at the stand level. The increased levels of retention have led to more complexities in
collecting and reporting forest cover data. Under FRPA, a silviculture surveyor is a professional that is often responsible for collecting the data necessary for an agreement holder to report an update of the forest cover inventory, including free growing declaration to the district manager as required under the Forest Planning and practices Regulation (FPPR) section 86. A concern noted by the Coast Region Implementation Team (CRIT) with respect to forest cover data is that as practices have evolved with silvicultural systems and varying levels of retention the forest cover data reporting to RESULTS has not kept pace (CRIT 2008). Accurate forest cover data is required to model understory yields appropriately and forecast the residual timber contributions to future timber supply. Without this information the Chief Forester’s determination of the AAC may carry an unacceptable level of uncertainty.

Forest cover data submitted to RESULTS is used to generate statistics that reflect current management practices and estimate available timber supply. This information is the link between the real forest and modelled forest considered by the Chief Forester when setting an AAC. Dr. Gordon Baskerville commented that TSR forecasts should mimic the on ground reality (current practice) in the forest both in terms of yield curves and harvest flows citing “If stands in the real forest function with yields curves that are different from those in the model forest, then the forecast is wrong. That is unequivocal – it is the forecast that is wrong because it does not mimic evolving reality.”

Across the province forest cover data with unreported retention has led to a concerning divergence between the real forest conditions in the field and the statistical attributes applied in timber supply modelling. This is pertinent to geographic areas where dispersed retention is occurring. Conversely, unplanned retention has been occurring on the coast in addition to unmapped aggregate reserves (>0.1 ha), both of which are often not reported as part of the forest cover submission.

In either case, whether planned or unplanned, retention is occurring and needs to be reported to ensure an accurate forest inventory that includes total basal area to inform modeling (e.g., yield curve development) as part of the timber supply analysis process.

Modelling of stand-level retention:
To understand the implications of stand-level retention to timber supply, it is necessary to apply modelling approaches in the absence of long term growth (>20 years) and yield studies on retention systems. All models consistently indicate that as retention levels increase with group or dispersed retention the amount of length of tree edge (forest influence) increases causing reduced understory growth and species shift. From a timber supply perspective, modelling understory growth and yield to account for the spatial distribution and impacts of treed retention can be done in a number of ways.

CRIT developed messaging for Reporting Forest Cover data

Gordon Baskerville 1998. Opportunities for using Forest Level Planning & Silviculture to Enhance Forestry in the Future
Simulated stand modelling was applied to produce a “Variable Retention Adjustment Factor” (VRAF) so that analysts can explore the impacts of retention to future harvest yields. VRAF is based on the level and pattern of both group and dispersed retention.

Based on the edge effect and spatial distribution of retention, Figure 5 and 6 indicate, as the forest influence increases the understory yield decreases for Fdc. This is consistent with CRIT Single Entry Dispersed Retention Stocking Standard (SEDRSS) for Fdc framework.
For example, with 30% dispersed retention the understory yield reduction is 63% or the VRAF is 0.37 (1 – 0.63). Dispersed retention has the highest yield impact on timber productivity. For group retention systems applied to Fdc stands, the more edge effect that is created the greater the forest influence and thus the higher the yield reduction to the understory, but less so than an equivalent level of dispersed retention as noted in Figure 6.

Another measure of yield output for dispersed retention can be done using TASS. TASS runs that have been completed for Fdc indicate between 4 to 5 m²/ha of dispersed retention can be retained without impacting the even aged regeneration and predicted yields assumed with open growing conditions that are generally modelled in the majority of timber supply reviews. Similarly, cedar-hemlock TASS runs indicate that up to 8 m²/ha of dispersed retention can be retained while maintaining even aged management yields. When the amount of dispersed retention retained is above these specified levels of 4 and 8 m²/ha respectively practices are no longer considered even aged management based on timber supply yields or the CRIT SWG definition for even aged management.

**Stand-level retention and basal area:**
The common link between retention silvicultural practices, biological over-story and understory relationships, forest cover inventories, growth and yield, and timber supply modelling is basal area per ha (m²/ha). Once the significance of this link is established, the importance of collecting and reporting on basal area with accuracy is reinforced. A tool for collecting basal area in an effective manner during the silviculture survey is the recently developed Single Entry Dispersed Retention Stocking Standard (SEDRSS).

Within a fixed radius 3.99 m regeneration plot, basal area from mature stems both inside and beyond the plot radius may be impacting regeneration performance. This is a critical link between the biological relationship between understory and mature tree distribution on site. As regeneration performance may be impacted by the crowns of mature trees well beyond the regeneration plot radius the levels of regeneration stocking require further consideration. SEDRSS takes this into consideration.

For the application of SEDRSS timber supply modellers may want to use the inventory label for the mature layer 1 component, with total basal area instead of the silviculture label that represents crop tree basal area only. The reason for this is that the non-crop tree component (e.g., for cedar-hemlock dominated sites the dead and standing cedar volumes) can contribute to timber supply as part of inventory. To use only the silviculture label would mean foregoing some of this volume.

---

8 Areas ≥ 1.0 ha. with < 8m²/ha of Dispersed Retention for Cw/Hw sites, <=5m²/ha for Fdc sites (i.e., Open stands, clear-cuts or stands with low levels of dispersed retention

Figure 8: CWHvh1 01 Cedar-Hemlock SEDRSS table and surveying card for the CWHvh1 01 Cedar-Hemlock Stands governed by overstory basal area that contributes to stocking obligations with the silviculture label. The total basal area includes all trees to be reported with inventory label for future timber supply modelling.

In the case of SEDRSS for Douglas-fir stands (not shown), the field reviews and development indicated that the silviculture label for the regeneration layers may likely reflect a higher component of hemlock since the planted, more shade intolerant Fdc, often cannot compete as well in areas with > 10m²/ha of dispersed retention (degree of competition dependent upon environmental variables such as slope, aspect, elevation and latitude).

Stand-level retention inside opening boundaries has become more common on the coast in recent years. The implication to growth and yield of mature timber retained within blocks is demonstrated through modelling and supports the necessity of collecting and accurately reporting forest cover to RESULTS so that timber supply analysis reflects what is happening on the ground.

3.3 Density

Stocking density is represented by number of trees per unit area (e.g., hectare) and has two components; a planting component and a natural ingress component. It is a key input into generation of managed stand yield tables which are used to estimate future volumes. Stocking density is an important variable since it has the potential to influence both timber quality and timber volume production.

The selection of initial establishment density is an important silvicultural decision that can greatly influence both future stand productivity and individual tree characteristics. Initial establishment or planting density when combined with natural ingress density affects both basal area per hectare and total volume per hectare at rotation. Except at very high stocking densities, top height (height of the 100 largest diameter at breast height (DBH) trees/ha) and periodic height are not influenced by stocking density and escapement. However all basal area variables are affected by stocking density with individual tree variables being inversely related to stocking density.
density. Low stocking densities produce trees of lower timber quality with large diameter crowns, large branches and high stem taper. Higher stocking densities produce trees of higher timber quality with smaller diameter crowns, smaller branches, smaller percent live crown, greater height to the lowest live limb and reduced stem taper. Individual tree volumes are higher at low stocking densities whereas total volume per hectare increases with increased stocking densities because of the disproportionally greater number of smaller trees. Figure 9, illustrates the effect of stocking density on merchantable volume per hectare. These relationships mean that density should be carefully considered due to its implications to timber supply.

![Stocking / Density Impacts: Merch. Vol/ha](image)

**Figure 9:** Stocking density impacts. From B. Larson and C. Farnden – Forrex Webinar December 2, 2010.

There is an expectation that stands will be managed towards target stocking densities not minimums.

3.4 **Site Index**

3.4.1 **Site Index and the Provincial Site Productivity Layer**

Site Index (SI) is commonly utilized as a measure of forest growth and productivity. When site index is used in an analysis model such as the TIPSY it allows for the comparison of productive potential of stands across a wide range of growing conditions and forest practices. Predicting the productivity of forest stands is an important tool for decision making for forest managers as well as for supporting the Chief Forester’s AAC determination during a TSR.

Two sources of site indices used provincially are:

- Site index estimates from the Provincial Site Productivity Layer
Site index estimates from the Vegetation Resource Inventory (VRI)

The Provincial Site Productivity Layer (PSPL) is a spatial coverage of potential SI estimates for commercial tree species. The PSPL is based on ecosystem mapping which is the stratification of a landscape into map units using a combination of ecological features including; climate, physiography, surface material, bedrock geology, soil and vegetation. Terrestrial Ecosystem Mapping\(^{10}\) (TEM) and Predictive Ecosystem Mapping\(^{11}\) (PEM) are the two commonly used methodologies for ecosystem mapping. PEM/TEM information (spatial delineations and descriptions) is combined with provincial Site Index Biogeoclimatic Ecosystem Classification (SIBEC) approximation tables. The SIBEC approximation tables indicate SI by tree species by BEC site series. The TEM/PEM mapping is used to estimate or predict the BEC site series and the SIBEC model is used to estimate the SI based on the site series predictions made through TEM/PEM. Where no TEM/PEM mapping information exists, a biophysical model based on biophysical data and species ranges is used to predict site index values and fill in gaps in the data. Data is collected from a large number of sample points across the province using standard methods. The data is subject to a verification review before incorporation into the data base.

The following process is recommended for applying the different site index data sources in a TSR:

- For currently unmanaged natural stands VRI site index estimates should be used.
- When unmanaged stands are harvested in a timber supply model (i.e. become future managed stands) the SI estimates from the PSPL should be used.
- For current managed stands the site index estimates from the PSPL should be used.

The PSPL consists of a series of site index data points that are distributed across the landbase on a 1 hectare grid. The grid is based on a system developed from standards determined by the “Hectares BC” project. The distribution of site index estimates on the 1 hectare grid allows the user flexibility in how data points are grouped (i.e. by analysis unit).

The user should be aware that the PSPL is best suited for strategic-level decision making, like a TSR, where the effects of errors in the site index estimates are reduced from the grouping and averaging of individual site index values for points into large groups of points across a broader area such as an analysis unit. If used for site specific operational decision making the data should be verified for accuracy via a ground-based survey. Local surveys conducted to verify site index estimates need to be based on sound sampling methodology and careful consideration needs to be given to how the data will be incorporated into the timber supply analysis.

Significant differences in site index values between the VRI and PSPL may be realized. There is potential for a volume increase in timber supply simply by using the PSPL data. The user should determine the sources used for compiling their PSPL data set. For example has the data been generated via TEM/PEM mapping with a completed verification process, or were data gaps filled

\(^{10}\) A methodology which requires direct air photo interpretation of ecosystem attributes

\(^{11}\) A modeled approach to ecosystem mapping used to predict ecosystem representation on the landscape
using the biophysical model and if so to what extent? When using any predictive model the user should review the outputs and verify that the data is a reasonable reflection of results demonstrated on the ground. This is important due to the impacts errors in site index can have on modeling timber supply.

A note of caution is put forward with respect to the use of select (“A” class) seed and genetic worth. Site Index derived from the PSPL is based on the SIBEC table and as such there is likely no overlap with any select seed source from SIBEC plots. Site index derived from VRI can come from a number of sources which may include RESULTS. If RESULTS is the source of SI estimates there is the potential to overestimate the growth benefit from genetic worth if a separate genetic worth factor has also been applied to the analysis unit.

### 3.4.2 Determination of Years to Breast Height

The concept of site index is based on breast height age, not total age. Total age is the number of years since seed. The number of years it took a tree to grow from seed to breast height is termed years to breast height (Y2BH). The number of years of growth above breast height is termed breast height age. Breast height is 1.3 m above ground measured from the high side.

Site index is the total height of site trees at breast height age of 50 years when they have been able to grow to their full potential. A site tree is defined as the largest diameter, dominant or co-dominant tree at breast height (DBH) for a given crop species in a 0.01 ha plot. For younger plantations, site trees can be the tallest tree in the plot.

Growth models rely on site index curves that are specific to species and site index. For example, a timber supply analysis would involve many site index curves, one for every combination of species and site index. These site index curves typically, but not necessarily, rely on assumptions that estimate the Y2BH. From a breast height age of zero, the models grow the trees based on the site index curves. An opportunity exists to better inform the site index curves by providing real data for Y2BH to replace the default assumptions currently used. In the vast majority of cases, actual Y2BH is less than the default assumptions. Reducing the Y2BH will have a significant positive impact to a timber supply analysis.

Timber supply analysis for coastal Douglas-fir uses Bruce’s site index curves\(^{12}\). Bruce’s site index curves rely on these assumptions that estimate Y2BH:

<table>
<thead>
<tr>
<th>SI</th>
<th>&lt; 17</th>
<th>17-22</th>
<th>23-28</th>
<th>29-35</th>
<th>36-41</th>
<th>42-47</th>
<th>&gt; 47</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y2BH</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

The majority of sites managed for timber supply have an estimated Y2BH of between 7 and 9 years. In reality, Y2BH is more likely to be achieved much sooner with commensurate benefits to timber supply. For example, for site index 35, planted at 1000 Fdc/ha, reducing the years to

---

breast height from the default to 4 years increases the predicted merchantable volume at age 45 by approximately 10%. For SI 30, the increase at age 45 is approximately 9%.

Determining Y2BH can be a relatively simple and inexpensive task. Most of the information is either already gathered or can be gathered during silviculture surveys. Two methods to determine Y2BH are presented below.

The first method for determining Y2BH, which works for both indeterminate and determinate species, uses the heights of well-spaced trees collected during the silviculture survey and reported in the silviculture label. As surveys are completed, results can be added to a database that captures species, height of well-spaced trees in the silviculture label, the number of growing seasons since establishment and the site index. An excellent substitute for site index is BEC variant and site series as standards units are easily linked to site series. Charting the height performance of species growing on similar site series (site index) over time will provide a reasonable, though conservative, measure of Y2BH. If this method is chosen, it is advisable to limit well-spaced to target density (M), not M+. Using M+ will produce a longer estimate of Y2BH as shorter trees are added to the average height calculation. Even with limiting the average height to M, this method will provide a more conservative estimate of Y2BH than if only the heights of site trees were used. The advantage of this method is that it fits easily within the current silviculture survey practices widely used throughout the province and is suitable for all species.

The second method for determinate species only, is a Y2BH survey that can most accurately define Y2BH for any young plantation that is taller than breast height. The methodology for doing this is as follows:

- Pick the tallest tree (by species) in a 0.01 ha plot – the site tree
- Measure to the first whorl below 1.3 and to the first whorl above 1.3 m
- Record the number of whorls above 1.3 (not including tip)
- If possible, record the number of whorls below 1.3
- Obtain the total age of the tree, if planted, from planting records or use whorl count plus 1
- \[ Y2BH = \text{total age} - (\text{whorls above} + 1) + \left(\frac{1.3 - \text{height to whorl below}}{\text{height to whorl above} - \text{height to whorl below}}\right) \]

This method will provide a precise measure of Y2BH that does not require charting height growth over time. The Y2BH survey can be done independently of silviculture surveys or can be done at the same time, using the same plot center. As with the previous method, aggregating Y2BH measurements by site index or by site series will provide Y2BH values that can be exported directly into timber supply analysis.

Determining Y2BH has the potential to provide a significant positive impact to timber supply. Most of the costs of determining Y2BH are already sunk in silviculture surveys. The opportunity to apply better Y2BH knowledge in timber supply analysis is perhaps more easily done in
management units where consistent survey methodologies are being use (e.g. TFLs) but can also be done in other management units (e.g., TSAs) where licensees are cooperatively motivated and agree to a common method of data collection.

3.4.3 **Importance of Site Index**

The impact of site index on timber yield is significant. Using the Table Interpolation Model Program for Yield for windows version 4.2 (Wintipsy 4.2) a simple analysis was completed using the exact same parameters (i.e., species, regeneration delay, planting density, operational adjustment factor (OAF) and slope) with changes to the site index. The gross volume at the rotation age of 80 using a site index (SI) of 26 is 620 m$^3$ compared to a SI of 28 which results in a gross volume of 714 m$^3$, an increase in projected volume of 12.4%. The significant variation emphasizes the importance of having sound site index information, in order to accurately inform future timber supply modeling.

3.5 **Regeneration Method and Stem Distribution**

Reforestation is the practice of regenerating and growing healthy trees on previously forested sites. Reforestation can include both natural and artificial or a combination of both methods. Natural regeneration methods include natural seeding; advanced regeneration and vegetative re-sprouting (e.g., root suckering and stump sprouting). Artificial regeneration methods include aerial and ground seeding, machine planting and hand planting. Regardless of what methods are chosen for reforestation, all harvested blocks on crown land must meet time - limited stocking standards that are both ecologically suitable and species specific in the context of management objectives. At the landscape level the intent is that reforestation efforts meet or exceed timber supply assumptions.

For the most part, coastal B.C. reforestation efforts are done by hand planting container stock of various sizes. Although costly, the benefits of planting are numerous. Planting ensures prompt reforestation, promotes a desirable species mix and facilitates the use of genetically improved seed where available for increased volumes, improved tree quality (e.g., density, tree form), forest health resistance and genetic diversity. Another advantage of planting is a more uniform and desirable espacement of crop trees that improves stem size and form, promotes self-pruning and improves stand receptiveness to later silvicultural treatments (e.g., fertilization). All of these are considered positives in the yield curve equation for timber supply modeling.
Photo 7: Natural ingress of conifers and broadleaf species occurred and cottonwood is now the tallest tree on the site. A review of silviculture costs should indicate broadleaf regimes be considered where conifer reforestation is challenging and costly.

Where natural regeneration is feasible, for example on remote or high elevation sites, silviculture allocations may be directed to activities with better potential for return on investment. However, natural regeneration can reduce timber yields and supply by exacerbating regeneration and green-up delays, reducing full site occupancy and uniformity and by missing yield gains from tree improvement as well as opportunities for assisted migration and species mixtures. Trees established through natural regeneration may also be less adapted to future climates than trees established through planting. This forest management choice is feasible on some mesic hemlock sites on the coast of B.C. but does not represent the current trend of practice.

Photo 8: Natural Red Alder can be a productive, reliable, and feasible regeneration choice.

Although both reforestation options may be feasible, the choice of option has the ability to influence the timber supply. Professionals considering a natural regeneration option vs a planting
option need to consider the trade-offs between the impacts to timber supply and economic objectives before making a decision. The provincial goals are to maintain or enhance an economically valuable supply of commercial timber and non-timber values, forest health, and resilience, through the management of tree species composition. One provincial objective is where it is ecologically feasible, reliable and productive, a resilient mix of species at the landscape, and where appropriate at the stand scale, will be used to reduce long-term forest health risks and maintain future options. Over 90% of the coastal B.C. reforestation efforts are by artificial regeneration. This effort supports the provincial goals and objectives and is an overall positive for timber supply.

![Diagram showing planting levels on coast since 1987 approaching 90%]

**Figure 10**: Planting levels on coast since 1987 are approaching 90%.

### 3.6 Regeneration Delay

Regeneration delay, for timber supply purposes, is the average elapsed time after the completion of harvest assumed in a timber supply analysis unit before harvested areas (sites) become occupied by a specified minimum number of ecologically acceptable, well-spaced trees. In Timber Supply Analysis, regeneration delay depends on whether a stand is of natural or planted origin. For most management units, the assumed regeneration delay for stands of planted origin is 0-2 years and greater than 3 years for stands of natural origin. Information to

---

13 Forest Planning and Practices Regulation
14 Provincial Timber Management Goals and Objectives May 26, 2014
15 % indicates how much of the NAR was planted. We consider anything >50% planted as relying on artificial reforestation for stocking; anything below 50% planting is considered a natural regeneration strategy.
16 Regeneration delay for the purpose of stocking standards in a Forest Stewardship Plan (FSP) is the maximum elapsed time from the commencement of harvest.
support regen delay assumptions in timber supply modeling is obtained through reporting of RESULTS data.

There is a theoretical timber supply impact (positive or negative as the case may be) when practices differ from the assumptions used in a timber supply analysis prepared in support of an AAC determination. Considering the potential impact to timber supply associated with regeneration delay, estimates based on accurate data are critical.

Longer regeneration delays can be caused by a number of factors, including: plantation failures or (over) reliance on natural regeneration. Management decisions to declare regeneration delay prematurely, for example at the time of planting, could have some unforeseen consequences on timber supply if stocking levels are not at desired levels at the predicted time interval stated or assumed. The longer a site is not fully occupied with vigorously growing trees, the lower the timber supply available from the entire land base.

Another consideration that is related to regeneration delay is the length of time it takes to meet adjacency/green-up requirements. The sooner a stand reaches green-up height the less spatially constrained the land base is and therefore the greater the available timber supply. Long-term timber supply is maximized when the entire land base is continuously covered with fully stocked stands that are at or younger than the age at which the maximum mean annual increment (MAI) is reached (i.e., our ideal normalized forest).

There is an obvious link between regeneration delay and years to breast height with consequential impacts to affected yield curves.

3.7 Operational Adjustment Factors

There are two types of operational adjustment factors (OAFs) in TIPSY to account for elements that reduce potential yield; OAF1, which addresses reductions in physical growing space (e.g., unmapped stocking gaps, rock outcrops, swamps) and OAF2, which is meant to address decay, waste and breakage and forest health concerns that are not static over the life of the stand (i.e., increase towards maturity).

OAFs are used to adjust yield curves in order to simulate a more realistic and operational environment (e.g., capture natural variability in managed stands due to natural gaps at establishment and stand damage progressing through rotation). OAFs are therefore used as an approximation factor to account for differences between modeled yields (TASS/TIPSY) and actual yields.

OAF1 reduces volume to account for small stocking gaps due to; natural areas such as swamps, rocky outcrops, non-commercial cover, slash piles, forest health losses, wind-throw, espacement patterns, and other factors that are not already accounted for in the growth and yield model (i.e., TASS). OAF1 is broken down in to subcategories:
• OAF1a – Non Productive areas such as rock outcrops and swamps that are too small to map out under current mapping conventions. OAF1a is not influenced by management.

• OAF1b – Management effects such as espacement and non-commercial cover. This OAF is influenced by management (e.g. gaps caused by untreated brush) and regeneration regimes (natural vs artificial regeneration).

• OAF1c – Losses due to forest health factors (e.g., losses to insects, fungi and abiotic impacts).

• OAF1d – Losses due to random risk factor.

The current recommended default value is 15% for OAF1 in timber supply reviews. Some professionals consider this conservative but for many analysis units very little site specific information is available to suggest an alternative value. OAF1 influences the yield curve from initial regeneration until the stand is harvested. It is constant throughout the life of the stand.

The reductions associated with OAF2 start at year zero and increase over time with age. OAF2 accounts for decay of solid wood overtime due to the impacts of pests and disease. The decrease in yield is small in the early years of a stand’s development and increases gradually over time. Typically OAF2 is 5% but can be increased (e.g., 12.5 %) in certain analysis units due to increased forest health risk (e.g., root disease) or other information that may come to light. OAF2 with a 5% value would increase annually by 0.0005% over a 100 year rotation. Silvicultural practices such as stumping of Douglas–fir in high hazard root disease zones (e.g., CWH dm, xm) have the potential to reduce the OAF2 (e.g., from 12.5 % to 5 %). The impacts of forest health agents (e.g., root disease) can also be addressed through the use of empirical modules, developed for application in TASS, which specifically simulate the effects of the agent on tree and stand growth.

It is well recognized that default OAF estimates need to be improved (Nussbaum, Ministry of Forests, Research Branch (1998)). Two projects were initiated, one was to establish a ground based survey methodology to assist in estimating OAF1 (1996) for TIPSY and one was to use the methodology on a TSA to help inform the timber supply review and AAC determinations by the Chief Forester. The Bulkley and Morice Lakes TSAs (Laing & McCulloch FMS Ltd.) project was completed in 2003. The objective of the project was to collect sufficient data to develop localized OAF1 estimates. One of the objectives of the 1996 project was to develop a survey technique to determine a combined OAF1, both a and b, for the current rotation of a given stand. This would be a stand specific OAF1 estimate and applied in similar stand types within a management unit. To improve local estimates of OAF1 at minimal cost, data could be collected concurrently as surveys are conducted in target strata and accumulated over several years of surveying.

Light Detection and Ranging (LIDAR) will offer an opportunity to better estimate OAF1.

Forest professionals should be aware of the impacts of OAF, in particular OAF1, to timber supply and relate these impacts to their on the ground experience when performing silviculture surveys.

17 LIDAR a remote sensing technology which uses light pulses from a laser to collect measurements which can be used to create three dimensional models and maps of objects and environments.
3.8 Genetic Worth by Species

Select seed refers to seed that is produced in seed orchards or derived from natural stands of superior provenance and has some amount of genetic gain. Genetic gain is the percentage increase (genetic worth) in certain traits (e.g., stem quality, pest resistance, or wood density) when compared to seed originating from natural stands. The genetic gain of a seedlot is expressed as its genetic worth. The genetic worth for stem volume is measured as the percent gain in volume expected for a seedlot at or near harvest age. The genetic worth for every seedlot is recorded on the Seed Planning and Registry System (SPAR).

Planting of trees grown from select seed has a direct effect on timber supply through increasing volume available in the future when those trees are harvested (longer term volume gain). Use of select seed also has an indirect effect on timber supply through the effects on factors that constrain timber (e.g., timber flow requirements, visual/ hydrological green-up, minimum harvest age etc.).

Green-up age is reduced through increased height growth achieved through genetic gain. Minimum harvest age may be reduced if based on a minimum volume requirement, or minimum diameter requirement or combination of the two. Extra volume through genetic gain therefore may be made available earlier through changes in harvest flow (an allowable cut effect) which affects timber supply.

Genetic gain increases volumes in yield tables by a general estimate of percent gain. For more precise estimates of gain:

- Identify species specific seed planning zones and elevation bands in THLB
- Define analysis units to reflect seed planning zones and elevation bands by species
- Adjust green-up ages and minimum harvest ages (as appropriate)

Genetic gain for managed stands is modelled using the TIPSY as an increase in top height which results in accelerated stand development. Genetic gain affects several stand attributes, most importantly height, volume and diameter. Gain is highest closest to the selection age (measurement age of progeny tests) and then declines.

There is some inherent risk at estimating gain when trees are tested through progeny tests at a younger age than expected harvest. There should be a reduction in risk as longer term results from progeny tests become available. Despite this inherent risk, it is clear that genetic gain has positive direct and indirect impacts to timber supply.

3.9 Forest Management Activities

3.9.1 Density Management: Juvenile Spacing

Juvenile spacing, also referred to as pre-commercial thinning, is the cutting of undesirable trees within a young stand to reduce competition among the residual trees for sunlight, water and nutrients. This is different than commercial thinning which is, “a silviculture treatment that ‘thins'
out an overstocked stand by removing trees that are large enough to be sold as products.” Juvenile spacing is a silvicultural tool that should be tied to objectives/assumptions outlined for timber supply.

Juvenile spacing is a relatively expensive silvicultural treatment that typically offers a poor return on investment and negatively impacts mean annual increment. Care must be taken to understand the risks of exacerbating forest health concerns when undertaking a juvenile spacing treatment.

Juvenile spacing may be done to:

- Control density to meet tree growth or timber supply (e.g., age class imbalance) objectives
- Manage timber flow through creation of merchantable stands sooner
- Maintain or enhance biodiversity and wildlife habitat resource values
- Maintain or enhance forest health by removing insect or disease infected trees
- Manage species composition and stand structure and/or increase stand value by changing species or product outcomes

Typically the effects of reducing stand density are:

- An increase in diameter growth of residual trees
- Trading volume from many small trees for increased volume in a few larger trees
- An increase in juvenile wood production and an increase in average knot size
- A reduction in the length of financial and technical rotations (i.e., time it takes to achieve a merchantable stand) and a delay in the culmination of mean annual increment (MAI) or a decrease in volume over a specified rotation.
- Avoidance of height-growth repression that can occur in high density stands growing on poor sites (regression spacing)
- A decrease in harvesting costs on some sites due to uniform and increased average piece size.

When recommending juvenile spacing, the prescribing forester’s rationale should outline the reasons for implementing the treatment as well as how it effectively links to timber supply objectives/assumptions.
3.9.2 Competition Management

Non-crop vegetation can adversely affect tree seedlings by competing for light, water, and nutrients, causing physical damage to seedlings, altering soil and air temperatures, and harbouring rodents or other organisms that damage young trees.

High competition levels can have a significant effect on seedling establishment, survival, density, species composition, vigour, growth, height to diameter ratios and competitive ability. All of these factors can have a negative impact on future stand volume predictions during timber supply modeling by increasing the number of years required to attain breast height, increasing tree mortality and by affecting operational adjustment factors associated with site occupancy and spatial distribution of stems. Gaps caused by poor competition management, with the resulting clumpy distribution of trees, will have an impact on growth and yield whereas full stocking with uniform tree distribution will optimize growth and yield.

What is considered to be deleterious competition depends on the crop tree species, non-crop vegetation and other site factors such as moisture and nutrient availability. When assessing sites, deleterious competition needs to be identified and potential treatments prescribed.

Effective management should reduce current competition, minimize future competition and result in minimal damage to crop trees. Possible treatments include\(^\text{18}\):

\(^{18}\) Treatments not presented in any particular order of rank or preference

Photo 9: An example of juvenile spacing more than a decade post treatment.
• Site preparation prior to planting to reduce short term above and below ground vegetative competition. Site preparation increases the number of planting spots and raises soil temperature which improves micro-site growing conditions. Longer term benefits will vary dependent upon site conditions. For example, on nutrient poor CWH xm1 03 salal sites, longer term benefits may be maintained though free growing and beyond. On nutrient rich sites however mineral soil exposure from mechanical site preparation may result in increased natural regeneration from competitive broad leaf species such as red alder.

• Selection of tree species with determinate growth (e.g., Sitka spruce) and a sturdy stem are well suited to competing with brush as well as more resistant to herbicide application.

• Planting immediately after timber harvest to capture a window of reduced competition. Challenges encountered when planting immediately following harvest include having planting stock available, increased forest health risks on some sites (e.g., conifer seedling weevil\(^\text{19}\)) and planters having to plant in and around fresh logging slash. This treatment will also serve to minimize the regeneration delay period modeled in a Timber Supply Review.

• Planting larger stock types where site conditions warrant the use of stock types such as plug styroblock (PSB) 512 or 615 that may lead to improved initial growth and better seedling survival. Where nutrient rich sites pose a high risk for early and aggressive competition the larger stock types can eliminate or reduce the requirement for follow-up brushing treatments. In addition where physical damage from crushing can be expected from rapidly growing species such as fireweed or bracken fern, the larger caliper of the stock type may reduce physical damage to the seedling. For aggressive competition areas, where planting occurs immediately after harvest with smaller stock types, the advantages of larger stock type may be superseded by prompt planting.

• Time of planting fertilization is another way of increasing early growth and reducing the need to do a brushing activity.

• Increasing planting density when dealing with competition such as found on Cedar/Salal sites. Higher densities can lead to a shading effect that will reduce the above and below ground competition exerted by salal.

• Manual cutting of competing brush to remove or temporarily reduce the effect of brush species on seedlings. Manual brushing is effective but may need to be repeated in the same year or following years as with aggressive species like salmonberry. The period for vegetative treatment to have the greatest effect is just before or soon after full leaf out before carbohydrate reserves can be rebuilt.

• Herbicide treatment is effective, often as a single low cost treatment. For workers, with proper personal protective equipment, herbicide treatments are safer than power saws. Herbicide treatments are suitable for steep slopes. Social expectations can be the limiting factor for herbicide applications and an Integrated Pest Management Plan needs to be in place prior to treatment.

\(^{19}\) A root collar weevil, \textit{Steremnus carinatus}, that typically attacks planted seedlings less than 2 years old
Photo 10: An example of a brushing treatment using herbicide. Left hand side of road treated with herbicide whereas right hand side of road converted to broadleaf management.

Often it is a combination of activities that need to be employed on a given site to result in the most cost effective and well performing plantation.

It should be recognized that non-crop vegetation at non-deleterious levels can provide benefits including: shade on south aspect sites, nutrient recycling, nitrogen fixation (e.g., red alder), improving the long term productivity of the site, providing some protection from browsing animals (e.g., deer) and reducing damaging forest health agents.

The practices stated above can serve to reduce the negative effect of competitive species and provide opportunities to optimize seedling growth over a given set of site conditions. If this can be achieved then the growing potential of the site will be captured, and the risks associated with achieving free growing are minimized and ultimately a positive effect on timber supply will be realized.

3.9.3 Fertilization
Fertilization is a silvicultural treatment that can be effectively used to increase the merchantable timber volume and value in established stands in a manner that mitigates falls in mid-term timber supply. By increasing harvest volume and accelerating stand operability fertilization can best be considered as a tool to reduce rotation length and mid-term timber supply shortfalls. At the forest level it can accelerate the development of specific structural age classes and timber types
for timber supply purposes. Since every tree to be harvested in the next 10 to 50 years is currently in the ground and growing, fertilization is considered one of the best investment options to improve growth in the short and mid-term. The increase in mid-term timber supply through fertilization supports the transition from harvest of old growth to the harvest of second growth. Fertilization facilitates a more even supply of timber and helps to mitigate “pinch points” in mid-term timber supply. Management unit silviculture strategies can be used for identifying these “pinch points” thereby helping to focus fertilization application to areas where returns are greatest. An alternative objective is the rehabilitation of disturbed sites.

![Photo 11: Active fertilization operation on the coast. The helicopter bucket is being reloaded with fertilizer pellets for application.](image)

Fertilization as an investment is typically best applied to older immature stands within 10-15 years of planned harvest. The magnitude of fertilizer response is related to the space available for crown expansion and crown vigour. For the coast, older immature Douglas-fir (Fdc) dominated stands with site indices of between 24 and 36 along with often younger western red cedar (Cw) dominated stands on sites with site indices between 17 and 32 are targeted for fertilization.

Currently both Fdc and Cw dominated stands are typically fertilized with urea at an application rate of 435 kg per ha which is equivalent to 220 kg of nitrogen per ha. Fertilization response from this treatment is estimated to be 30 m$^3$ per ha of additional volume 7 to 10 years after the original application for Fdc dominated stands. A similar response is expected for Cw dominated stands, although some results have shown a higher response for both western hemlock (Hw) and Cw on the Hemlock / Amabilis (HA) site phase types on northern Vancouver Island. Currently the application of the Salal Cedar Hemlock Integrated Research Program (SCHIRP) fertilizer blend (i.e., 225 kg per ha urea combined with 100 kg per ha of triple super phosphate) is not applied on non salal phase sites as Cw is seen to be less dependent on phosphorus than western hemlock (Hw). The nitrogen only application to mixed Cw/ Hw stands will hopefully preferentially benefit the Cw.
With the exceptions of fertilization at the time of planting, and on cedar salal sites, stands targeted for fertilization should be at a minimum free growing (20 years) and 2 metres taller than competing shrub layer, although late rotation fertilization (e.g., 10-15 years prior to rotation) is preferred for economic reasons. This is to ensure that tree foliage can expand without being impacted by the shrub layer. Stands should have well-spaced dominant and co-dominant trees with live crowns at least 30% and a height to diameter at breast height ratio of less than 100 (ideally 85). Stands that have been spaced, pruned, and/or have favourable spatial distribution make ideal candidates. Generally late rotation fertilization provides the most positive return on investment and increases near term timber supply.

Slow release fertilizer can be added at the time of planting (teabags) near or in the planting hole where:

- Growth of seedlings is inhibited by inadequate nutrients available
- Rapid growth is required to reduce competition with other vegetation
- Rapid early growth is desired to meet forest level objectives such as green-up for adjacency

Fertilization is an effective tool for managing establishment and survival at planting and to increase growth rates in maturing stands closer to planned harvest dates. As such, it has implications to timber supply which should be clearly articulated when prescribing treatments.

### 3.10 Climate Change

In today’s forest resource management paradigm it is important to consider climate change. While there is uncertainty in modelling the impacts of climate change, attention should be given to managing for diverse and resilient landscapes, watersheds and stands. When deliberating on silviculture options through a climate change lens, some items the forest professional should reflect on are:

- Consider mosaics of different leading species across the landscape to facilitate salvage, provide fire breaks, and slow/prevent pest epidemics.
- When planting manage for more than one compatible species. Consider novel mixtures at the stand and watershed level for short conifer rotations.
- Consider short rotations of broadleaf species.
- Understand what species and seed sources are projected to adapt well to climate change by site series.
- Deploy seedlots to fully utilize the flexibility and opportunities provided by the provincial climate based seed transfer guidelines.
- Expect the unexpected in terms of forest health issues that place risks on timber supply.

---

20 The underline emphasis equates to reduced risk
Prior to reducing stand stocking levels on the coast a detailed forest health and climate change risk assessment should be performed. Be observant, review your plantation surveys and mid-rotation second growth stands with a lens to climate change (+, -).

Remember that the climate is changing and this will affect forest ecosystems. Adapt management practices over time by sharing successes within and beyond your professional community of practice. Despite the uncertainty, when forest practices successfully mitigate climate change they can support AAC.

4 CONCLUSION/RECOMMENDATIONS

There are strong linkages between silviculture practices, information collected and reported to RESULTS and timber supply analysis. Forest professionals must understand the silvicultural factors that influence timber supply and the role they have in affecting these elements through prescribing treatments, collecting data and reporting accurately to RESULTS.

There are many complex and dynamic elements at play when considering silviculture in relation to timber supply. Key silviculture factors that affect timber supply are: species composition, density, site index, regeneration method and stem distribution, regeneration delay, operational adjustment factors and genetic worth by seedlot. Silviculture surveyors and forest professionals directly impact timber supply analysis when they make management decisions in regards to silviculture factors such as:

- Reflecting the most probable crop tree in the silviculture label species composition
- Determining how stand level retention data is collected and reported as forest cover
- Prescribing regeneration methods, species composition and genetic worth
- Improving accuracy of information used for plantation performance monitoring by implementing techniques such as Y2BH measurement methodologies
- Deciding on regeneration delay timelines

In addition, prescribing silviculture treatments such as density management, competition management and fertilization influences timber supply. Risk and opportunities related to climate change must also be considered by the forest professional. In order to manage the timber resource value over time, professionals must have a grounded understanding of how these factors and treatments can influence timber supply and their role in influencing these silviculture components over time. Inherent to this discussion is an appreciation of the complexity of these interrelationships and acceptance that knowledge will grow with time and practice.

Currently there is momentum in the province to increase understanding among professionals in regards to the linkages between silviculture and timber supply analysis. The Forest Analysis and Inventory Branch (FAIB) and the Resource Practices Branch (RPB)21, are working to develop a

---

21 Led by Hubert Burger and Dan Turner
common, transparent, defensible method to extract and use RESULTS data as inputs to TASS/TIPSY for developing yield curves used in timber supply analysis. The success of initiatives such as this hinge on forest professionals understanding the relationships between information collected in the field, data summarization and reporting, and ultimately the estimate of timber yield and future timber supply. The underlying theme: *is that timber supply analysis is directly linked to silvicultural practices.*

*What does this mean for professionals?* With respect to timber supply, foresters have an important role to play in advancing the achievements and benefits of silviculture.

In conclusion, the recommendations forest professionals can take from this discussion paper are:

1. Stand level information gathered in the field for silviculture milestone reporting has the potential to influence future timber supply modelling, thus survey practitioners and forest professionals should have an understanding of how collected information is used for timber supply analysis.
2. Current silviculture practices, new information and uncertainties (i.e. climate change) further influence the relationship between stand level information and timber supply analysis. Survey practitioners and forest professionals are encouraged to have a sound understanding of these causal relationships.
3. Timber supply has many drivers that are related to silviculture. Most often silviculture inputs to timber supply are based on assumptions that can be augmented with real data (e.g., OAF, Y2BH). With minimal to no additional costs or added complexity, an opportunity exists to replace these assumptions with real knowledge and therefore provide an improved estimate to timber supply.
4. Silviculture surveyor training and the Silviculture Survey Procedures Manual should be updated to reference how survey information is utilised in timber supply analysis.
5. Forest professionals should become engaged in the discussion of how best to measure and roll up their positive work in a manner that can reliably inform timber supply while keeping in mind that there is strength in a common approach.
6. Expertise and knowledge of timber supply should be shared with other professionals at workshops, forums, and within a community of practice to ensure the value of the timber resource is maintained over time despite the ever increasing pressures on timber supply.
### APPENDIX 1

**Table 3. Landbase Area Netdown Summary**

<table>
<thead>
<tr>
<th>Land Base Element</th>
<th>Total Area (ha)</th>
<th>Effective Area (ha)</th>
<th>% Total</th>
<th>% PFLB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total area (Mid Coast TSA Bdy – less ocean)</strong></td>
<td>3,012,310</td>
<td>3,012,310</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private Land, Indian Reserves</td>
<td>14,276</td>
<td>14,276</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TFL’s, CFA’s, Woodlots, Misc Leases, Etc</td>
<td>270,786</td>
<td>270,786</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timber License’s (unreverted)</td>
<td>7,767</td>
<td>7,767</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total TSA Area</strong></td>
<td>2,719,481</td>
<td>2,719,481</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>Non forest / Non-productive forest</td>
<td>1,691,972</td>
<td>1,691,972</td>
<td>62.2%</td>
<td></td>
</tr>
<tr>
<td>Non-Commercial Brush</td>
<td>481</td>
<td>481</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
<td>Existing Roads, Trails and Landings</td>
<td>3721</td>
<td>3,520</td>
<td>1.1%</td>
<td></td>
</tr>
<tr>
<td><strong>Total Productive Forest Land Base (PFLB)</strong></td>
<td>1,023,508</td>
<td>1,023,508</td>
<td>37.6%</td>
<td>100%</td>
</tr>
<tr>
<td>Less:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parks and Ecological Reserves</td>
<td>490,122</td>
<td>490,122</td>
<td>18.0%</td>
<td>47.0%</td>
</tr>
<tr>
<td>Inoperable/Inaccessible</td>
<td>865,883</td>
<td>353,227</td>
<td>13.0%</td>
<td>34.5%</td>
</tr>
<tr>
<td>Environmentally Sensitive Areas (ESA’s)</td>
<td>263,675</td>
<td>7,906</td>
<td>0.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Non-Merchantable or Problem Forest Types</td>
<td>197,679</td>
<td>36</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Low Productivity Sites</td>
<td>178,222</td>
<td>18,060</td>
<td>0.7%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Grizzly Wildlife Habitat Areas (WHA’s)</td>
<td>13,659</td>
<td>3,902</td>
<td>0.1%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Mountain Goat Winter Range</td>
<td>32,558</td>
<td>163</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>FRPA Riparian (not including S6’s)</td>
<td>17,423</td>
<td>6,340</td>
<td>0.2%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Recreation Values</td>
<td>10,586</td>
<td>3,376</td>
<td>0.1%</td>
<td>0.3%</td>
</tr>
<tr>
<td>EBM – High Valve Fish Habitat (Obj 9)</td>
<td>5,784</td>
<td>1,629</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td>EBM – Non High Value Aquatic Habitat (Obj 10)</td>
<td>6,625</td>
<td>2,083</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td>EBM – Active Fluvial Units (Obj13)</td>
<td>5,693</td>
<td>1,163</td>
<td>0.0%</td>
<td>0.1%</td>
</tr>
<tr>
<td>EBM – Sensitive Grizzly Bear Habitat (Obj 17)</td>
<td>3,957</td>
<td>157</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Spatial Timber Harvesting Land Base (ha)</strong></td>
<td>135,293</td>
<td>5.0%</td>
<td>13.2%</td>
<td></td>
</tr>
<tr>
<td>Non Spatial Netdowns Applied to Each THLB Polygon:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FRPA Riparian – S6’s (0.3%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EBM – Arch/FN (Obj 4-7 = 1.3%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EBM – Red and Blue (Obj 15 – 3.0%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EBM – Stand Level Retention (Obj 16 – 3.3%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Effective Timber Harvesting Land Base (ha)</strong></td>
<td>124,605</td>
<td>4.6%</td>
<td>12.2%</td>
<td></td>
</tr>
<tr>
<td>Future Reductions:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Future roads, trails and landings</td>
<td>2,713</td>
<td>0.1%</td>
<td>0.3%</td>
<td></td>
</tr>
<tr>
<td>Future Gains:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TL Reversions</td>
<td>7,767</td>
<td>0.3%</td>
<td>0.6%</td>
<td></td>
</tr>
<tr>
<td><strong>Long Term Timber Harvesting Land Base (ha)</strong></td>
<td>129,669</td>
<td>4.8%</td>
<td>12.7%</td>
<td></td>
</tr>
</tbody>
</table>

* Effective netdown area represents the area that was actually removed as a result of a given factor. Removals are applied in the order shown above. Thus areas removed lower on the list do not contain areas that overlap with factors that occur higher on the list. For example, the parks netdown does not include any non forested area.

** Productive forest in this context denotes the forest area that contributes to forest management objectives, such as landscape-level biodiversity, wildlife habitat and visual quality. It does not include alpine forest or Non productive areas with tree species.
APPENDIX 2

BACKGROUND INFORMATION

CLOVERPOINT Report – FLNR Provincial Site Productivity Layer PEM/TEM-SIBEC and Biophysical Analysis

CRIT Silviculture Working Group (CRIT SWG) messaging with respect to reporting of forest cover data into RESULTS (November 2008)
http://www.for.gov.bc.ca/rco/stewardship/CRIT/docs/RESULTS%20Retention%20Reporting%20Memo.pdf

Growth and Yield Prediction Systems Special Report Series 7
https://www.for.gov.bc.ca/hfd/pubs/docs/srs/Srs07.pdf

Ministry of Forests and Range Glossary of Forestry Terms in British Columbia (March 2008)

Provincial Site Productivity Layer Website
https://www.for.gov.bc.ca/hts/siteprod/provlayer.html

RESULTS Submission Specifications for licensees (2016)
https://www.for.gov.bc.ca/his/results/RISS__ls__4__ed__Mar%202016%20final.pdf

RESULTS Treed Retention reporting for reserves and un-harvested stems (standing waste)
https://www.for.gov.bc.ca/his/results/Forest_Cover_Retention_Submissions_May%202016%20final.pdf

Single Entry Dispersed Retention Stocking Standard Framework Implementation Guide (SEDRSS)

Silviculture Survey Procedures Manual

Spatially Explicit Genetic Gain Estimates in Operationally Applied Timber Supply Analyses
Timber Supply Sensitivity to Silvicultural Assumptions

Presented To: TimberWest Forest Company

Dated: May 2017
Ecora File No.: KE-11-054-TWF
THIS PAGE IS INTENTIONALLY LEFT BLANK
Presented To:

TimberWest Forest Corp.
4475 North Island Highway
Campbell River, BC V9W 5C5

Prepared by:

Jerry Miehm, RPF
Senior Resource Analyst
jerry.miehm@ecora.ca

4 May 2017

Version Control and Revision History

| Version | Date       | Prepared By | Reviewed By | Notes/Revisions |
|---------|------------|-------------|-------------|-----------------|-----------------|
| A       | 4 May 2017 | Miehm       |             |                 |                 |
Table of Contents

1. Background .................................................................................................................. 1
   1.1 Geographic Location ............................................................................................... 1
   1.2 Age Class Distribution ............................................................................................ 2

2. Yield Curve Construction ......................................................................................... 3
   2.1 Species Composition ............................................................................................... 3
   2.2 Regeneration Delay / YTBH ................................................................................... 4
   2.3 Operational Adjustment Factors ............................................................................ 5
   2.4 Genetic Gain ........................................................................................................... 5

3. Forest Estate Modeling ............................................................................................... 6

4. Results ......................................................................................................................... 6

List of Tables in Text
Table 2.1 Analysis Unit Species Composition .................................................................. 4
Table 2.2 Analysis Unit Establishment and Early Growth .................................................. 5
Table 2.3 Genetic Gain Assumptions ............................................................................... 5
Table 4.1 Sensitivity Analysis Harvest Levels .................................................................. 6

List of Figures in Text
Figure 1.1 EBM Area of TFL 47 .................................................................................... 2
Figure 1.2 Age Class Distribution of the EBM Area ....................................................... 3
Figure 4.1 Silviculture Scenario Harvest Levels ............................................................. 7
Figure 4.2 Silviculture Scenario Harvest Levels - % of Base Case ................................ 7

Appendices
Appendix A Complete List of Forest Estate Model Runs
# Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>AU</th>
<th>Analysis Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEC</td>
<td>Biogeoclimatic Ecosystem Classification</td>
</tr>
<tr>
<td>BH</td>
<td>Breast Height</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>OAF</td>
<td>Operational Adjustment Factor</td>
</tr>
<tr>
<td>MP</td>
<td>Management Plan</td>
</tr>
<tr>
<td>TFL</td>
<td>Tree Farm Licence</td>
</tr>
<tr>
<td>YTBH</td>
<td>Years to Breast Height</td>
</tr>
</tbody>
</table>
1. Background

TimberWest needs to better understand the timber supply impacts of different silvicultural strategies and assumptions. In particular, regenerating stands are subject to manipulation in the following ways:

a. Regeneration delay can be reduced by planting immediately after harvesting;

b. Years-to-breast-height can be reduced by applying fertilizer and reducing competing brush.

c. The use of genetically improved stock results in increased tree height and volume growth

d. Improved planting practice (and quality assurance), along with field measurements of the extent to which a regenerating stand ‘fully’ occupies a site could provide justification for using operational adjustment factors lower than the default 15% (for OAF1) generally used in timber supply analysis.

These interventions – individually and in combination – can significantly increase the timber volume at the stand level. Forest estate model (Patchworks) runs have been completed in an effort to quantify the amount of additional timber that could be harvested annually based on these interventions (or assumptions).

1.1 Geographic Location

The forest estate modelling data sets that were assembled in support of the last Management Plan (MP #4 in 2012) provide a foundation for this analysis. For simplicity, only the portions of TFL 47 that fall within the EBM area have been used for this study. Figure 1.1 shows the full extent of the TFL, and the part within the EBM area.

Eliminating the Bonanza Lake and Quadra Island portions of the TFL for this analysis reduces the number of yield curves required for the analysis.

\[1\] the area subject to Ecosystem-Based Management (EBM) under the authority of the South Central Coast Order: https://www.for.gov.bc.ca/tasb/slrpfrmp/nanaimo/central_north_coast/legaldocs/orders/2007/2007_SCC_Order/south_central_coast_order_corrected_8november2007.pdf
Figure 1.1  EBM Area of TFL 47

1.2 Age Class Distribution

The age class distribution for the study area is shown in Figure 1.2. For the purpose of this analysis, it was considered important to have a reasonably well-balanced age class distribution. An unbalanced age class distribution with an excess of immature stands (with the corresponding short-term timber supply impacts) would have had the potential to either mask or exaggerate the timber supply impacts of the silviculture issues under consideration. By starting with a balanced age class distribution, the highest even-flow harvest level can be found for each of the scenarios. An age class distribution that resulted in different short-, medium- and long-term harvest levels would have made the results more difficult to interpret. Under the even-flow scenario, harvest level differences can be attributed directly to changes in silvicultural assumptions.
2. Yield Curve Construction

The managed stand yield tables from the previous (MP #4) timber supply analysis have been used as the starting point for this project. Species and density were held constant, but the remaining input variables were adjusted to generate yield curves for each of the sensitivity analysis runs.

2.1 Species Composition

Managed stands are grouped into analysis units and a yield curve is compiled for each AU. Aggregation for managed stand yield tables is based on BEC zone/subzone/variant and site series, and genetic gain era. Table 2.1 shows the AU aggregation and regeneration assumptions. Each analysis unit has three lines in the table:

1) the planted component of the stand
2) the natural component of the stand; and
3) the proportion (by species) the each of the planted and natural component of the stand will contribute to the eventual volume harvested.

Existing and future managed stands have the same planting prescription applied, and similar assumptions have been made about the composition and amount of natural ingress. Each natural stands regenerates to one of these analysis units based on its BEC zone/subzone/variant and site series.
Table 2.1 Analysis Unit Species Composition

<table>
<thead>
<tr>
<th>BGC Zone</th>
<th>Site Series</th>
<th>Plant / Natural</th>
<th>Species Density (stems / ha)</th>
<th>Total Density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td>H</td>
</tr>
<tr>
<td>CWHvm2</td>
<td>All</td>
<td>P T/ha</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N T/ha</td>
<td>0</td>
<td>1700</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crop %</td>
<td>0</td>
<td>44</td>
</tr>
<tr>
<td>CWHxm</td>
<td>1</td>
<td>P T/ha</td>
<td>840</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N T/ha</td>
<td>0</td>
<td>2200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crop %</td>
<td>62</td>
<td>29</td>
</tr>
<tr>
<td>CWHxm</td>
<td>03,02</td>
<td>P T/ha</td>
<td>900</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N T/ha</td>
<td>0</td>
<td>2300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crop %</td>
<td>53</td>
<td>27</td>
</tr>
<tr>
<td>CWHxm</td>
<td>05,04</td>
<td>P T/ha</td>
<td>800</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N T/ha</td>
<td>0</td>
<td>1600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crop %</td>
<td>67</td>
<td>19</td>
</tr>
<tr>
<td>CWHxm</td>
<td>6</td>
<td>P T/ha</td>
<td>500</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N T/ha</td>
<td>0</td>
<td>2590</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crop %</td>
<td>32</td>
<td>41</td>
</tr>
<tr>
<td>CWHxm</td>
<td>07,08</td>
<td>P T/ha</td>
<td>500</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N T/ha</td>
<td>0</td>
<td>1900</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crop %</td>
<td>48</td>
<td>26</td>
</tr>
<tr>
<td>CWHxm</td>
<td>12,14</td>
<td>P T/ha</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N T/ha</td>
<td>0</td>
<td>1700</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crop %</td>
<td>6</td>
<td>47</td>
</tr>
</tbody>
</table>

2.2 Regeneration Delay / YTBH

For modelling purposes, regeneration delay and years-to-breast-height have been dealt with in concert. Both are accomplished by shifting each yield curve to the left (advanced growth) or right (delayed growth) along the x-axis. Table 2.2 shows the regeneration and early growth assumption that were used in the MP#4 base case. For this analysis, all analysis units have been assumed to reach breast height at a stand age of four (4) years.
Table 2.2 Analysis Unit Establishment and Early Growth

<table>
<thead>
<tr>
<th>Analysis Unit</th>
<th>Regen Delay (years)</th>
<th>Years to BH</th>
<th>Total (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J-CWHvm2-01</td>
<td>2</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>J-CWHxm-01</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>J-CWHxm-03</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>J-CWHxm-05</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>J-CWHxm-06</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>J-CWHxm-07</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>J-CWHxm-12</td>
<td>2</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

2.3 Operational Adjustment Factors

OAF1 is used to represent reduced yield due to gaps in stocking; and OAF2 is used to represent decay and losses due to disease and pests when they are present in large magnitudes. OAF1 is a constant reduction factor that shifts the yield curve down whereas the influence of OAF2 increases with age and therefore alters the shape of the curve. For MP#4, an OAF1 of 15% and an OAF2 of 5% were used. Operational experience indicates that that OAF1 is significantly less than 15% in managed stands, and may in fact be below 10%. For this analysis, the impact of an OAF1 value of 10% has been tested.

2.4 Genetic Gain

For MP#4, improvements in growth due to the use of genetically improved seed were modeled during yield curve construction. Genetic gains were applied to any stands established after 1999. These are summarized in Table 2.3.

Table 2.3 Genetic Gain Assumptions

<table>
<thead>
<tr>
<th>Era</th>
<th>Fd</th>
<th>Cw</th>
<th>Ba</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 to 2004</td>
<td>8.0%</td>
<td>5.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2005 to 2009</td>
<td>6.3%</td>
<td>5.1%</td>
<td>0.9%</td>
</tr>
<tr>
<td>Future</td>
<td>11.3%</td>
<td>15.0%</td>
<td>0.7%</td>
</tr>
</tbody>
</table>

For this analysis, a genetic gain of 15% has been assumed for Douglas-fir and cedar. To simplify interpretation of the result, no genetic gains have been applied in the base case.
3. Forest Estate Modeling

Patchworks was the forest estate model used for MP#4, and it will be used for this analysis also. It is a spatially explicit harvest scheduling optimization model. More specifically, it is a multiple-objective goal-programming model that consists of two components:

1) A GIS interface with map viewer and viewer functions; and
2) A harvest scheduler that runs continuously in the background - searching for improvements in the allocation to improve the value of the objective function.

The planning horizon for this analysis is 200 years. Harvest blocks have been scheduled in forty 5-year periods.

Five modeling scenarios have been run:

3) A base case that assume pre-EBM management, but no genetic gain;
4) Assume that all managed stands reach breast height at four years;
5) Applied 15% genetic gain for Fd and Cw;
6) Reduce OAF 1 from 15% to 10%; and
7) Apply all of the foregoing improvements.

4. Results

Table 4.1 shows that change in harvest level that results from each of the sensitivity analysis runs. The harvest level varies from 413,000 m$^3$/year for the base case to 479,000 m$^3$/year when all silvicultural improvements are applied.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Average Annual Harvest Volume (m$^3$/year)</th>
<th>Harvest Percent of Base Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>413,012</td>
<td>100.0</td>
</tr>
<tr>
<td>4 Years to BH</td>
<td>429,505</td>
<td>104.0</td>
</tr>
<tr>
<td>15% GG Fd/Cw</td>
<td>439,727</td>
<td>106.5</td>
</tr>
<tr>
<td>OAF 1 10%</td>
<td>433,990</td>
<td>105.1</td>
</tr>
<tr>
<td>All Improvements</td>
<td>479,180</td>
<td>116.0</td>
</tr>
</tbody>
</table>
Figure 4.1 shows the annual harvest level that was found for each of the five scenarios (base case and four sensitivities). Figure 4.2 shows the harvest level for each scenario as a percent of the base case.
Appendix A

Complete List of Forest Estate Model Runs
<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td>Alternative Harvest Flow</td>
</tr>
<tr>
<td>S01</td>
<td>Future Stand Volume + 10%</td>
</tr>
<tr>
<td>S02</td>
<td>Future Stand Volume - 10%</td>
</tr>
<tr>
<td>S03</td>
<td>Managed Stand Yields Based on OAF1 of 13%</td>
</tr>
<tr>
<td>S05</td>
<td>TIPSY-Generated Years-to-Breast-Height</td>
</tr>
<tr>
<td>S06</td>
<td>Managed Stand Yields Based on SIBEC</td>
</tr>
<tr>
<td>S07</td>
<td>MHA Minus 10 Years</td>
</tr>
<tr>
<td>S08</td>
<td>MHA Plus 10 Years</td>
</tr>
<tr>
<td>S09</td>
<td>VQO Green-up Minus 1 Metre</td>
</tr>
<tr>
<td>S10</td>
<td>VQO Green-up Plus 1 Metre</td>
</tr>
<tr>
<td>S11</td>
<td>Lower Stump Height</td>
</tr>
<tr>
<td>S12</td>
<td>Immediate Old Seral Recruitment</td>
</tr>
<tr>
<td>S13</td>
<td>Alternative VDYP Phase 2 Adjustment</td>
</tr>
<tr>
<td>S21</td>
<td>Pre-EBM Scenario</td>
</tr>
<tr>
<td>S22</td>
<td>70% RONV</td>
</tr>
<tr>
<td>S23</td>
<td>70% Oldest Seral Recruitment</td>
</tr>
<tr>
<td>S41</td>
<td>EBM Area - Base Case Management</td>
</tr>
<tr>
<td>S42</td>
<td>EBM Area - Pre-EBM Management</td>
</tr>
<tr>
<td>S51</td>
<td>Bonanza Base Case</td>
</tr>
<tr>
<td>S52</td>
<td>Quadra Base Case</td>
</tr>
<tr>
<td>S53</td>
<td>Johnstone Base Case</td>
</tr>
<tr>
<td>S61</td>
<td>Oldest Seral Recruitment with SSG</td>
</tr>
<tr>
<td>S62</td>
<td>Oldest Seral Recruitment with SSG - EBM Area Only</td>
</tr>
<tr>
<td>S63</td>
<td>Base Case with SSG</td>
</tr>
<tr>
<td>S64</td>
<td>Base Case with SSG - EBM Area Only</td>
</tr>
<tr>
<td>S65</td>
<td>Immediate Old Seral Recruitment (SSS) - EBM Area Only</td>
</tr>
<tr>
<td>S66</td>
<td>Base Case with SSG (EBM) - 01/03 Alternate Grouping</td>
</tr>
<tr>
<td>S67</td>
<td>Base Case with SSG (EBM) - 01/03 Alternate Grouping - 2015 Targets</td>
</tr>
<tr>
<td>S71</td>
<td>Base Case 2012 w/ Goshawk Habitat</td>
</tr>
<tr>
<td>S72</td>
<td>Goshawk w/ 400m Nest and HSI Constraint</td>
</tr>
<tr>
<td>S73</td>
<td>Goshawk w/ 400m Nest and Forage Constraint</td>
</tr>
<tr>
<td>S74</td>
<td>Goshawk w/ 400m Nest Only</td>
</tr>
<tr>
<td>S75</td>
<td>Goshawk w/ 750m Nest and JS-Wide Forage Constraint</td>
</tr>
<tr>
<td>S81</td>
<td>Forsite EBM Model for Johnstone Strait</td>
</tr>
<tr>
<td>S82</td>
<td>Forsite EBM Model w/o Road and Patch Constraints</td>
</tr>
<tr>
<td>S83</td>
<td>S82 - Old Seral Enforced Final Period Only</td>
</tr>
<tr>
<td>S84</td>
<td>S82 w/ Adjusted Regen Delay and YTBH</td>
</tr>
<tr>
<td>S91</td>
<td>Thurlow Even-flow with SSG - 01/03 Grouping</td>
</tr>
<tr>
<td>S92</td>
<td>Thurlow Even-flow with Spatial Reserves</td>
</tr>
<tr>
<td>S93</td>
<td>EBM Area Pre-EBM</td>
</tr>
<tr>
<td>S94</td>
<td>YTBH is Four Years</td>
</tr>
<tr>
<td>S95</td>
<td>Genetic Gain 15% on Fd/Cw</td>
</tr>
<tr>
<td>S96</td>
<td>OAF1 10%</td>
</tr>
<tr>
<td>S97</td>
<td>S94+S95+S96</td>
</tr>
</tbody>
</table>