Williams Lake TSA – Type 4 Silviculture Strategy

Modelling and Analysis Report

Version 1.1

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Project 419-25

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1 Introduction

The purpose of this Type 4 Silviculture Strategy is to clarify the status quo management approach in light of the devastating timber supply impacts from the Mountain Pine Beetle (MPB) infestation and provide direction that might improve future outcomes. Ultimately, the project will provide – through a tactical plan –direction for investing in silviculture-related activities that address challenges for the Williams Lake TSA.

Underlying assumptions to this analysis are documented in the project's Data Package[1]. It identifies several key assumptions as sources of significant uncertainty (e.g., shelf-life, current live/dead volumes, secondary structure under attacked stands, MPB impacts in young stands).

1.1 Context

This document is the third of four documents that make up a Type 4 Silviculture Strategy:

- Situational Analysis – describes in general terms the situation for the unit – this could be in the form of a PowerPoint presentation with associated notes or a compendium document.
- Data Package - describes the information that is material to the analysis including the model used, data inputs and assumptions.
- **Modelling and Analysis Report – describes modelling outputs.**
- Silviculture Strategy – provides a rationale for choosing a preferred scenario and describes treatment options, associated targets, timeframes and benefits.

2 Base Case

The results presented in this section describe outcomes for three broad areas: 1) timber quantity or harvest forecast, 2) timber quality or product profile, and 3) non-timber value outcomes.

2.1 Timber Quantity

The following sections discuss the volume of timber harvested in the Base Case harvest forecast for the Williams Lake Type 4 Silviculture Strategy (WLT4).

2.1.1 Harvest Forecast

Key modelling assumptions for the WLT4 Base Case harvest forecast included:

- Focus on salvaging dead pine stands until the shelf-life for the degrading pine is exhausted,
- Maximize the mid-term harvest level.

Figure 1 shows the WLT4 Base Case harvest forecast resulting from the data, assumptions and modelling approaches documented in the Data Package. For the first 5 years, the harvest level was set to be consistent with recent harvesting (3.20M m^3/yr) and then it begins a sharp decline to 2.36M m^3/yr in years 6-10 and then to a mid-term trough at 1.76M m^3/yr until year 50. After this, the harvest level

[1] Forsite Consultants Ltd. (2013). Lakes TSA - Type IV Silviculture Strategy, Data Package. Technical Report.

rises in a series of steps to reach a long-term level of harvest level of approximately 3.57M m³/yr in year 120.

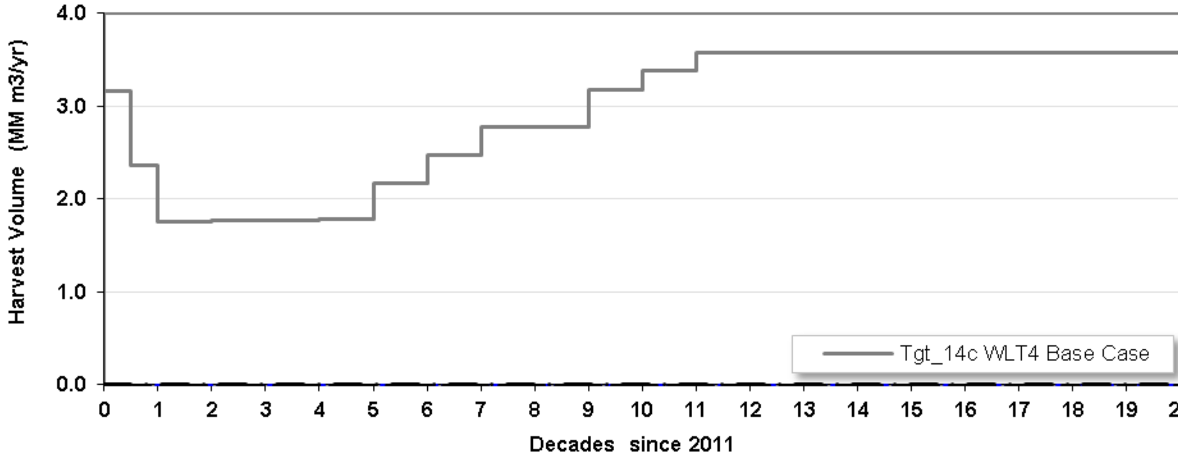


Figure 1 Harvest forecast (WLT4 Base Case)

2.1.2 Harvest Forecast Details

Figure 2 shows the proportion of the harvest comprised of pine (live and dead) in the first period is over 91%, falling to 30% and 14% in periods 2 and 3. Following the mid-term period (after the 5th decade), the proportion of pine harvest within each period ranges between 44% and 75%.

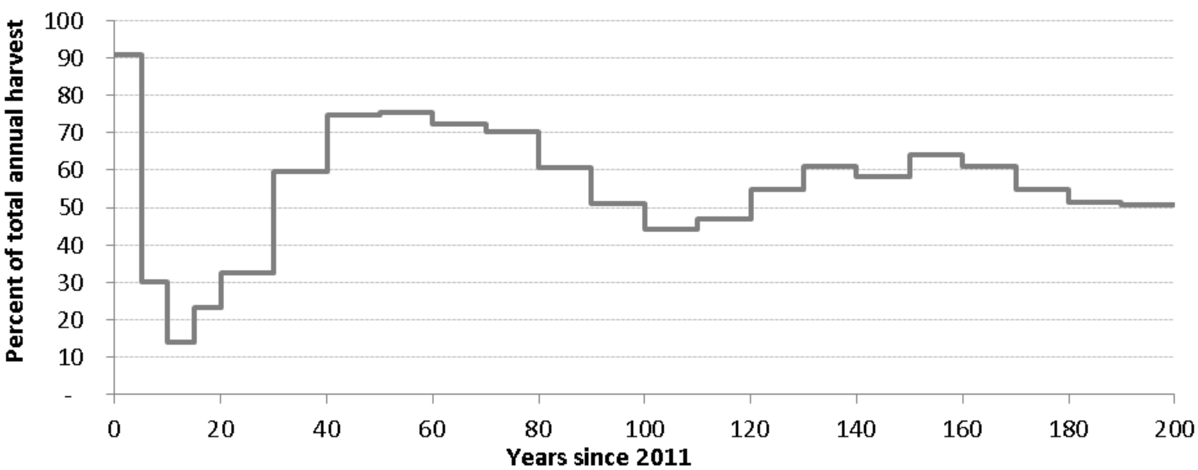


Figure 2 Proportion of the harvest comprised of pine (dead and live combined).

The amount of pine harvested throughout the salvage period (first 10 years) is significantly influenced by assumed shelf-life and minimum stand merchantability criteria. At the start of modelling many stands are either <u>too young to have reached merchantability</u>, or have lost so much dead pine volume from shelf life assumptions they <u>are no longer eligible for harvest</u> – even though they were eligible at their year-of-death. For example, lowering the minimum harvest criteria from 110 m³/ha to 80 m³/ha throughout the salvage period makes 11.4M m³ more pine volume available for harvest. This lower threshold for salvage opportunities is appropriate because these stands tend to be older with larger piece sizes for a given volume compared to younger regenerating stands.

Figure 3 shows that salvage (clearcutting) is predominant in the first and second periods but afterwards clearcut-with-reserves is the prevalent silviculture treatment type. Harvesting from shelterwood systems within the IDF is the second-most prominent treatment after period 3 while a very small component of the harvest is through group and single tree selection methods (Caribou or UWR).

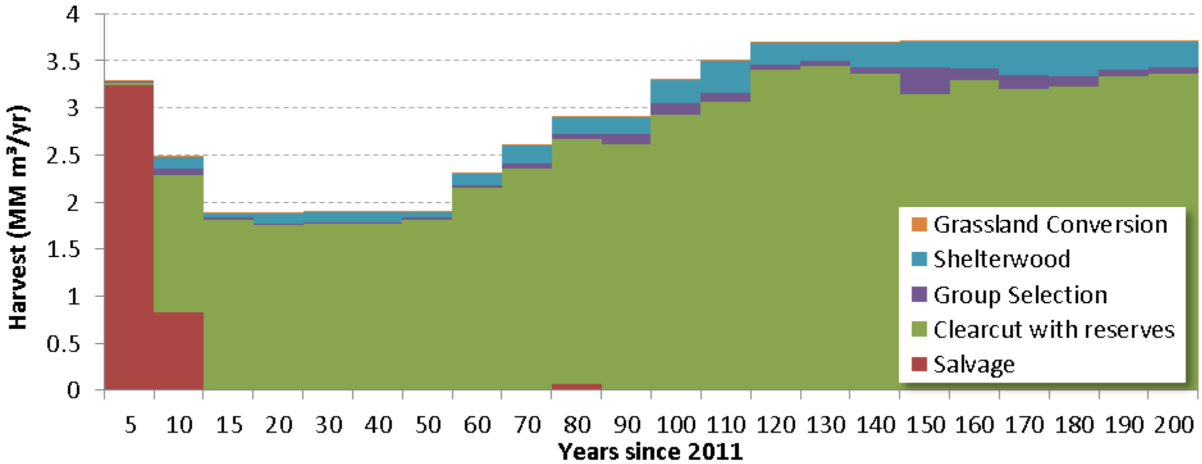


Figure 3 Harvest forecast by silviculture treatment type (WLT4 Base Case)

The transition from natural stands to managed stands (Figure 4) begins in years 16-20. By year 31, the majority of the harvest is from managed stands. Natural stands continue to be harvested into the longer term as natural regeneration becomes available from stands recovering from MPB impacts, stands associated with single tree selection systems, and components from group selection treatments.

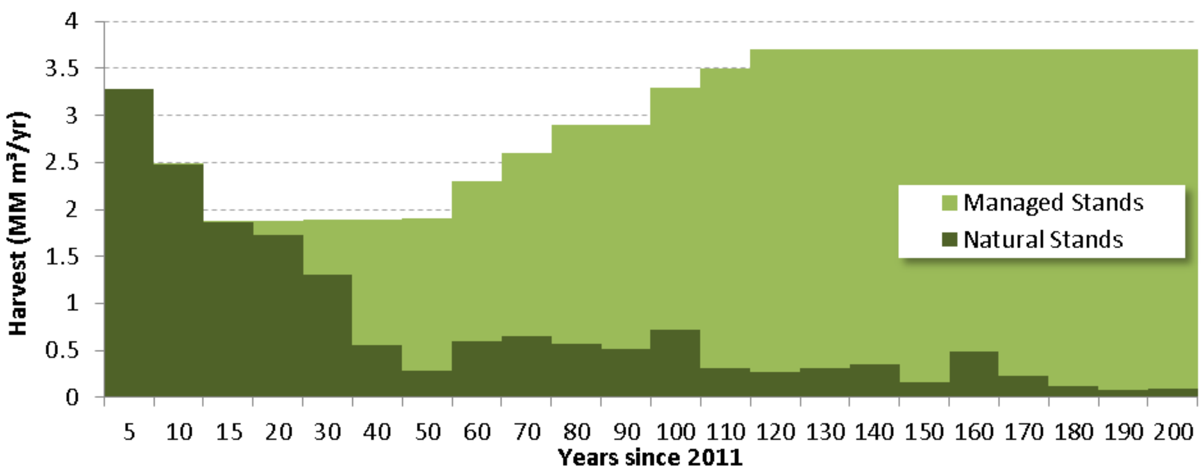


Figure 4 Harvest forecast transition of natural stands to managed stands (WLT4 Base Case)

Figure 5 shows the harvest volume from non-MPB impacted stands is less than 1% in the first 5 years while 99% of harvest comes from stands in MPB kill classes 00, 20, 40, 60, and 80 (≥60 yr old). In period 2, the harvest from MPB-impacted stands drops to 34%. Harvesting stands with lower levels of attack but still viable after all of the pine is lost help mid-term harvest levels. Following the mid-term, some of the heavily impacted, unsalvaged stands are later harvested once understory volumes regenerate enough to make the stand viable.

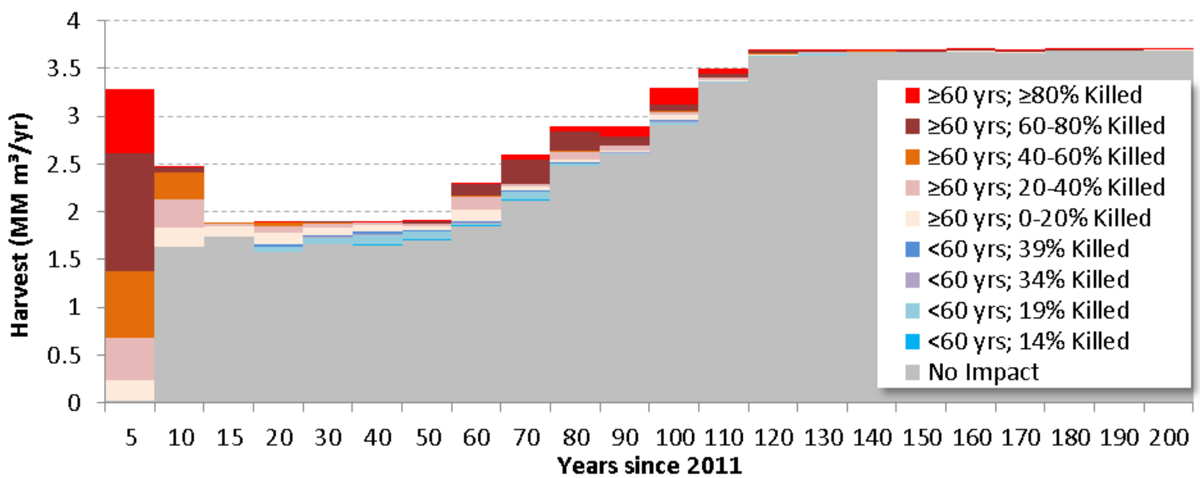


Figure 5 Harvest forecast by MPB kill class (WLT4 Base Case)

2.1.3 Growing Stock over Time

Total growing stock on the THLB (Figure 6) starts at 140.4M m^3 and falls to the lowest level of 94.6 M m^3 after 15 years as stands are harvested or adjusted to reflect shelf life assumptions. After the second decade, growing stock steadily increases as young, managed stands reach their highest mean annual growth. The growing stock begins to level-off after 100 years at just over 200 M m^3.

Figure 6 also shows that in 30-50 years, the TSA reaches a low point in available merchantable volume. This is a key timeframe for developing strategies that might improve timber supply. While total growing stock is lowest in year 10-30, the lowest level of merchantable growing stock is delayed because the large area of regenerating pine stands become merchantable again – delaying the recovery by 20 to 30 years.

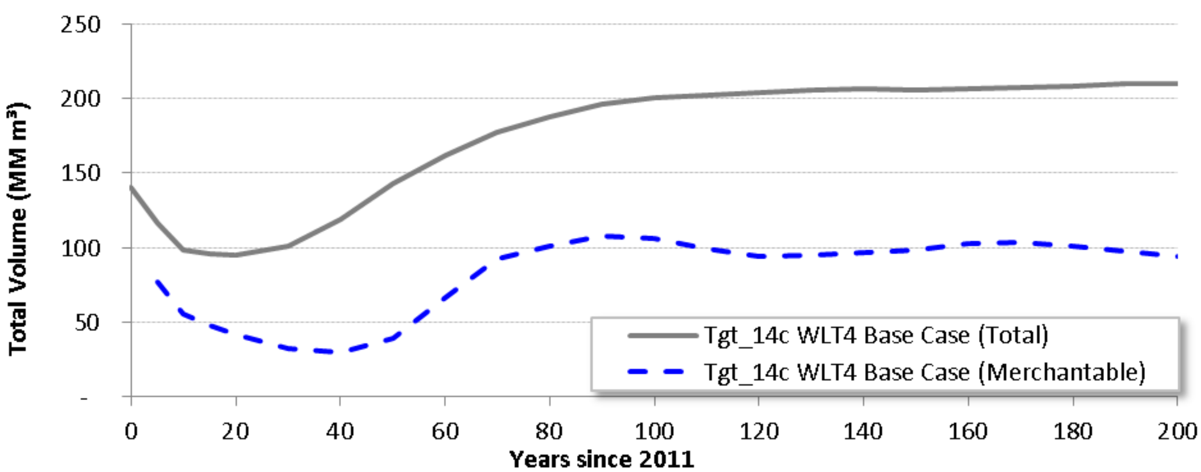


Figure 6 Total and merchantable growing stock volume (WLT4 Base Case)

As expected, age class distributions of the total growing stock (Figure 7) change significantly as most stands transition from natural to managed stands.

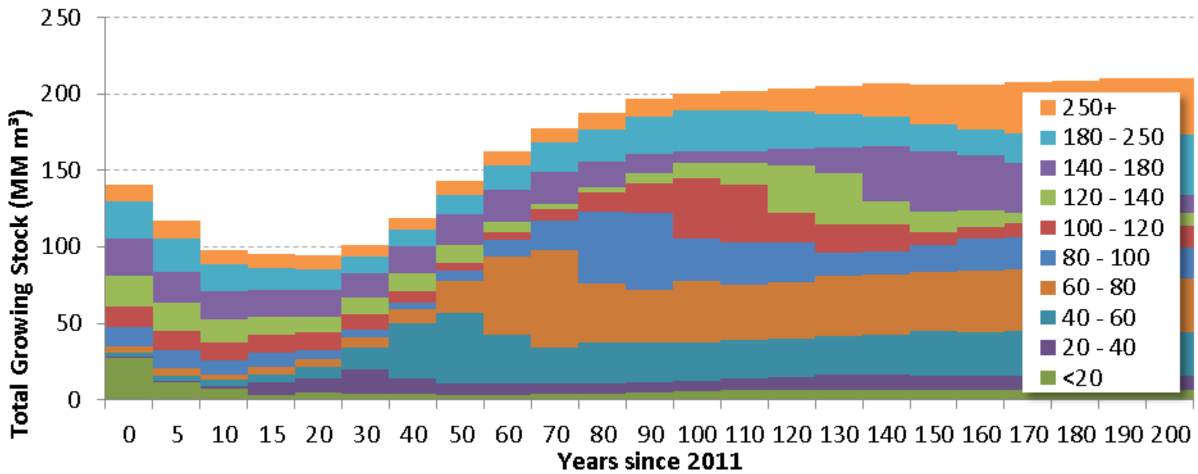


Figure 7 Total growing stock volume THLB by age class (WLT4 Base Case)

The proportion of older stands steadily increased following the mid-term trough. For example, the 250+ year old stands comprised 7.5 % of the growing stock at the start, and 34% at the end of the planning horizon. This occurred for a few reasons.

Firstly, at the start of modelling (year 2011) stands with ≥60% volume killed by MPB were adjusted with ages set to zero at year of death (YOD) in 2006. While most of these stands are still available for harvest, they start as 5-year old stands (stand age 0 in 2006 = age 5 in 2011).

Secondly, a proportion of the landbase was reserved from harvest for stand-level retention or to meet other non-timber resource objectives (e.g., mature-plus-old seral objectives). Still another portion of the THLB was reserved from harvest because it is deciduous leading and was not considered merchantable for harvest in the base case.

Finally, the group (GRP) and single tree selection (STS) treatment types tend to retain stands at older ages. The high ages in the GRP and STS stands, however, must be adjusted (downwards) somewhat as the “effective age” of these stands is lower than the oldest cohort in the stand, which is the stand age being tallied by the model. One artefact of the partial harvest treatment type is that the growing stock in these stands appears disproportionately high, compared to the harvest level. Figure 8 shows the proportions of growing stock in the STS, for example, are higher than the actual harvest from these treatment types (Group selection in Figure 3).

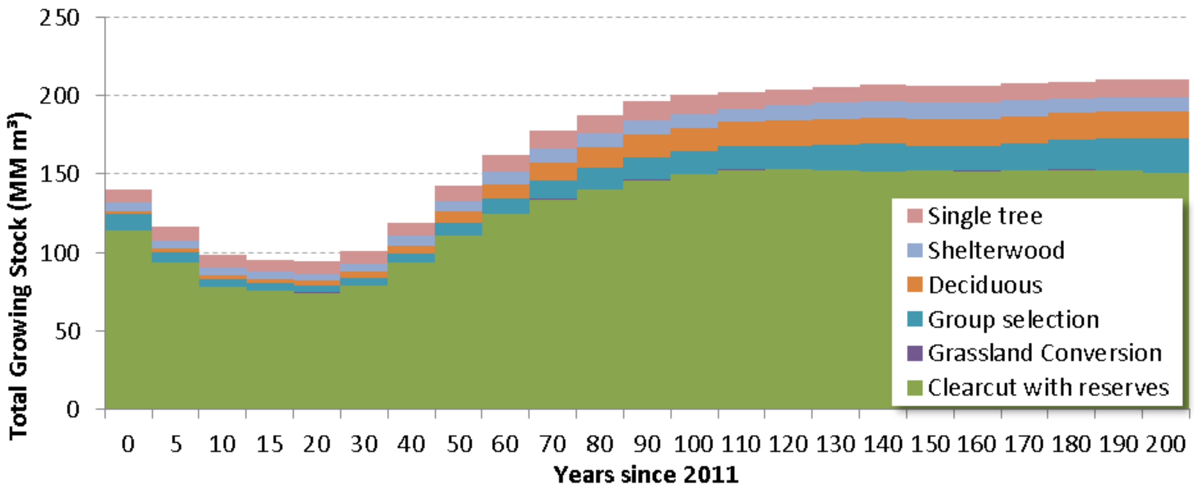


Figure 8 THLB growing stock by silviculture system (WLT4 Base Case)

Figure 9 depicts the growing stock on the THLB by leading species group, which was defined as the leading species of the stand at the start of modelling. Pine volumes decline rapidly in the first two periods but then recover. Deciduous volume continued to grow over time within natural stands that were not harvested. The deciduous growing stock is overestimated as these stands are more likely to transform into coniferous stands.

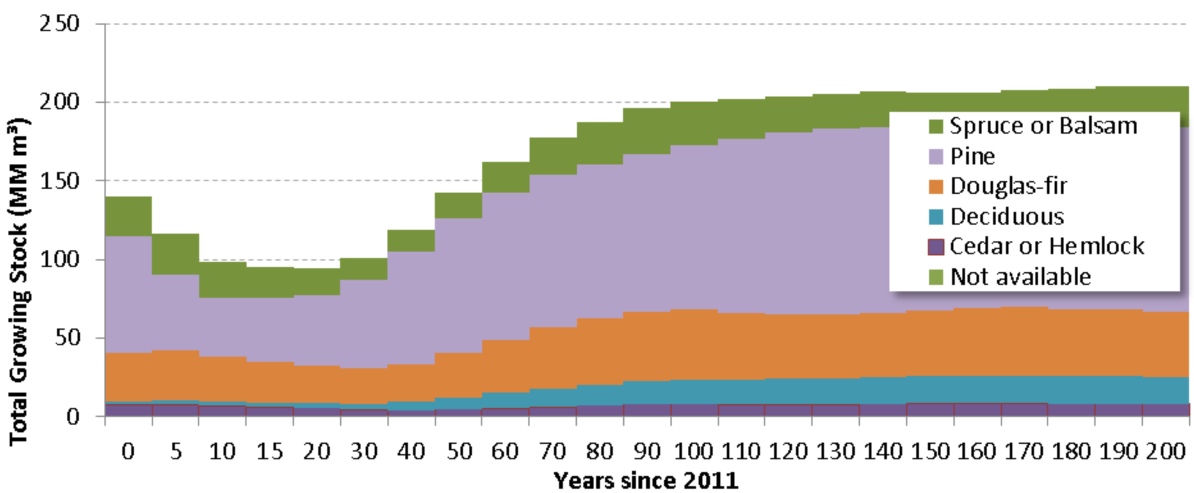


Figure 9 THLB total growing stock by species group at the end of the period (WLT4 Base Case)

2.2 Timber Quality

The following sections discuss aspects of timber quality associated with the WLT4 Base Case harvest forecast.

2.2.1 Average Harvest Volume, Area and Age

The minimum harvest age (MHA) was determined as the age when stands achieve the merchantable volumes shown in Table 1.

Table 1 Minimum harvest thresholds

	Clearcut (1)		Partial Cut (1)	
Stand Types	<= 40% Slope (ground)	> 40% Slope (cable)	<= 40% Slope (ground)	> 40% Slope (cable)
Pine-Leading (Salvage) (2)	80 m³/ha	200 m³/ha		
Pine-Leading	110 m³/ha	200 m³/ha	150 m³/ha	450 m³/ha
Non-Pine Leading	150 m³/ha	200 m³/ha	(50 m³/ha removal)	(200 m³/ha removal)
Deciduous Leading	100 m³/ha	200 m³/ha		

(1) Minimum merchantable volumes as standing stock. Volumes removed equal the total volume divided by number of passes.

(2) Lower thresholds were applied throughout the salvage period to reflect the larger trees present within decaying pine stands.

The average volume, area, and age harvested (Figure 10) highlights the changes in stands throughout the planning horizon. Both average stand age and harvest areas are high during the salvage period but as older natural stands are depleted they level out to approximately 70 years and 15,000 ha/yr, respectively. Average stand volumes in the short term are 100 m³/ha that rises abruptly once the salvage period is over, then eventually settles at approximately 225 m³/ha.

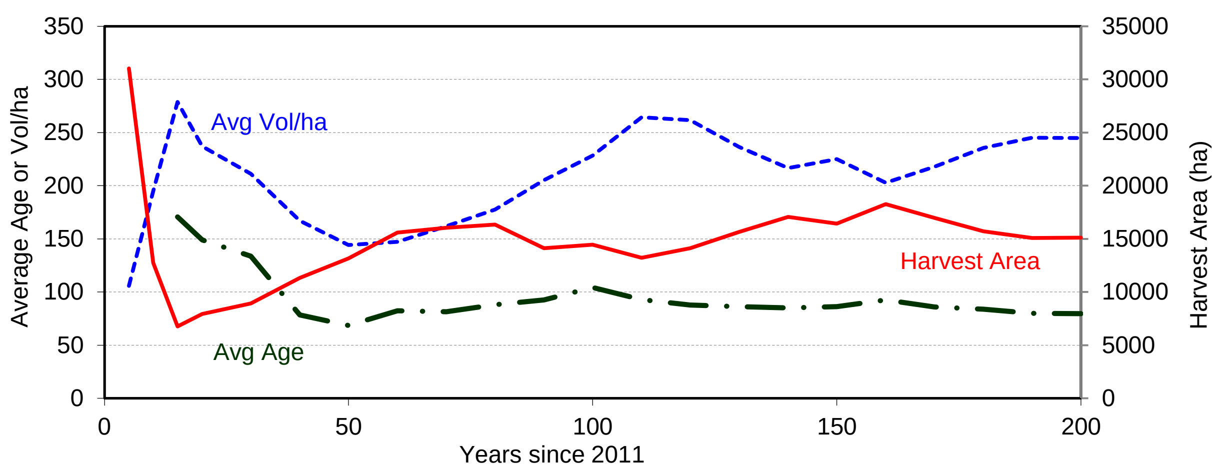


Figure 10 Average harvest volume, age and area (WLT4 Base Case)

Figure 11 shows that 58% of the volume in the first two periods came from the 0-40 age class (stands with ≥60% MPB kill had ages set to 0). After the salvage period, however, a small fraction of the harvest comes from stands with ages less than 40 years. In 30-50 years, the figure shows a very young age class profile is being harvested (most <70 years old).

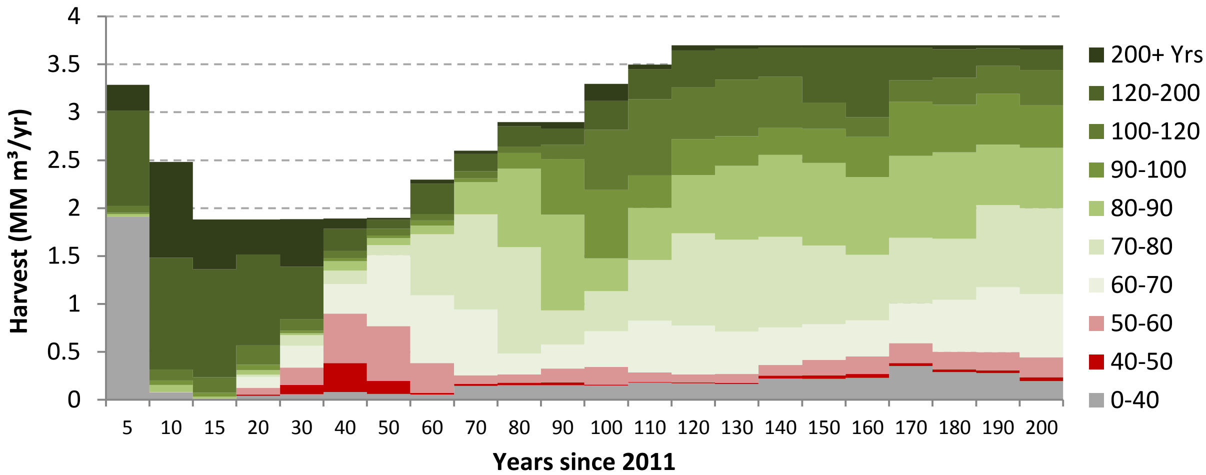


Figure 11 Harvest volume by age range

2.2.2 Product Profile

Stand merchantability assumptions (Table 1) significantly influence the harvest flow and ultimately, the product profile over time. With lower thresholds, the model is able to access younger stands during critical pinch points when merchantable growing stock is at its lowest point. Any improvement in timber supply comes at the expense of product profile (more small wood) now and into the future as stands are managed on shorter rotations. Figure 12 shows the product profile over time derived from a report of the harvest forecast by age class and species group.

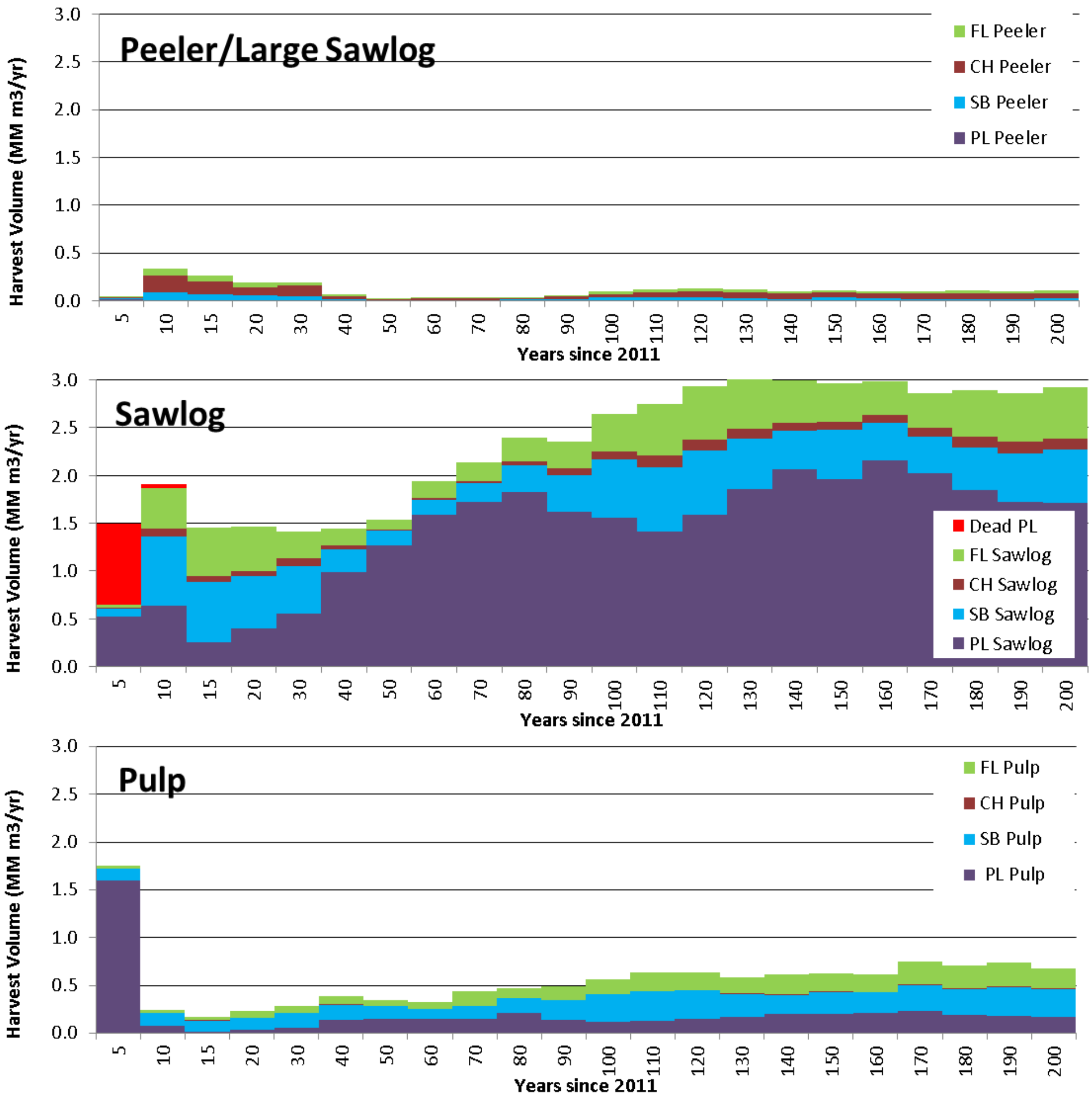


Figure 12 Product profile harvested over time (WLT4 Base Case)

The short-term harvest produces mostly dead and live pine sawlog/pulp logs while most of the mid-term and long-term harvest delivers pine sawlogs, as well as spruce/balsam sawlogs and Douglas-fir sawlogs. Figure 13 combines species to show general product types. The pulp percentage is expected to drop once salvage is complete but then return to current levels. During the period when natural stands make up the bulk of the harvest (years 0-30), approximately 10-15% of the harvest volume is from large sawlogs/peelers. Beyond this timeframe, when average harvest ages are generally less than 100 years old, only 1 to 3% of the harvest delivers large sawlogs (peelers).

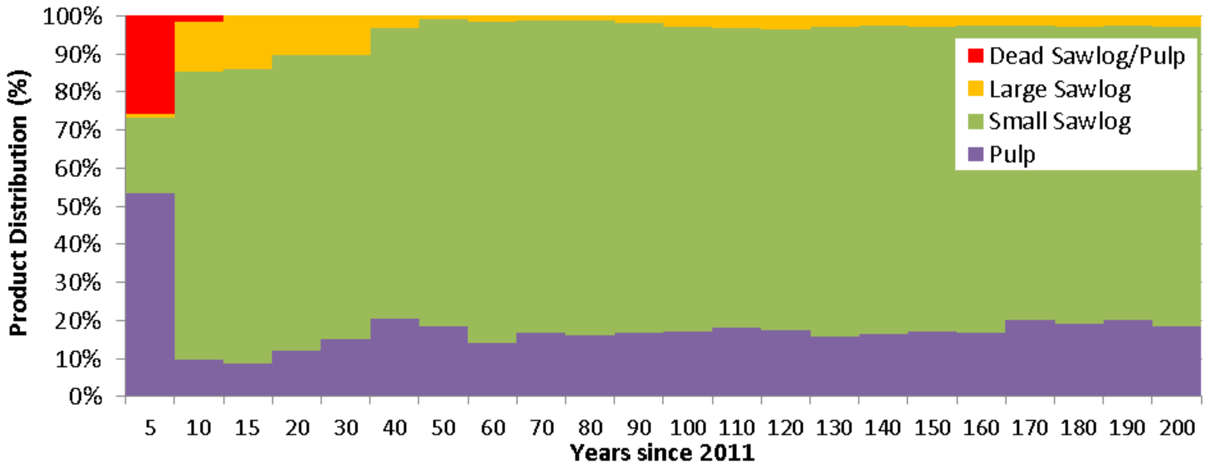


Figure 13 Product profile harvested over time (WLT4 Base Case)

2.3 Non-Timber Value Outcomes

The following sections describe results of the non-timber and environmental considerations incorporated in the model. Only a few examples are provided since the full detail of these considerations is very lengthy and cumbersome to report.

A key modelling assumption was to set >60% dead stands to an age of zero as of the year-of-death (YOD). While these revised ages are not entirely accurate, it would equally inaccurate to assume that these dead pine stands provide the same ecological function as live stands. As a result, a large area impacted by MPB is now identified within the 0-10 year age class causing the initial condition of many non-timber targets to appear as significantly beyond established thresholds.

2.3.1 Age Class over Time

Figure 14 shows the age class distributions for both the THLB and NHLB at 0, 50, 100, and 200 years. Because the ages of stands with ≥60% MPB mortality were initially set to 0 at the year of attack, a large area begins in the 0-10 year age class.

Over time, as the harvest area within the THLB becomes more regular, a portion of the THLB reaches a “normalized forest” condition with a fairly even distribution of area in the age classes from 0 to 70 years old in the clearcut stands. Some stands within the THLB become very old to meet non-timber resource objectives or as a result of reserving deciduous-leading stands. The latter would likely succeed to coniferous types over this period, and would be better modeled as NHLB (as per next paragraph).

The NHLB also becomes normalized as natural disturbance is regularly applied (~4100 ha/yr) and as stands age within the STS and GRP selection stands.

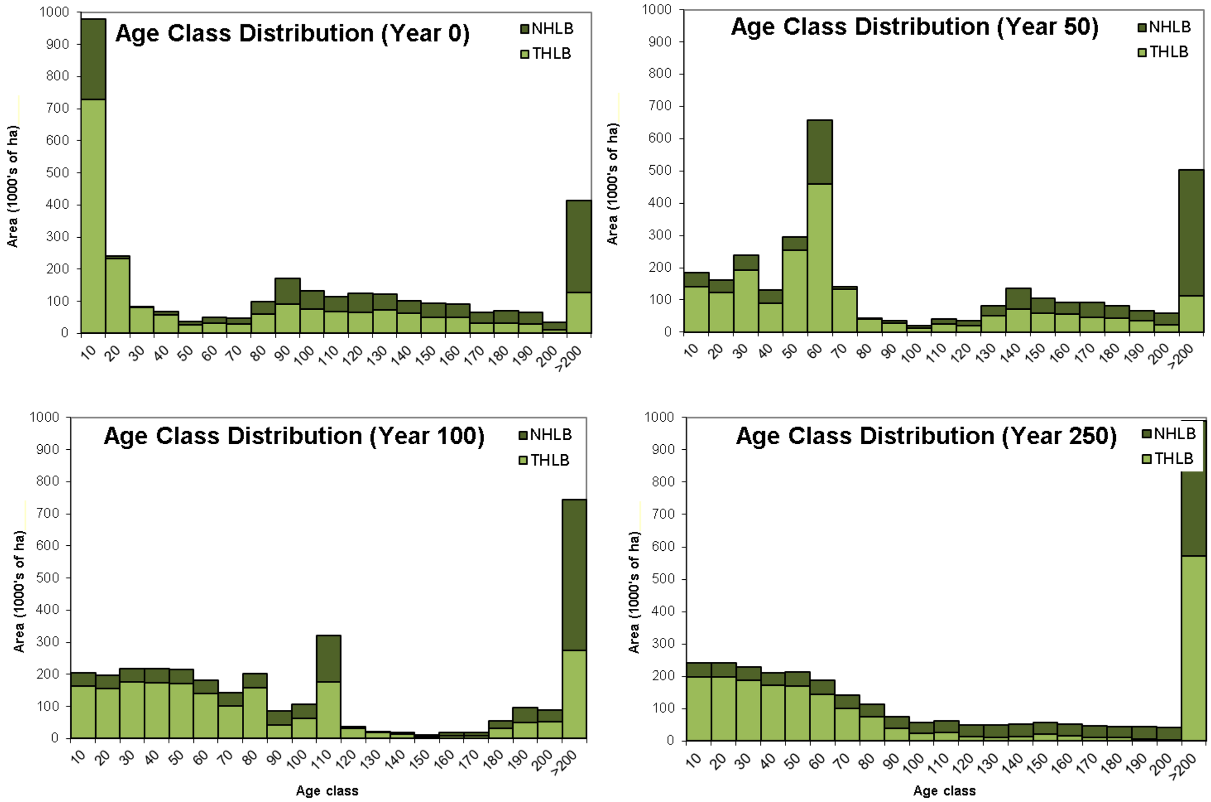


Figure 14 Age class distribution in THLB and NHLB at 0, 50, 100, and 250 years (WLT4 Base Case)

2.3.2 Landscape Level Biodiversity

Seral stage distribution targets were specified for the crown forested land base (CFLB) in combinations of BEC, landscape unit, NDT type, and biodiversity emphasis option. Figure 15 and Figure 16 show examples of seral stage targets and levels were applied.

The mature-plus-old seral target report for the Hawks Creek SBSmc1 NDT3 (Figure 15) are not met at the beginning of the planning horizon, but forest growth recovers to provide excess old seral levels that is subsequently drawn down to the minimum allowable percentage (23% - the top of the red shaded area).

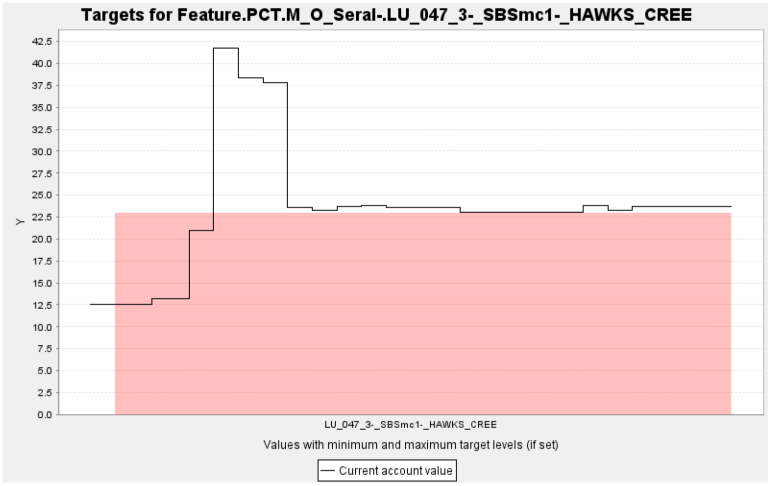


Figure 15 Examples of mature-plus-old seral cover targets and levels (WLT4 Base Case)

The target report for the Horsefly ESSFwk1 NDT1 example (Figure 16) are never exceeded, but are harvesting draws this account close to the target level (the top of the red shaded area).

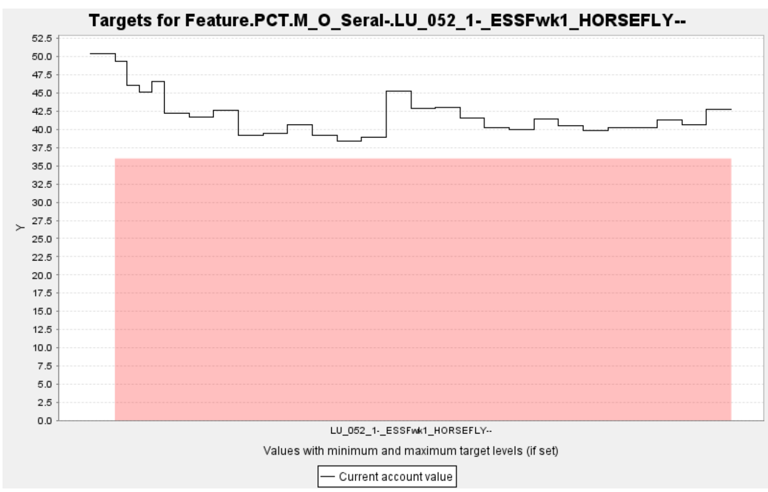


Figure 16 Examples of mature-plus-old seral cover targets and levels (WLT4 Base Case)

2.3.3 Lakeshore Management Zones

Separate forest cover requirements were modelled for lakeshore management zones (LMZ, classes B, C, D and E) in each landscape unit.

The target report for the Alakali LMZ class B (Figure 17) begins considerably over the target maximum disturbance level (the bottom of the blue shaded area). After 20 years the disturbance level percentage falls within the target range however this is later compromised again for two periods in the middle of the planning horizon. This may be due to: a) natural disturbance, which is applied randomly throughout the NHLB, or b) harvesting, which sometimes occurs when the model balances all its targets (i.e., the goal of reaching its target harvest level, versus staying within the target seral or non-veg targets).

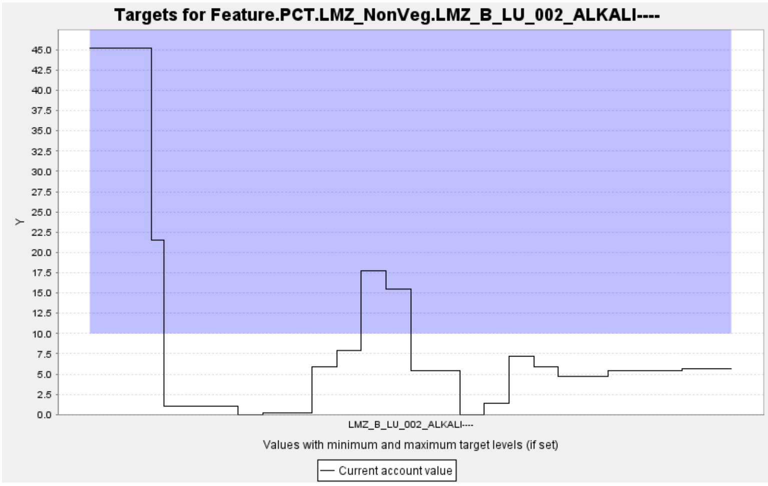


Figure 17 Examples of LMZ targets and levels (WLT4 Base Case)

The target report for the Anaham LMZ class C (Figure 18) also shows that the target is initially compromised (the bottom of the blue shaded area), but after 15 years the non-VEG[2] percentage reaches within the desired range, where it remains for the rest of the planning horizon.

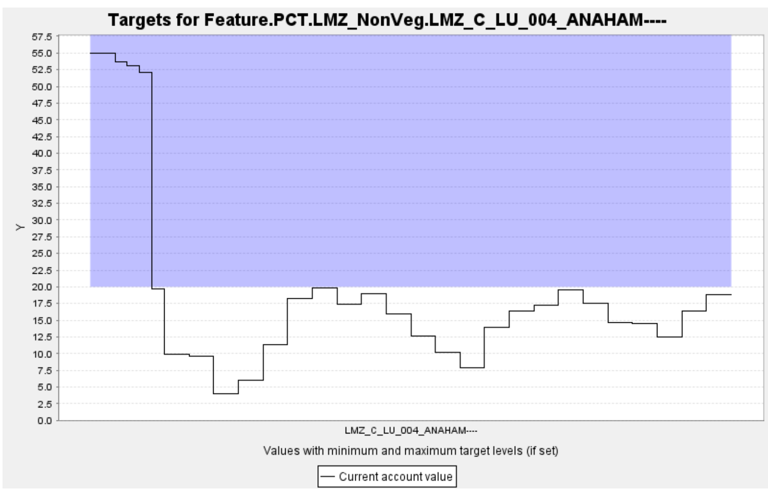


Figure 18 Examples of LMZ targets and levels (WLT4 Base Case)

2.3.4 Visuals

This analysis used visually-effective green-up (VEG) heights and planimetric disturbance % limits to model the maintenance of visual values. Figure 19 shows an example of a visual disturbance target report where the disturbance limit is exceeded over the first 4 decades. Afterwards, the model was able to maintain the maximum target level.

[2] Not accounted as visually effective green-up height

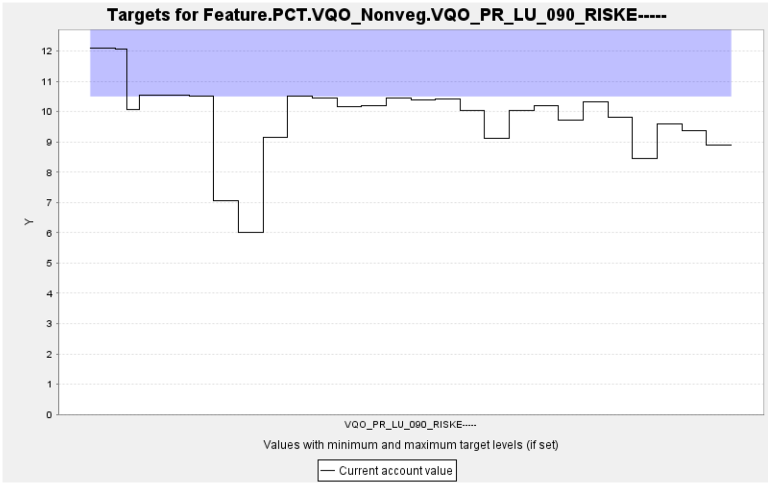


Figure 19 Examples of visual disturbance targets and levels (WLT4 Base Case)

2.3.5 Watersheds

Forest level targets were applied to three types of watershed units: community watersheds (CWS), watersheds (WS1), and watershed-basins (WS2). As the examples in figures below show, many of these watershed units had equivalent clearcut area levels that were above the target values at the start of the planning horizon. These levels often worsened during the first 20 years, and then fell within the target range. This was due to the ECA curve assigned to stands killed by MPB. The MPB-caused ECA followed a rising then falling shape (see the Data Package[3] for a detailed description). Hence, if a watershed had many MPB-killed stands the ECA level would rise for the first 20 years, then fall off, regardless of whether any harvesting occurred in that watershed unit or not. ECAs associated with harvesting start at 100 % and falls to 0% when regenerated stands achieve 12m in height.

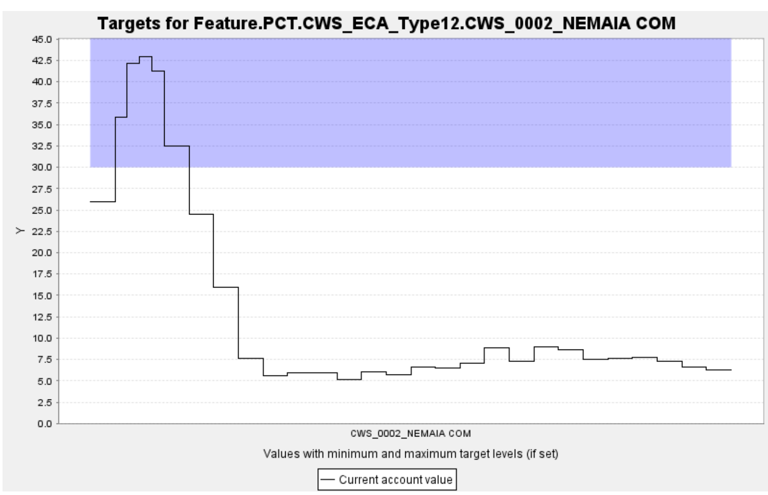


Figure 20 Examples of Community Watershed (CWS) ECA targets and levels (WLT4 Base Case)

[3] Forsite Consultants Ltd. (2013). Lakes TSA - Type IV Silviculture Strategy, Data Package. Technical Report.

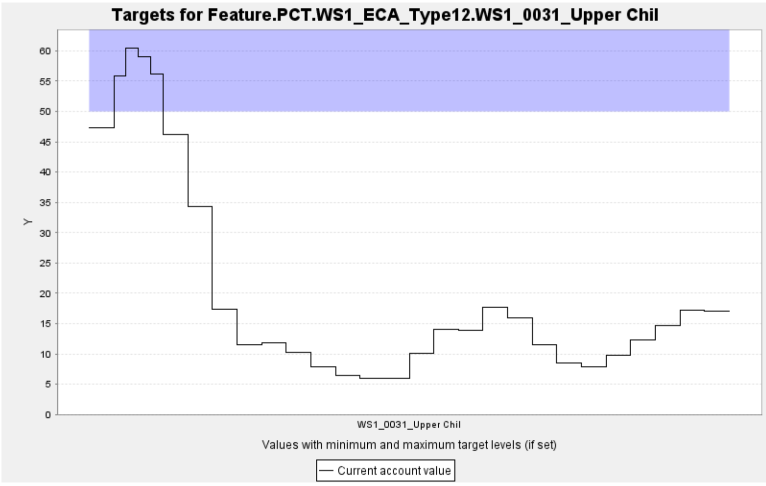


Figure 21 Examples of Watershed (WS1) ECA targets and levels (WLT4 Base Case)

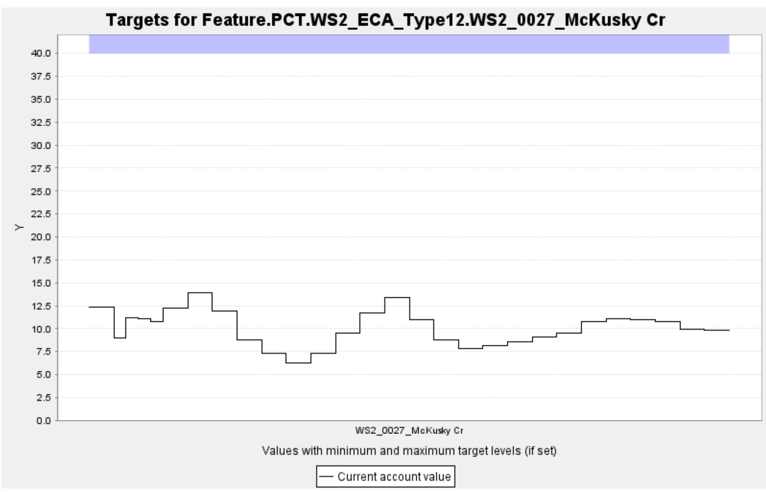


Figure 22 Examples of Basin (WS2) ECA targets and levels (WLT4 Base Case)

3 Comparison to Other Analyses

The base case is a benchmark to assess various changes to silviculture strategies. To ensure that the WLT4 Base Case is reasonable, it is often useful to compare some key outcomes against those from a previously-accepted analysis. This section discusses differences observed between the base case/reference scenarios for this WLT4 Analysis compared to (a) the 2008 Silviculture Type 2, and (b) the 2012 Mid-Term Analysis[4].

All three analyses applied similar assumptions to reflect: i) existing legal and land-use decisions, ii) non-timber value constraints, and iii) a focus on harvesting pine-leading stands. The two most notable differences with the WLT4 Analysis were: i) more aggressive assumptions for the dead pine shelf life and

[4] British Columbia Ministry of Forests, Lands and Natural Resource Operations. (2012). *Mid-Term Timber Supply Project Report for the Minister and Deputy Minister Forests, Lands and Natural Resource Operations.*

ii) significantly more complex growth and yield curves for mature stands, as they combined separate curves that reflect dead pine shelf-life, remaining live overstory and understory regeneration.

3.1 Land Base Comparison

Table 2 shows that the THLB for the WLT4 Base Case is 8.9% (0.16M ha) less than the long-term THLB used in the Mid-Term Analysis[5], and 5.0% (0.09M ha) less than the Type 2 Analysis[6]. Differences appear to be scattered over many netdown categories but known differences occurred with community forests, goal 2 parks, minimum volumes in cable ground (low productivity), and slope netdowns.

The net land base and modelling assumptions for the WLT4 analysis are more similar to the TYPE 2 Analysis than the Mid-Term Analysis. The THLB used in this project is 8.9% smaller than in the Mid-Term Analysis and 5% smaller than in the Type 2 analysis.

Table 2 Landbase – comparing WLT4 Base Case and two other analyses

Classification	WLT4 Analysis (M ha)	Mid-Term Analysis (M ha)	Area Difference M ha (%)	TYPE 2 Analysis (M ha)	Area Difference M ha (%)
Total Area	4.9	4.9	0%	4.9	0%
Crown Forest Land Base	3.2	2.84	-0.36 (-11.3%)	3.2	0 (0%)
Timber Harvesting Land Base	1.81	1.97	+0.16 (+8.98%)	1.90	+.09 (+5.0%)

3.2 Harvest Flow Comparison with Type 2

Figure 23 shows significant differences in the base case harvest flows for the WLT4 and the TYPE 2. The initial levels are different since the WLT4 no longer incorporates the uplift for salvaging dead pine. This reduction contributes to the WLT4's higher mid-term harvest level and slower climb rise from the mid-term trough. The Type 2 is also able to salvage considerably more dead pine stands because rather than a minimum volume threshold, it simply applied a 40 year minimum harvest age.

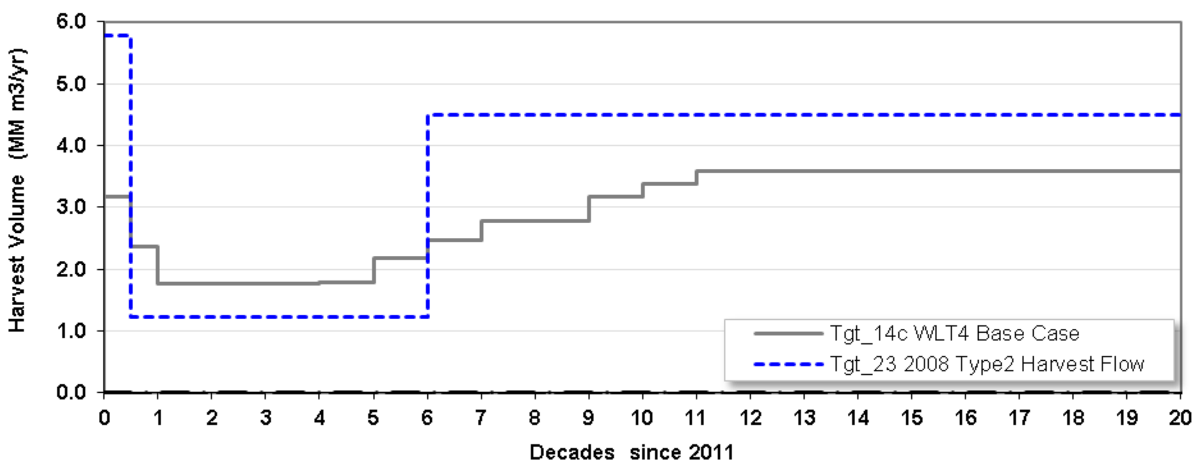


Figure 23 Harvest flow - comparison of the TYPE 2 Base Case and the WLT4 Base Case

[5] The Mid-Term Analysis results presented in this document and in the availale publications reflect the data compiled for 2012.

[6] Timberline Natural Resource Group Ltd. "Enhanced Type 2 Silviculture Analysis, Williams Lake TSA, Analysis Package." Unpublished report, 2008.

The significant difference in long-term harvest levels is attributed to the following factors:

- 5% Smaller THLB – as discussed above.
- MHA set to 40 years – The TYPE 2 analysis allowed the model to harvest MPB-impacted stands regardless of their actual volume. The WLT4 assumed that stands below minimum volume thresholds, now or into the future, could not be harvested. As a result, some never contribute to the harvest flow, which effectively reduces the long term THLB relative to the 2008 Type 2 modelling.
- Site Index adjustments for managed stands were applied in both analyses but there were differences in the data used to complete the adjustment. The current analysis used the provincial site index layer for managed stands (based on SIBEC).
- Other factors such as genetic worth, species composition of the regeneration, etc. cause some, but much less, of the difference.

Identified as the major contributing factor, the "MHA set to 40 years" hypothesis was tested in a sensitivity run. To mimic the TYPE 2 analysis, the WLT4 Base Case model was adjusted to reflect a similar initial harvest level and allow it to harvest any MPB-impacted stand that would never have otherwise reached the minimum volume threshold. The results from this run are presented in Figure 24. Differences between the two harvest flows largely disappear and the short- and long- terms become very similar. The new flow does, however, exhibit an earlier rise from the mid-term trough; likely due to the overly simplistic representation of the TYPE 2 assumptions, and possibly a large number of smaller differences.

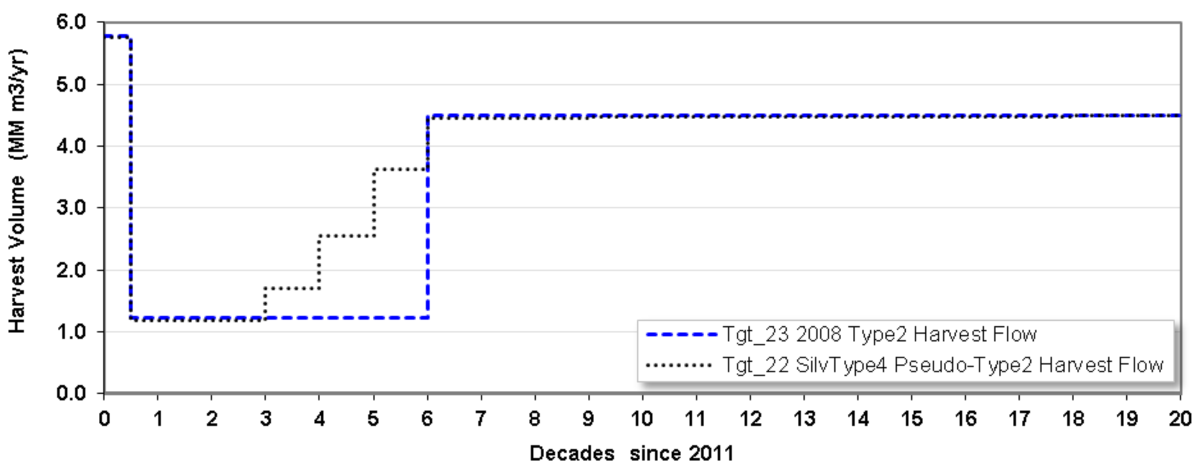


Figure 24 Harvest flow - comparison of the TYPE 2 Base Case and the WLT4 adjusted run

3.3 Harvest Flow Comparison with Mid-Term Harvest Flow

Figure 25 compares the harvest flow between the WLT4 and the Mid-Term Analysis. While the long-term harvest levels are quite similar, the short- and mid-term levels are much different (i.e., opposite trend to the TYPE 2 comparison.)

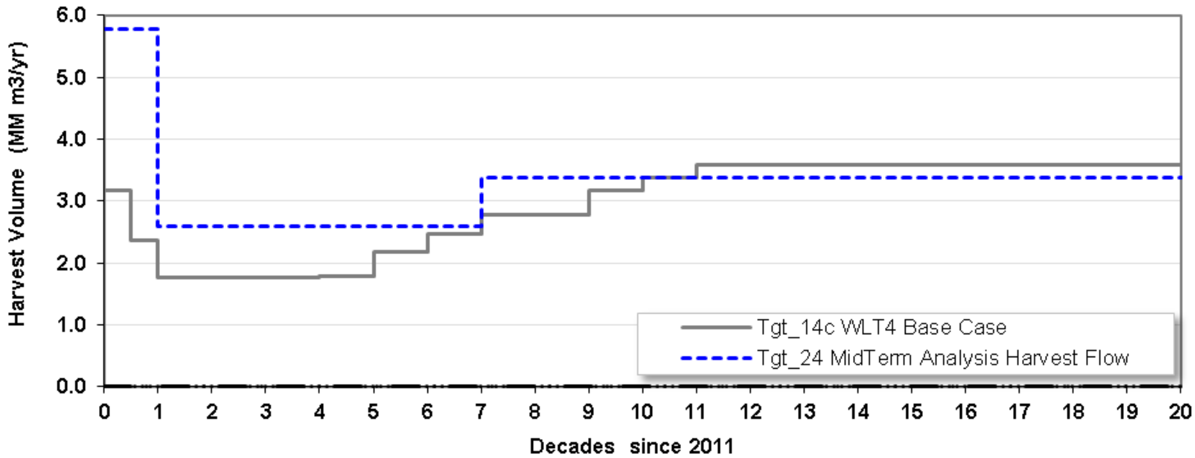


Figure 25 Harvest flow - comparison of the Mid-Term Base Case and the WLT4 Base Case

These differences are attributed to the following factors:

- Initial harvest level: The WLT4 no longer incorporates an uplift (5.7 M m^3/yr) to salvage dead pine. Instead, 3.2 M m^3/yr was used to reflect both current performance and the pre-MPB uplift harvest level.
- THLB is 8.9% larger: A larger landbase than the Mid-Term Analysis will improve both short- and long-term harvest levels.
- Shelf Life: The Mid-term Analysis assumed all dead pine volume was merchantable for 20 years from when it was killed after which it was completely removed. Combined with a minimum volume threshold of 65 m^3/ha, this allows significantly more MPB-impacted stands to be salvaged in the Midterm Analysis – leading to more short term volume and more long term landbase in active timber production. In contrast, the WLT4 analysis assumed a declining, straight-line shelf life curve to depict pine degeneration (100% merchantable at YOD, 50% available at year=7.5, and 0% available at year=15). The model started at year=5 (calendar year=2011) along the shelf-life curve for many stands, which meant that 33% of the MPB-killed volume was already non-merchantable, while the Mid-Term Analysis assumed all this volume was fully available. The trend continues once modelling begins as volume continues to fall away in the current model while the Midterm Analysis continues to have access to all of the dead pine volume. This is discussed further in section 4.1.
- MPB Year of Death: In the Mid-Term Analysis, the MPB kill appears to occur after the model starts. It is not stated how long this happens, or what proportion occurs before or after Model Year=0, but the harvest tables indicate that some of this MPB-kill happens as late as the 3rd (5-year) period.
- Minimum Harvest Ages: MHAs are determined by minimum volume thresholds in both analyses. The Mid-Term Analysis assumed a minimum volume threshold of 65 m^3/ha while the WLT4 assumed a minimum of 80 m^3/ha (Salvage) and 110 m^3/ha (or greater) post-salvage. Compared to the Mid-Term Analysis, this significantly reduced the available volumes for WLT4 in the short term and in the long term. The key difference is that many stands that contribute to the harvest in the Mid-Term Analysis are never harvested in the WLT4 Base Case.

These differences in the Mid-Term Analysis point to more volume being available to the model - for a longer period of time. This idea is supported by comparing the growing stock (Figure 26).

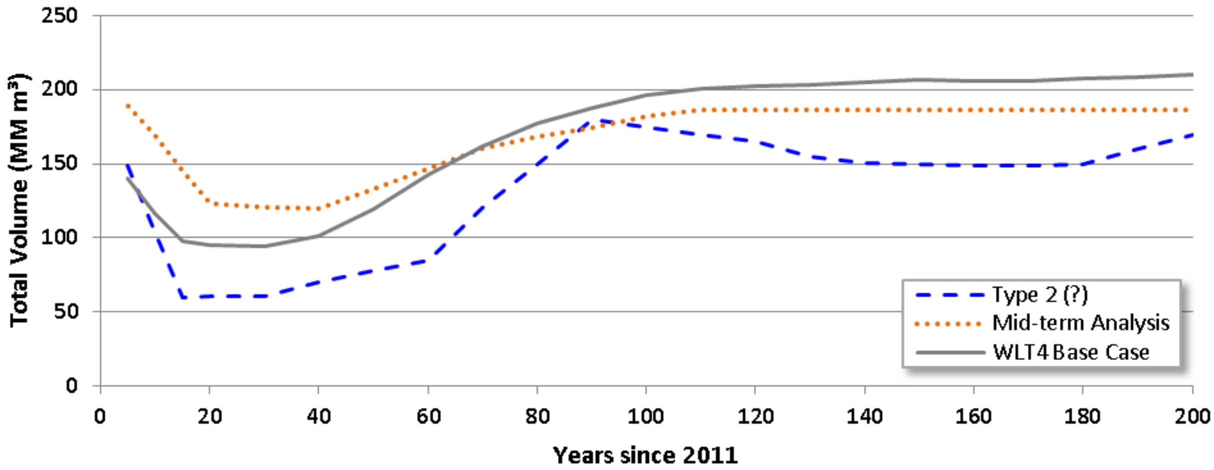


Figure 26 Growing stock – comparing WLT4 Base Case and Other Analyses

The shape of the growing stock curve is similar in all the analyses. As expected, however, the initial growing stock for the WLT4 Analysis is similar to the Type 2 analysis but lower than the Mid-Term Analysis. In the short and near-mid-term, the growing stock for the Mid-Term Analysis never falls as low as, and reaches its minimum level later than, the WLT4.

Unexpectedly, the growing stock trajectory in the TYPE 2 was more extreme than the WLT4. This is likely the result of using values from a figure in the TYPE 2 report, as specific data was unavailable in the report and the vertical axis on the figure was confused. It is possible that these TYPE 2 growing stock values are inaccurate.

The differences between the analyses shown here explain the different outcomes and provide confidence that the current harvest forecast is reasonable given the input assumptions.

4 Base Case Sensitivities

The following sections present the results of applying alternative assumptions to gauge the sensitivity of the revised harvest flow relative to the Base Case harvest flow.

4.1 Revised Minimum Harvest Criteria

In the WLT4 Base Case, minimum harvest criteria were lower for stands harvested during the salvage period than those harvested afterwards. Two sensitivities were undertaken to explore the impact to the harvest forecast by maintaining the same (110 m^3/ha and 80 m^3/ha) minimum harvest criteria for pine-leading stands throughout the planning period – for both natural and managed stands. The minimum harvest criteria are used to determine MHAs that identify stands as eligible for harvesting in the model. Lower volume criteria typically results in younger MHAs.

Figure 27 shows that applying the lower the minimum harvest criteria throughout the planning period (Tgt_13) improves the harvest flow in all periods while raising the criteria (Tgt_12) does the opposite. It clearly demonstrates how much an impact this single assumption has on the harvest forecast.

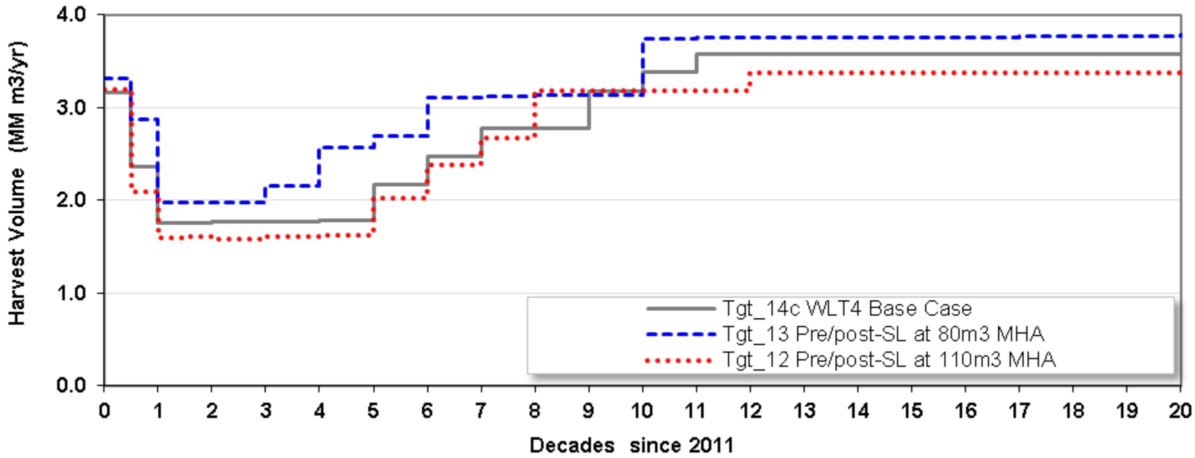


Figure 27 Harvest flow: Base Case compared to revised minimum harvest criteria

The WLT4 Base Case provided a more appropriate approach as the lower criteria considers the merchantability larger trees present within decaying pine stands during the salvage period. Throughout the mid-term and afterwards, the harvest dramatically shifts from natural to managed stands (Figure 4) that introduces significantly different product profiles (Figure 12). It is likely that the Tgt_13 harvest flow is likely too optimistic while the Tgt_12 is too pessimistic.

4.2 Revised Shelf-Life

In the base case, the shelf-life of decaying dead pine within MPB-attacked stands (≥60% killed) was assumed to steadily decline for 15 years from the point when 50% or more of the stand was killed (Figure 28). All dead pine volume was considered unavailable afterwards. As discussed in section 3.3, the Mid-term Analysis assumed that 100% of any dead pine volume could be harvested from MPB-impacted for up to 20 years from the year-of-death. This sensitivity aimed to examine the effect on the harvest forecast from implementing a revised shelf-life assumption that is similar to the Mid-term Analysis but reduced the decay period from 20 to 15 years.

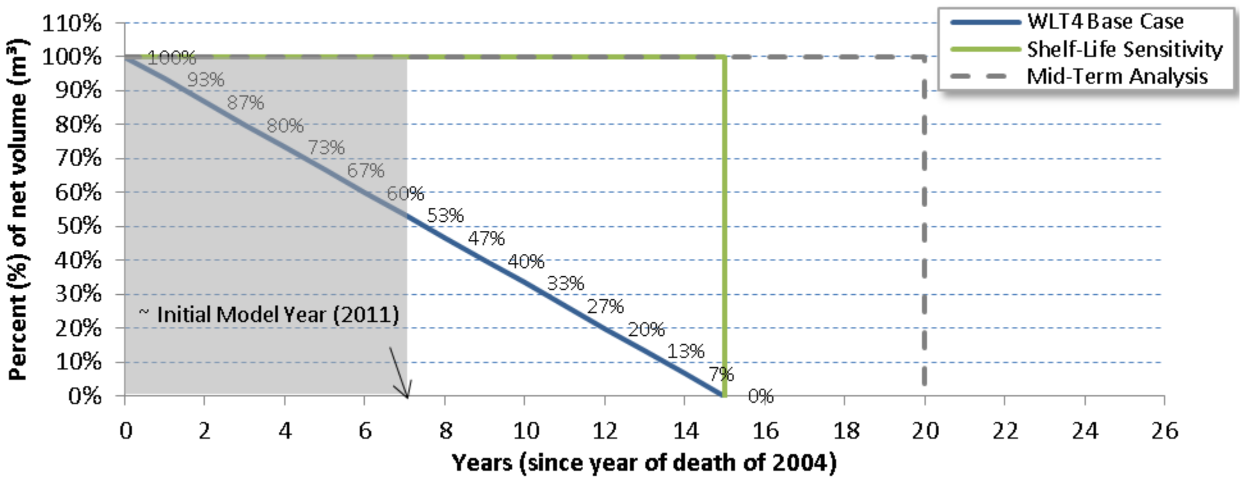


Figure 28 Comparison of shelf-life assumptions

How the WLT4 Base Case compares to the Mid-Term Analysis, including shelf-life assumptions, was discussed above in section 3.3.

The harvest flow derived from the revised shelf-life assumptions (SL1 – Figure 29) shows that harvest levels are improved in the second period, the rise from the mid-term and the long-term.

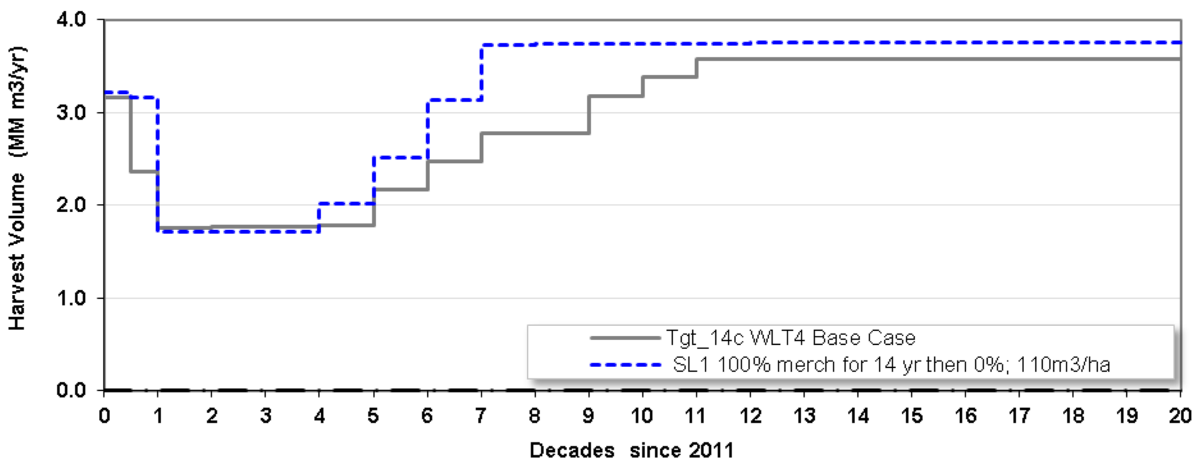


Figure 29 Harvest flow: Base Case compared to revised shelf-life assumption

Extending the harvest level in the short-term is mostly the result of being able to capture more dead pine stands before they are rendered non-merchantable by the shelf life assumptions. This is moderated, by an unintended difference in assumptions where the WLT4 Base Case applied a reduced minimum harvest criteria during the salvage period (80 m^3/ha – see section 4.1) while the SL1 sensitivity maintained the higher criteria (110 m^3/ha) throughout. Had the SL1 sensitivity incorporated the lower criteria, even more MPB-impacted stands could have been salvaged in the short term.

The increased rise from the mid-term and long-term harvest levels suggests that salvaging natural stands and converting them to managed stands – rather than assuming they immediately begin to degrade to a point where many stands are never eligible again – is an appropriate forest-level strategy when facing significant MPB impacts.

4.3 Revised Minimum Harvest Criteria – 90% of CMAI

This sensitivity aimed to examine the effect on the harvest forecast from including an additional criterion that requires stands to attain at least 90% of the volume at culmination of mean annual increment (CMAI). This approach effectively increases the MHA for most stand types and is typically used to ensure that long term productivity is not being compromised to meet short- or mid-term harvest goals.

A similar analysis was done for the Quesnel Type 4 (QT4) analysis[7] where MHAs were adjusted to the maximum CMAI, or the age when volume increment is the greatest; often described as the biological rotation. This approach maximized the long-term harvest level and increased the average MHA by 27 years or 44%. The average yield at CMAI was 305 m^3/ha versus 120 m^3/ha in the QT4 base case.

Figure 30 shows harvest flow differences from the QT4 resulting from using MHAs based on culmination age. The mid-term harvest level is approximately 701,000 m^3/yr lower than the QT4 Base Case. Even though the long-term harvest level is delayed by about 20 years, it is approximately 165,000 m^3/yr higher than the Base Case.

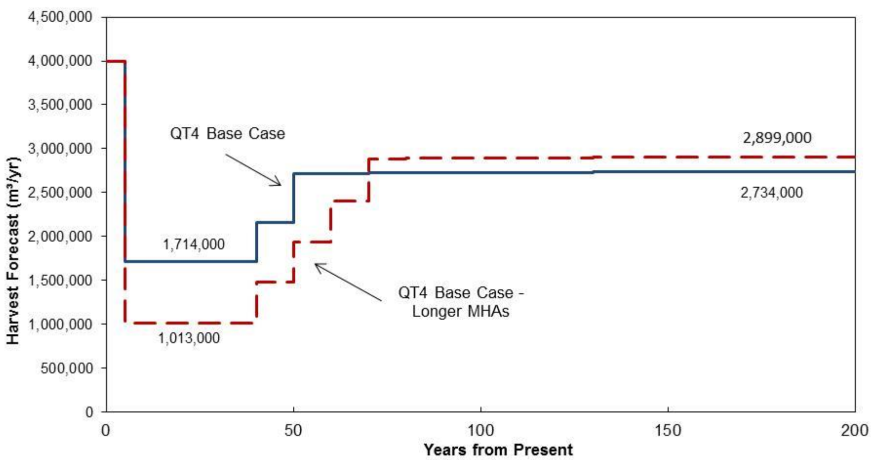


Figure 30 Harvest flow: Quesnel Type 4 Base Case compared to longer MHAs

Figure 31 compares the area harvested by the age class for the longer MHA sensitivity. It is clear that the extended period to access stands killed by MPB results in a future forest product profile that is significantly different using longer MHAs. For example, in the 6th decade, the average harvest ages are nearly double in the longer MHA sensitivity compared to the QT4 Base Case.

[7] Forsite Consultants Ltd. (2013). Quesnel TSA - Type IV Silviculture Strategy, Modelling and Analysis Report. Technical Report.

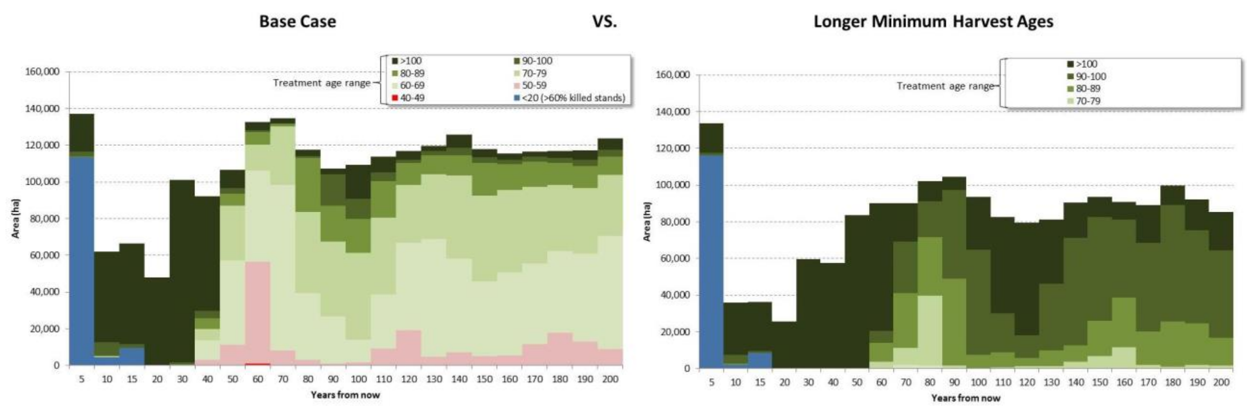


Figure 31 Harvest area by age class: Base Case compared to longer MHAs (Quesnel Type 4 Analysis)

Allowing managed stands to grow longer before harvesting has a major negative impact on midterm harvest levels. On the other hand, this approach provides several benefits in the longer term: higher AAC, better product profile, higher unit volumes that lead to lower harvesting costs and less area harvested, and more area with mature stands.

The same trends were predicted for this sensitivity, so it was decided that resources should be applied to explore silviculture strategies and the sensitivity to revise minimum harvest criteria was deferred for this analysis.

4.4 Incorporate Deciduous Stand Volumes

This sensitivity was intended to explore the impact of adding non-constrained deciduous-leading stands back into the THLB and including deciduous volumes from mixed stands (currently over 2 million m^3). It was anticipated that this would add volume to the harvest forecast (up to 100,000 m^3/yr) by including existing deciduous stands and potentially lowering minimum harvest ages, assuming minimum volumes are reached at younger ages.

Currently, very little deciduous material is being utilized within the Williams Lake TSA. This deciduous sensitivity would provide an estimate of the opportunity that exists if this material were merchandized. However, the priority for undertaking this scenario was deemed lower than the proposed silviculture strategies so the sensitivity for incorporating deciduous material was deferred for this analysis.

4.5 Limit the Harvest of Small Pine

This sensitivity was intended to examine harvest forecast impacts of limiting the harvest of stands with small pine. The approach for this sensitivity involved adjusting harvest thresholds relative to distances from processing facilities – principally at Williams Lake, but also Anahim Lake. This reflects the notion that harvesting small pine trees becomes more economic for stands with shorter haul distances.

Again, the priority for undertaking this scenario was deemed lower than the silviculture strategies proposed so the sensitivity for limiting the harvest of small pine was deferred for this analysis.

4.6 Harvest Sequence

This sensitivity examined the effect on short- and mid-term harvest levels from an immediate reduction in the current AAC uplift. This was done by first establishing the highest flat-line harvest level throughout the short- and mid-term (2.02 million m³/yr) then steadily increasing the first term harvest level while accepting some loss in harvest level (~10%) throughout the mid-term. Ultimately, this sensitivity aimed to achieve the highest harvest level across both the short- and mid-terms combined, by influencing the model to balance the salvage of dead pine volume in the short term with the retention of green, by-catch volume for in the mid-term.

The alternative harvest sequence (Figure 32 – Tgt_15) resulted in a lower harvest level in the first and second periods by 8% (234K m³/yr for 10 years) that supported a higher mid-term harvest level by 8% (143K m³/yr for 40 years).

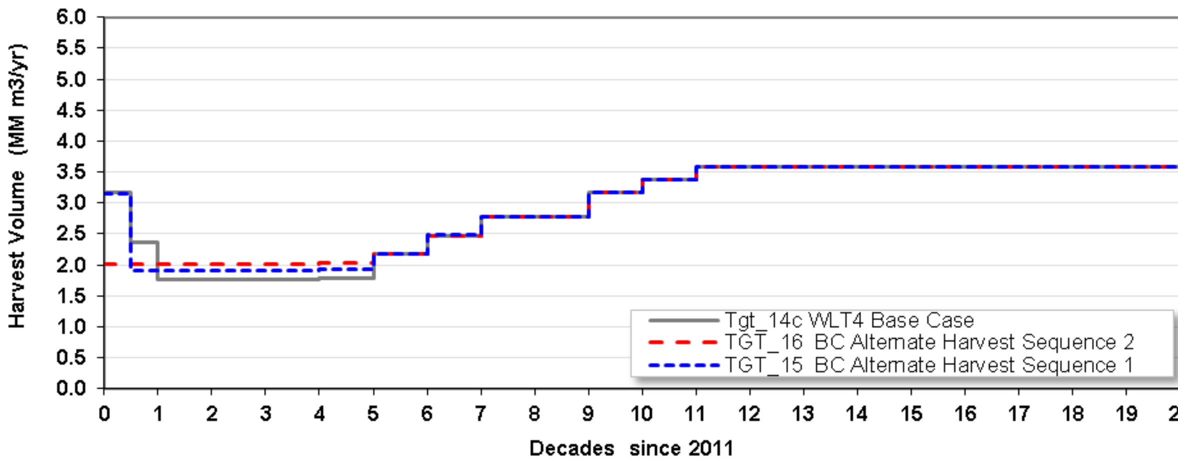


Figure 32 Harvest flow: Base Case compared to harvest sequence sensitivity

Over the first decade, less dead pine volume was salvaged with this sensitivity (118K m^3) compared to the base case, as some stands that would have been harvested with higher live volume components (by-catch), were retained for harvesting in the mid-term.

5 Silviculture Strategies

The following sections present the results of applying alternative assumptions, as silviculture strategies, relative to the Base Case harvest flow. Each section includes a brief summary of the modelling approach documented[8], a discussion of the key forest metrics affected by the strategies and a rationale for observed differences from the Base Case. All scenarios were individually constrained within a budget of $3 million/yr.

5.1 Single Fertilization

This silvicultural strategy examined the impact to harvest flows from applying fertilizer one time throughout the rotation of pine, Douglas-fir and spruce stands. This treatment intended to increase the

[8] Forsite Consultants Ltd. (2013). Lakes TSA - Type IV Silviculture Strategy, Data Package. Technical Report.

merchantable yield and value of stands by adding nutrients that are limited on sites that improve the growth of trees.

This strategy was expected to improve the mid-term harvest level because stands treated within the first two decades provides additional volume throughout this critical period and reduces the age that these stands become eligible for harvest (MHA). The existing volume, therefore, does not have to be metered out as long.

Eligible stands for this treatment were limited to only existing stands (natural or managed). This was intended to focus the increased volume onto stands that would most likely to support higher mid-term harvest levels. While single fertilization treatments certainly apply to future managed stands, gains from these stand types would be realized well beyond the mid-term period therefore these stands are less relevant to this analysis.

At a stand-level, a single treatment cost of $450/ha was applied but at the forest-level, the model was constrained with a maximum budget of $3 million/yr – or up to 6,667 ha/yr. No minimum budget was specified to permit the model to treat a stand only when it results in an improvement to the harvest forecast.

The stacked graph in Figure 33 shows that given the limited number of eligible stands, the model only treats an average of 1,620 ha/yr (32.4K ha total) over the first 20 years. This was less than expected because the model was not configured to treat according to a fixed schedule and there was no incentive to treat available stands earlier.

Stands eligible for treatment accumulate and dissipate from period to period as stands are: i) treated in a later period, ii) never available for harvesting and remain untreated, iii) harvested without treatment to overcome some other condition (e.g., better to harvest than wait for the retention period), or iv) retained and never treated for some non-timber value. Ultimately, all harvested stands that were eligible for fertilization at one time were treated.

Initially, spruce and Douglas-fir leading stands were treated but the proportion of pine stands steadily increased until becoming the majority between years 15 and 50.

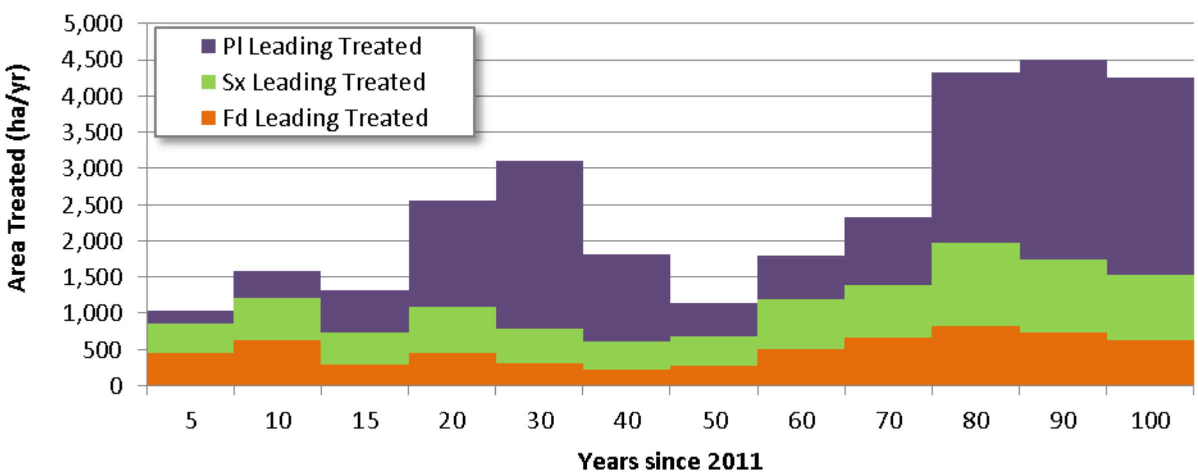


Figure 33 Area treated by stand type under the single-fertilization strategy

Given the limited number of available stands and the model's selection of treated stands, the maximum budget was never fully utilized (Figure 34). In time though, more stands would become eligible for treatment.

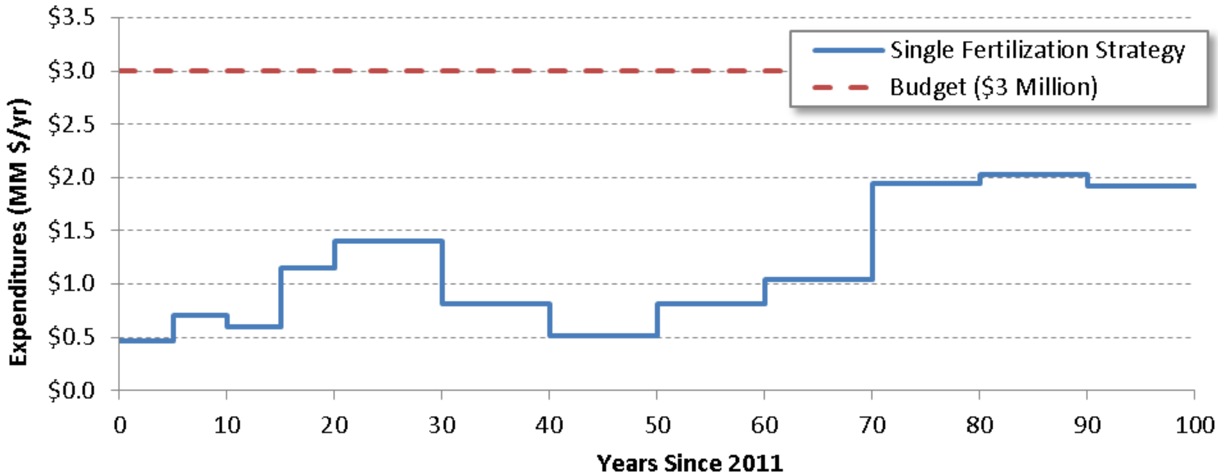


Figure 34 Expenditures over time for the single-fertilization strategy

The harvest flow resulting from the single-fertilization strategy was quite similar to the base case (Figure 35). The mid-term harvest level increased by only 39,000 m^3/yr (2%) whereas future applications led to further increases of 5% over the rise-to-the-long-run, as well as, within the long-term (128K m^3/yr and 193K m^3/yr, respectively).

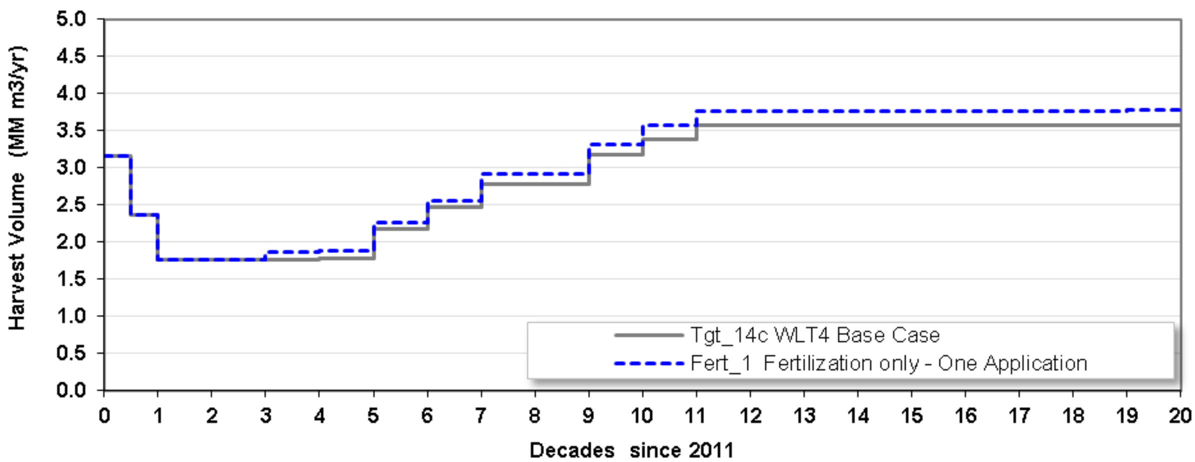


Figure 35 Harvest flow: Base Case compared to single-fertilization strategy

5.2 Multiple Fertilization

This silvicultural strategy examined the impact to harvest flows from applying fertilizer multiple times throughout the rotation of pine, Douglas-fir (every 10 years) and spruce stands (every 5 years). Treatment frequency regimes were developed for each species that reflected a fixed number of applications (up to 4 for Pl or Fd; up to 6 for Sx), as well as their corresponding responses and costs. The model could select only one treatment frequency regime for the stand.

Eligible stands for this treatment included existing and future natural or managed stands within age windows of 30 to 80 years (25 to 55 years for multiple fertilization of Sx). Stand-level treatment costs of $450/ha (Pl/Fd) or $600/ha (Sx) were applied and at the forest-level, the model was constrained with a maximum budget of $3 million/yr – or up to 6,667 ha/yr. No minimum budget was specified to permit the model to treat a stand only when it results in an improvement to the harvest forecast.

The stacked graph in Figure 36 again shows that shows that given the limited number of eligible stands, the model only treats an average of 3,718 ha/yr (74.4K ha total) over the first 20 years. This was less than expected because the model was not configured to treat according to a fixed schedule and there was no incentive to treat available stands earlier.

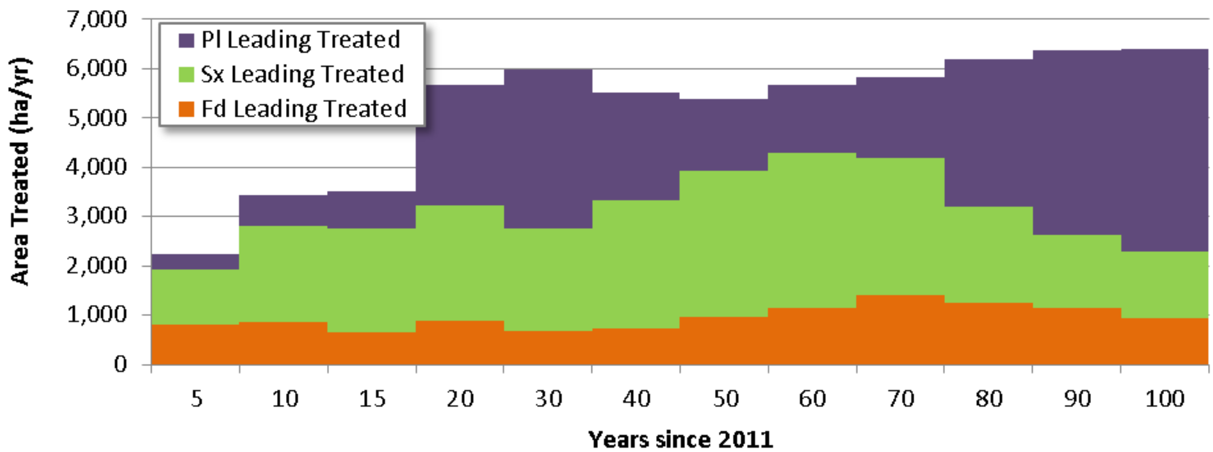


Figure 36 Area treated by stand type under the multiple-fertilization strategy

Due to the very favorable responses, most of the multiple fertilization treatments were applied to Sx leading stands at approximately 2,000 ha/yr.

Figure 37 shows that as stands become eligible, the budget for the multiple-fertilization strategy steadily increases until it is maximized after 15 years. The number of applications is distributed somewhat proportionally with slight increases in 6 applications of Sx at the end of the mid-term then cycles through the planning period every 90 years.

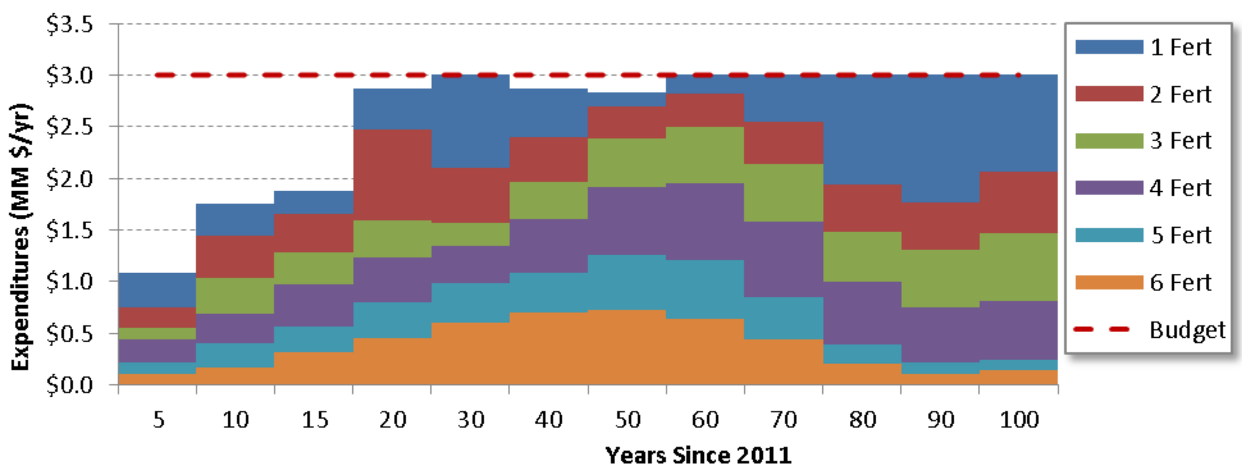


Figure 37 Expenditures over time for the multiple-fertilization strategy

Figure 38 shows improved harvest levels by 149K m³/yr (8%) over the mid-term (210K m³/yr at the back end) as harvesting transitions to managed stands. The harvest level also increased by an average of 185K m³/yr (7%) throughout the rise to the long-term and by 248K m³/yr (7%) in the in the long-term.

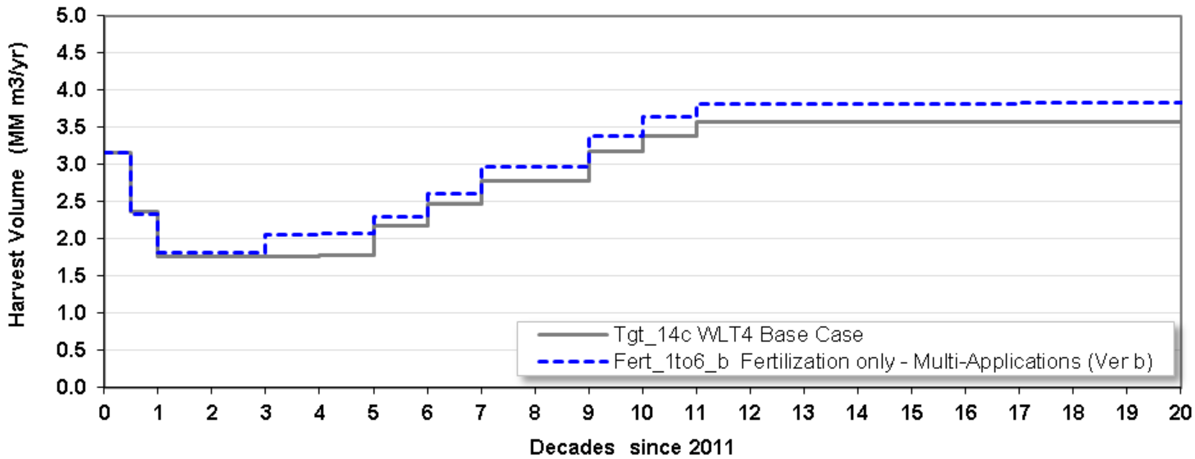


Figure 38 Harvest flow: Base Case compared to multiple-fertilization strategy

5.3 Pre-Commercial Thinning and Fertilization

This silviculture strategy was intended to explore the impact of pre-commercial thinning (PCT) dense Pl stands between the ages of 10-20 years old (typically 6,000-20,000 sph), to a target density of ~2,500 sph, then fertilize these stands according to the regimes applied for multiple fertilization. The purpose of the treatment is to improve stand quality/health/resilience through leave tree selection, increase stand volumes through fertilization and advance operability in these stands.

A variation of this strategy would explore subsequent thinnings down to 1000 sph at 30 years and 600sph at 50 yrs, to allow access to early volume while holding the stand through its peak MAI years to harvest at age 70. However, the criteria for this regime would likely apply to more stand types.

Due to the relatively minor amount of eligible area for this treatment (6,800 ha), this scenario was not pursued further at this time as it was not identified as a priority strategy within the available budget.

5.4 Spacing Dry-Belt Douglas-fir

This silvicultural strategy examined the impact to harvest flows from spacing stagnant thickets in the second and third layers of dry-belt Douglas-fir stands.

Eligible stands for this treatment included Douglas-fir leading stands within the IDF harvested between 1960 and 1980, when and where diameter-limit cutting was predominant. The response for this treatment incorporated a 10% increase to the initial entry harvest volume (shelterwood and selection) for stands treated at least 30 years prior to harvest. Treatment costs were applied at $750/ha. No minimum budget was applied to permit the model to only treat a stand when it results in an improvement to the harvest forecast.

Figure 39 shows the model treated an average of 429 ha/yr over the first 20 years. Most of the eligible stands were treated within the first 30 years.

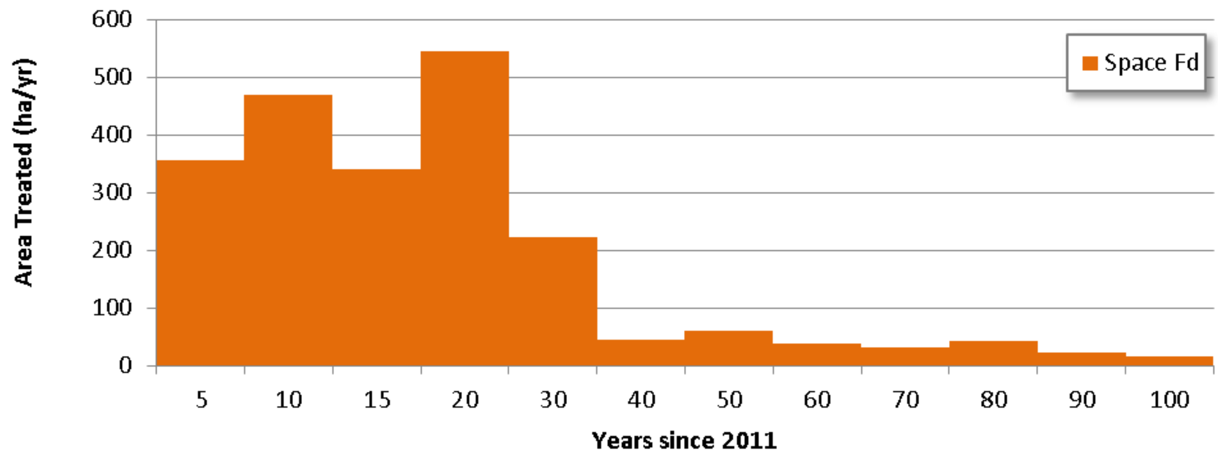


Figure 39 Area treated under the spacing dry-belt Douglas-fir strategy

Given the limited number of available stands and the model's selection of treated stands, the maximum budget was never fully utilized (Figure 40).

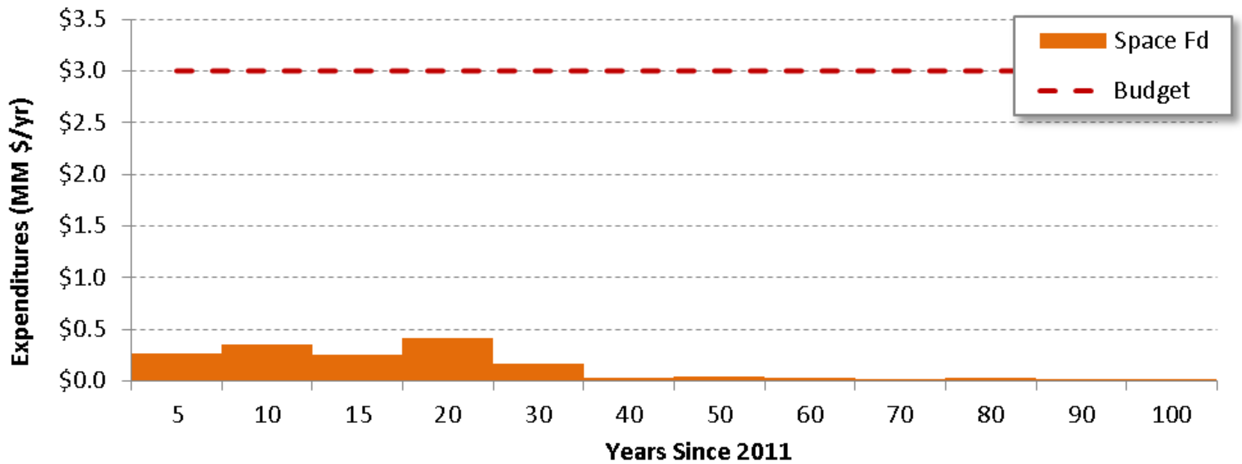


Figure 40 Expenditures over time for the spacing dry-belt Douglas-fir strategy

Figure 41 shows a slightly improved harvest flow at the end of the mid-term. The small gain and timing reflects the limited treatment opportunities combined with the 30 year harvest delay. Spread over the entire mid-term, this represents a gain of 50K m³/yr (3%). These results may be optimistic as the Base Case yields for these stands were generated using VDYP and were not adjusted for stagnant growth. On the other hand, the treatment response of 10% increase in yields may also be conservative.

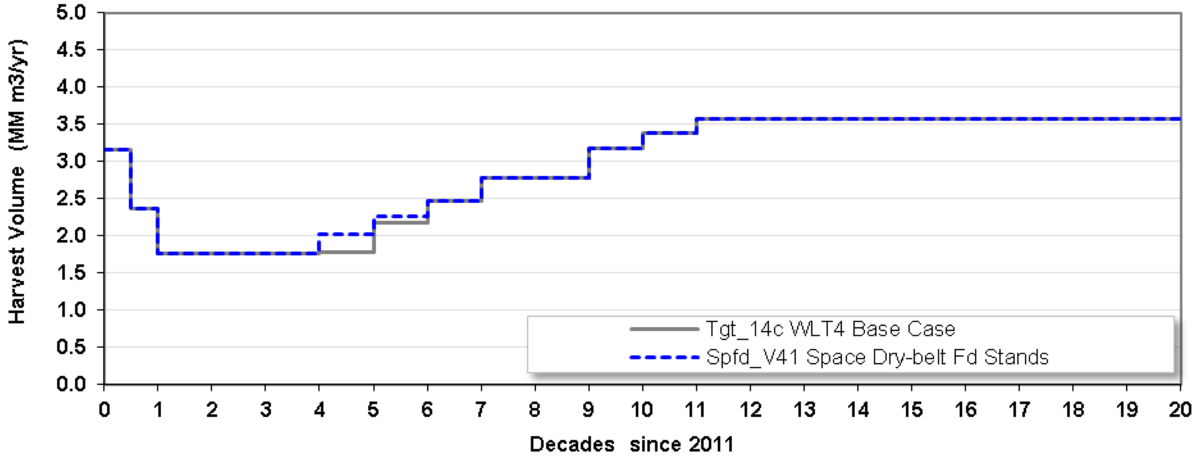


Figure 41 Harvest flow: Base Case compared to the strategy to space dry-belt Fd stands

5.5 Rehabilitating MPB-Impacted Stands

Over 440K ha were never harvested in the Base Case scenario because the MPB impact on these stands assumed that they do not achieve the minimum merchantability criteria - effectively reducing the landbase that contributes to the harvest flow.

This silvicultural strategy examined the impact to harvest flows from rehabilitating MPB impacted stands with little or no salvage opportunity. Rehabilitation provides extra merchantable (green) volume at the time of treatment (that would not have otherwise entered the marketplace) and increases the long-term harvest level as managed stand performance is significantly improved.

Figure 42 shows a rather even distribution, nearly 1,500 ha/yr, of stands rehabilitated over time with two classes of live merchantable volumes following the shelf-life period. The model salvages most of the high percent pine stands so many of the post-salvage stands selected under this rehabilitation strategy are low volume mixed stands. In fact, a majority of the rehabilitation (58%) was selected for stands with live volumes less than 50 m³/ha.

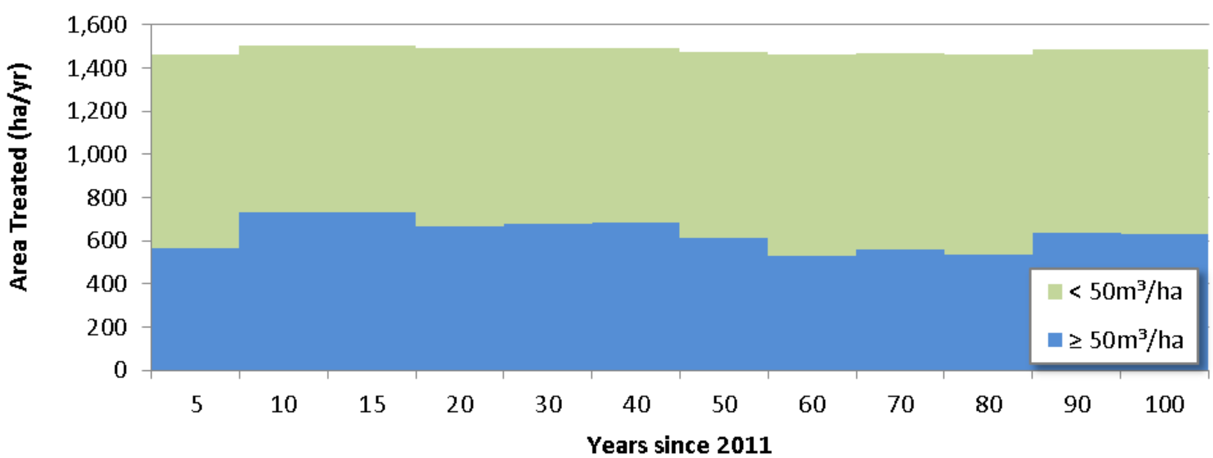


Figure 42 Area treated by merchantability class under the rehabilitation strategy

With plenty of stands available for rehabilitation, the model maximized the budget for nearly 200 years.

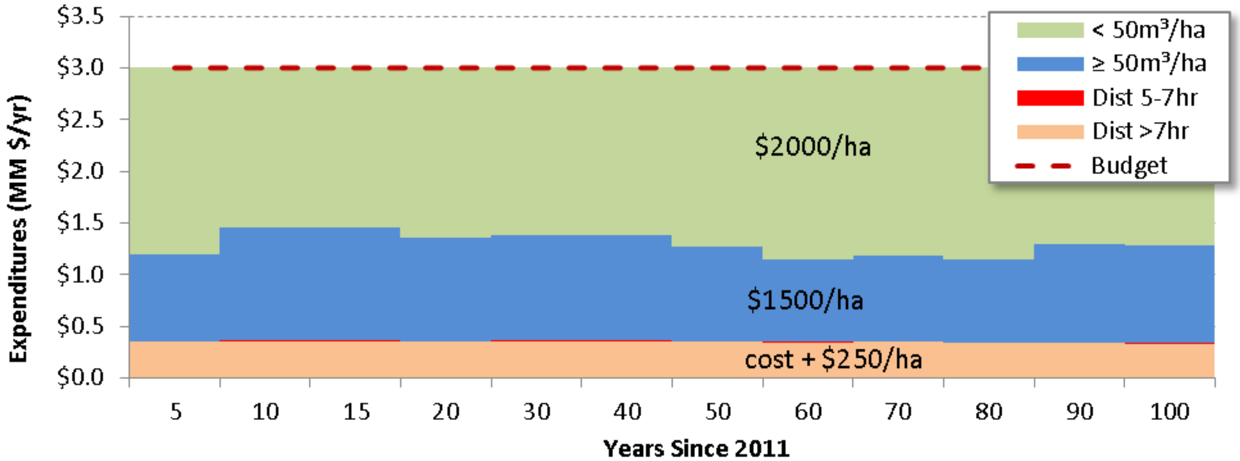


Figure 43 Expenditures over time for the rehabilitation strategy

Figure 44 shows a significantly improved harvest flow with the rehabilitation strategy. The mid-term increases by 147K m^3/yr (8%), the rise increases by 353K m^3/yr (13%) and the long-term increases by 463K m^3/yr (13%). As discussed above, these gains reflect the additional live volume harvested during the mid-term and the increased effective landbase.

Rehabilitation treatments were available through the planning horizon, where eligible stands had deteriorated below the minimum harvest volume criteria. In practice, the focus should initially be on treating younger or burned stands and those with lower merchantability while deferring stands with live volumes that can rehabilitated in the mid-term. Of course, access and market conditions also play a key role in prioritizing stands for rehabilitation.

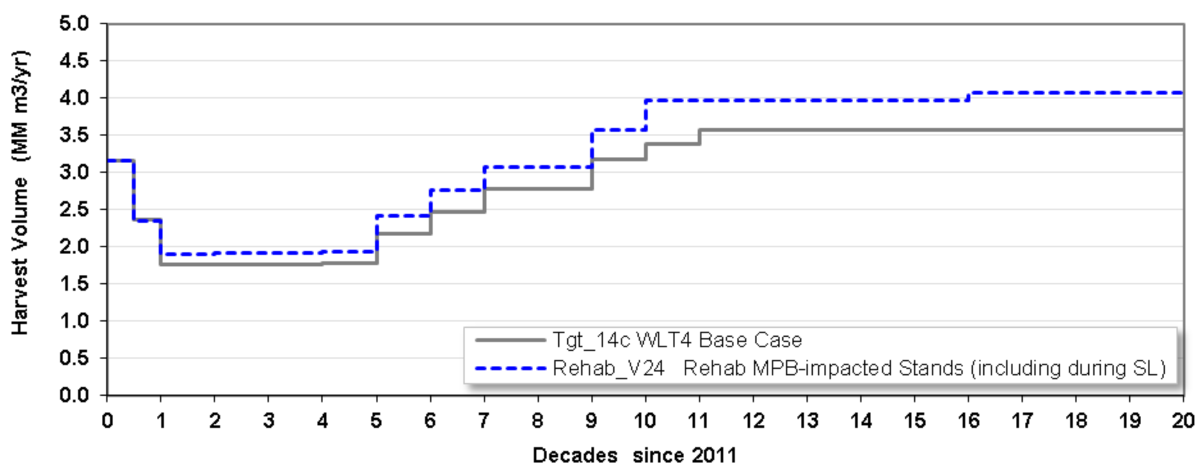


Figure 44 Harvest Flow: Base Case compared to rehabilitation strategy

5.6 Enhanced Basic Reforestation

This strategy examines the impact to harvest flows from enhancing basic reforestation practices where current performance is not optimal (achieving minimum well-spaced trees/ha versus target well-spaced trees/ha). The objective of this approach is to increase timber volume and quality when these stands are harvested rather than focusing on meeting minimum standards at free growing.

In this scenario, modeled reforestation assumptions were revised by increasing initial well-spaced stand densities and reducing stocking gaps through a combination of site preparation, planting to higher densities, and/or fill planting from select seed once ingress is complete. Accordingly, responses vary depending on inputs used to generate future managed yields.

The incremental cost for this treatment over Base Case regeneration assumptions was modelled at $450/ha for incremental planting of trees sown from select seed or $1000/ha where natural regeneration was originally applied. The budget of $3M/yr would therefore treat up to 6,667 ha/yr.

Figure 45 shows the model treated an average of 4,700 ha/yr over the first 20 years or 29% of the average area harvested over the same period. The model also applied this strategy to over 24K ha of salvaged stands.

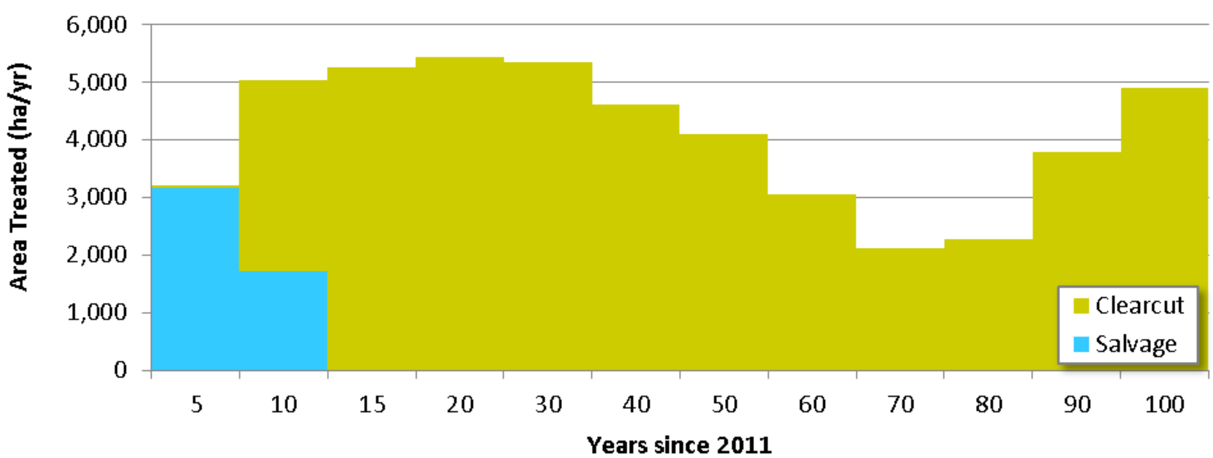


Figure 45 Area treated under the enhanced basic silviculture strategy

Figure 43 shows the **model utilized most of the budget** over the first 50 years but reduced spending afterwards as fewer stands were eligible for the enhanced treatments.

Figure 46 Expenditures over time for the enhanced basic reforestation strategy

Figure 47 shows an improved harvest flow with the enhanced reforestation strategy. The mid-term increases by 83K m³/yr (5%), the rise increases by 69K m³/yr (2%) and the long-term increases by 433K m³/yr (12%). The first treated stands are harvested in 35-45 years as minimum harvest volumes are reached sooner. The increased harvest levels are primarily a result of planting trees from select seed which increases yields and shortens rotation lengths and from lowering operational adjustment factors.

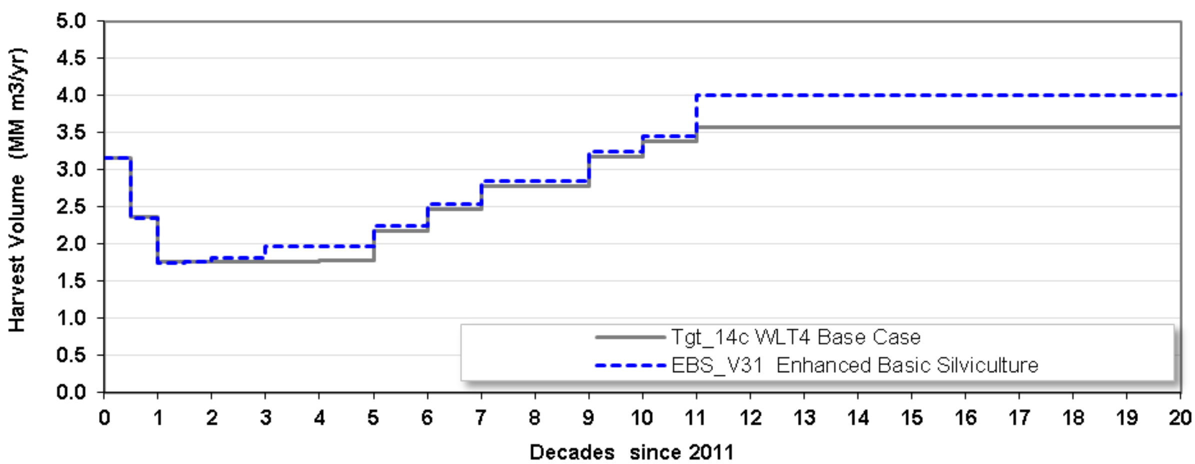


Figure 47 Harvest flow: Base Case compared to enhanced basic silviculture strategy

5.7 Partial Cut in Constrained Areas

This silviculture strategy examines the impact to harvest flows from a single removal of 1/3 of the volume within stands currently constrained for visuals, lakeshore management, mature-plus-old seral and watershed ECA requirements. Harvesting a portion of the volume from areas that are otherwise constrained areas effectively increases the volume available for harvest during critical periods of the harvest flow.

Eligible stands for this strategy include THLB areas with forest cover constraints applied to maintain specific conditions (limit disturbance, maintain older age classes): mature-plus-old seral constraints, visuals, lakeshore management classes and watershed ECAs. Stands severely impacted by MPB (≥60%

killed) were not eligible for this treatment as they are unlikely to maintain non-timber values after the partial harvest treatment.

This strategy was implemented by providing a selection harvest treatment option for identified stands to remove 1/3 of the existing volume but retain the existing age. The incremental cost of implementing the partial harvest treatment over clear cutting is estimated at \$7.50/m^3 for slopes <40% and \$12.50/m^3 for slopes ≥40%.

Figure 48 shows the model primarily treated stands between years 6 and 30 at an average of 661 ha/yr. This corresponds closely with the mid-term period between 11 and 50 years.

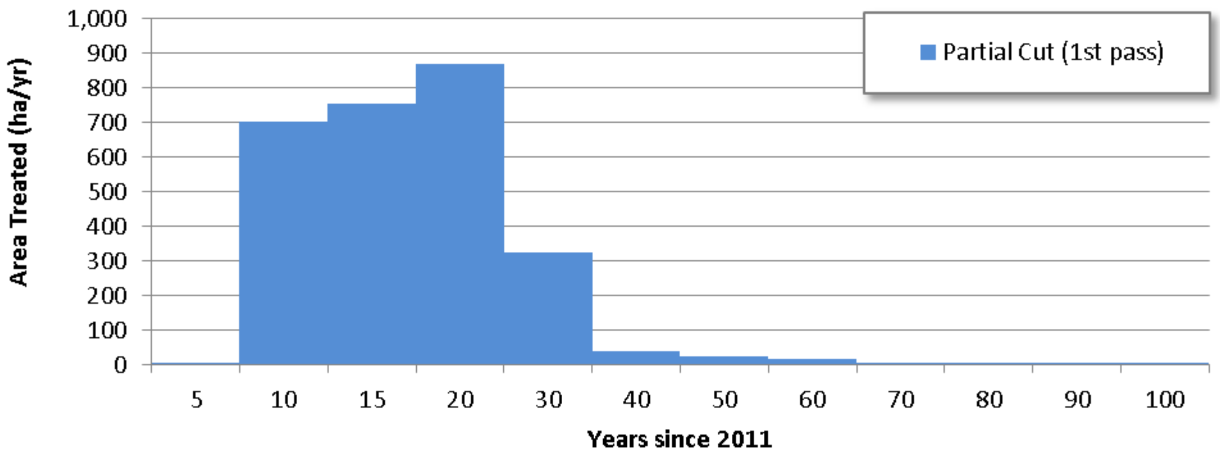


Figure 48 Area treated under the partial cut strategy

Given the limited number of available stands and the model's selection of treated stands, less than half of the maximum budget was utilized throughout the critical mid-term period (Figure 48).

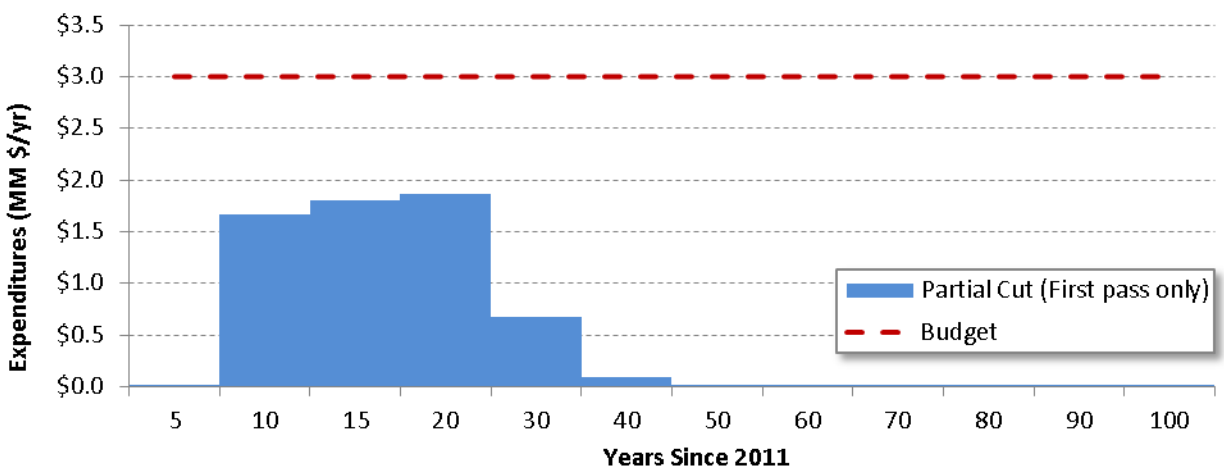


Figure 49 Expenditures over time for the partial cut strategy

Figure 50 shows the partial cut strategy produced a significantly improved mid-term harvest level with an increase of 241K m^3/yr (14%). Other periods remained relatively unchanged (not attempted). As discussed above, these gains reflect increases in available volume during critical periods of the harvest flow. The key premise behind this scenario is that the means and amount of volume removed is will maintain sufficient stand conditions to satisfy the non-timber values present. The actual harvest level from this strategy would vary across stands.

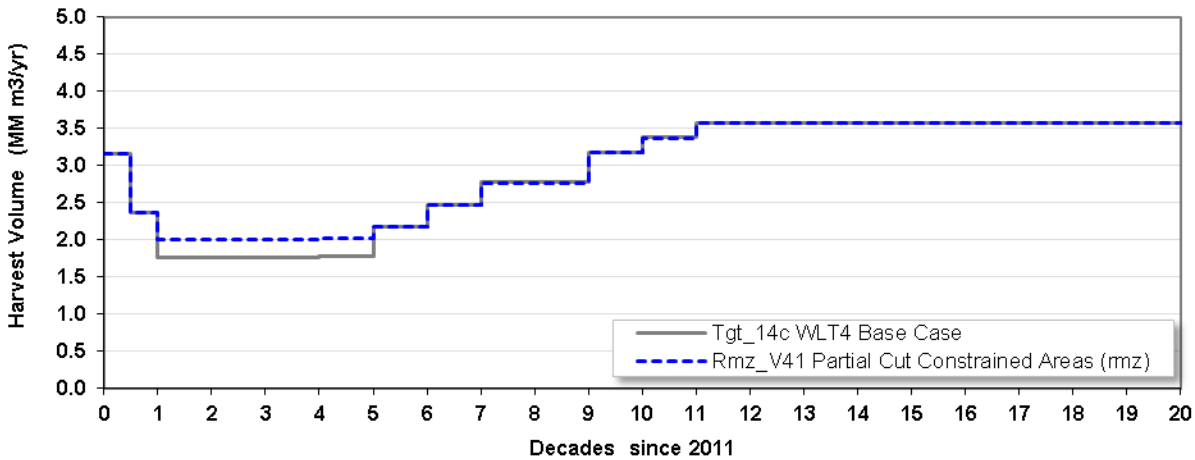


Figure 50 Harvest Flow: Base Case compared to partial cut strategy

5.8 Composite Mix of Strategies – Budget of $3 Million/year

For this scenario, the model was configured to include assumptions for all of the strategies presented above so that the model can select the timing and range of treatments that produces the most appropriate outcome. A budget constraint of $3 M/year was applied in this scenario to reflect realistic funding levels for these activities.

Under this scenario, the silviculture strategies treated an average of nearly 1,700 ha/yr over the first 20 years and 1,860 ha/yr over 100 years (Figure 51) where the strategies selected were dominated by rehabilitation for the first 150 years. Initially, fertilization represented less than 10% of areas treated but following the mid-term, as more stands reach ages within the eligibility window, this proportion increased significantly to nearly a third. Combined, the remaining three strategies steadily treated 280 ha/yr (ranging between 8% and 22%) over 100 years. The area treated using enhanced basic reforestation was very consistent, partial cutting was mostly implemented within the mid-term and most of the thinning of dry-belt Fd occurred early on.

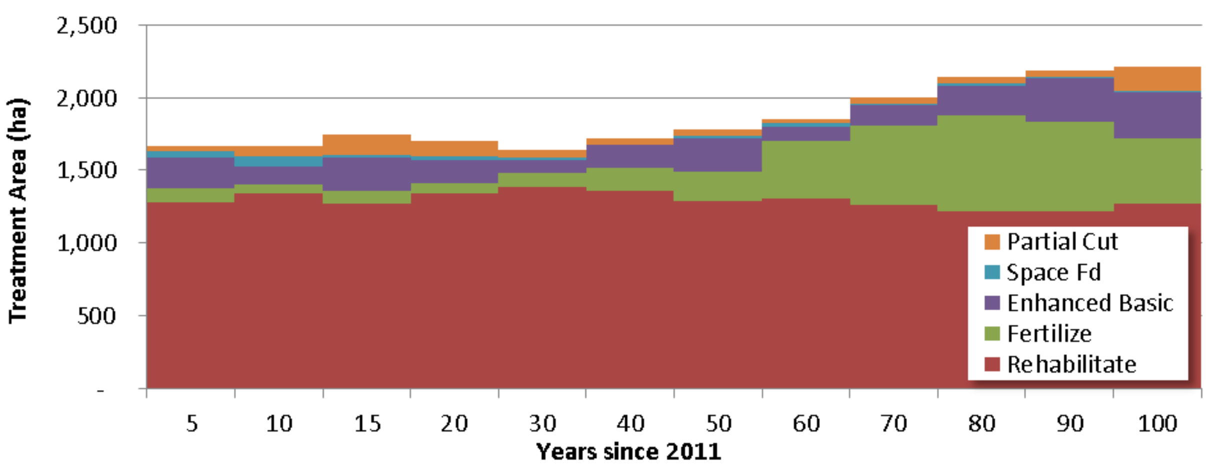


Figure 51 Area treated by silviculture treatment under the composite strategy at $3M/yr

The $3M/yr budget assigned to this composite scenario is maximized throughout the planning horizon (Figure 52). Overall, 77% of this is spent on rehabilitation.

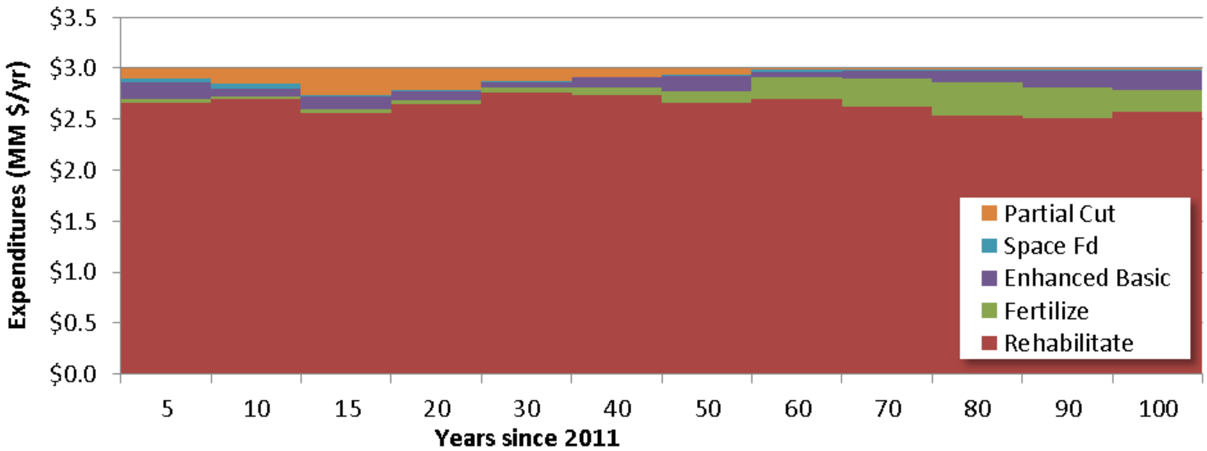


Figure 52 Expenditures over time by silviculture treatment for the composite strategy at $3M/yr

Figure 53 shows the harvest flow is considerably improved by combining allowing all silviculture strategies at a budget of $3M/yr. Compared to the Base Case, the mid-term harvest level increased by 397K m^3/yr (22%) over the Base Case while the long-term harvest level increased by 400K m^3/yr (11%).

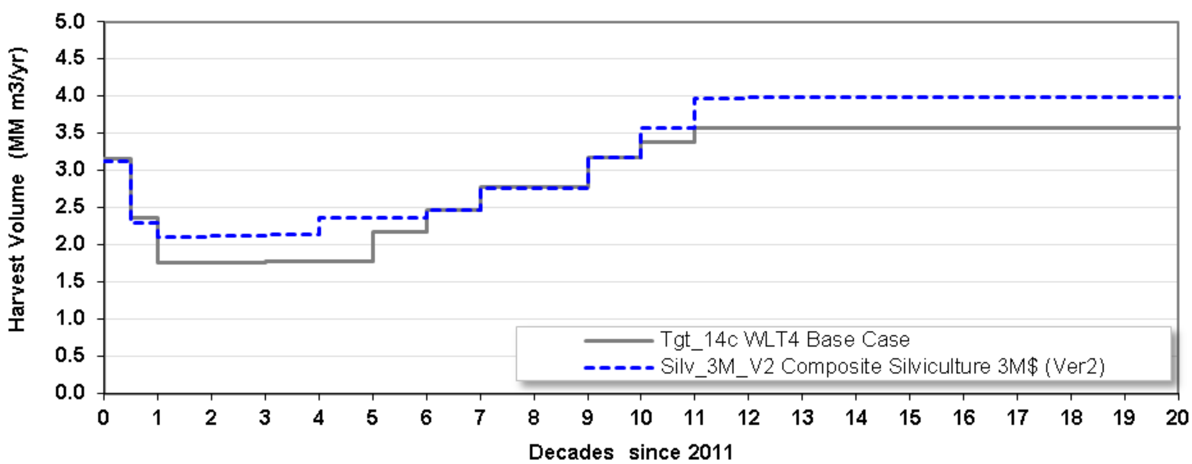


Figure 53 Harvest flow: Base Case compared to composite strategy at $3M/yr

5.9 Composite Mix of Strategies – Budget of $5 Million/year

Similar to the previous scenario all of the above-mentioned strategies were available to the model. In this case, however, the budget was increased to a more favourable level of $5M/yr. The increased funding provides the model with more flexibility to select more treatments that are less responsive than the rehabilitation treatments.

Under this scenario, the silviculture strategies treated nearly 3,000 ha/yr over the first 20 years increasing to 3,400 ha/yr over 100 years (Figure 54) and 4,760 ha/yr after 200 years (not shown). Again, the strategies selected clearly favoured rehabilitation at 69% of areas treated over the first 70 years that dropped steadily afterwards. Like the previous scenario, fertilization initially represented less than 10% of total area treated which increased to over half – more than 3,100 ha/yr - after the mid-term period. Similar trends to the previous scenario were observed for the partial cut, spacing dry-belt Fd and enhanced basic silviculture strategies. Combined, they make up a rather steady component of the areas treated ranging between 10% and 30% (670 ha/yr) over 100 years.

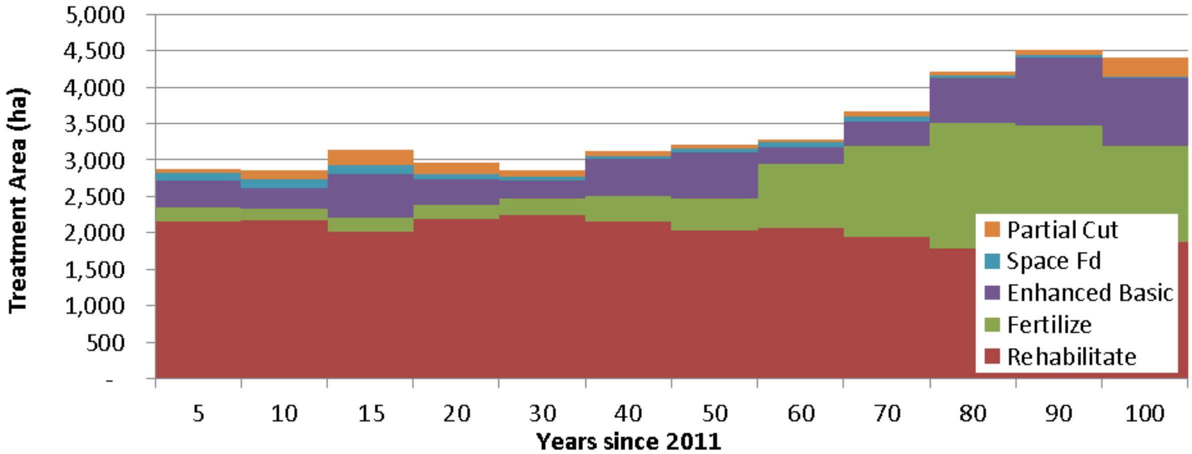


Figure 54 Area treated by silviculture treatment under the composite strategy at $5M/yr

The increased budget for this composite scenario ($5M/yr) is maximized throughout the first 100 years (Figure 52); 83% of this is spent on rehabilitation.

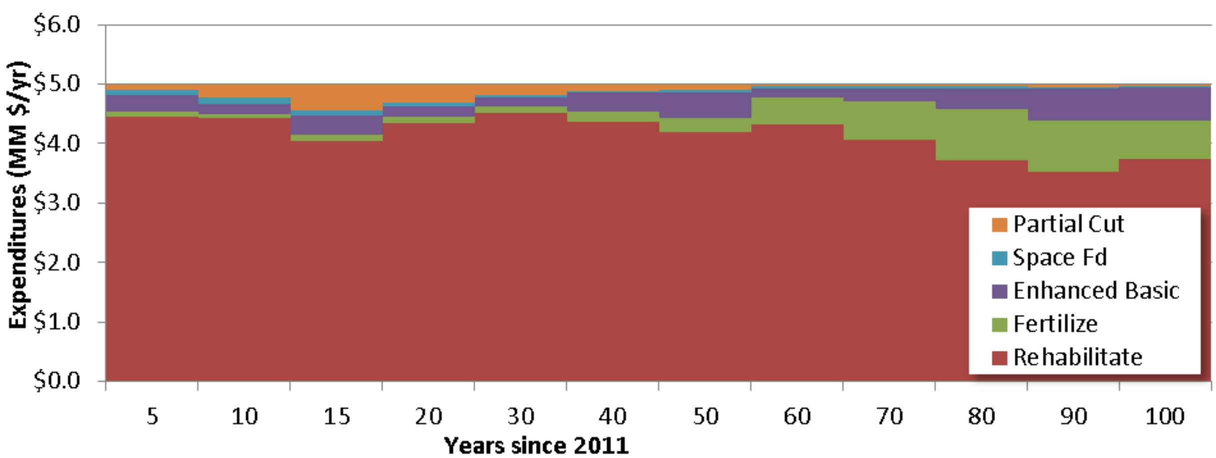


Figure 55 Expenditures over time by silviculture treatment for the composite strategy at $5M/yr

Figure 56 shows the harvest flow is considerably improved by combining all silviculture strategies at a budget of $5M/yr. Compared to the Base Case, the mid-term harvest level increased by 501K m^3/yr (28%) over the Base Case while the long-term harvest level increased by 600K m^3/yr (17%).

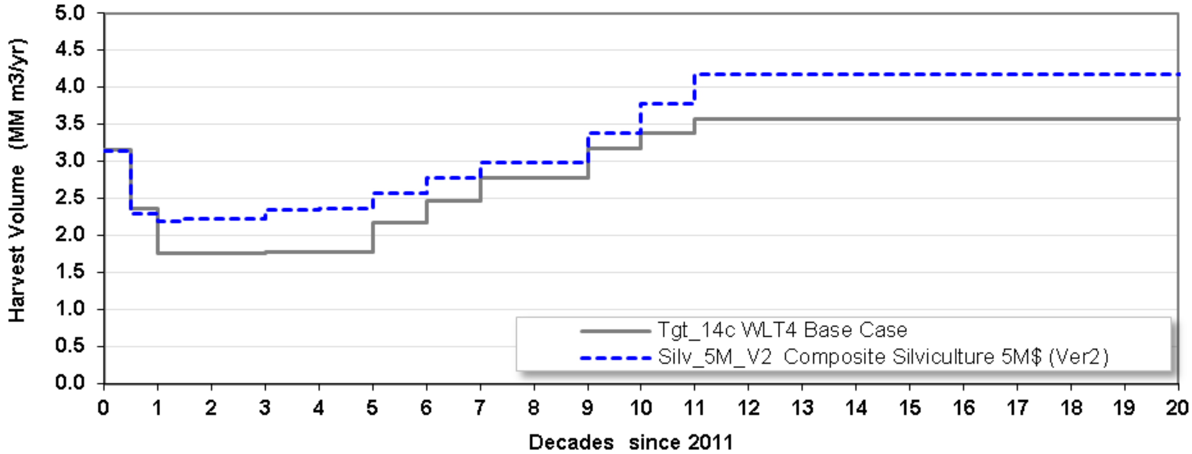


Figure 56 Harvest flow: Base Case compared to composite strategy at $5M/yr

6 Economic Considerations

The following section evaluates silviculture strategies using both stand- and forest-level economic criteria by providing relative comparisons of different strategies. The investment efficiency of alternative silviculture treatments were assessed using net present value (NPV) calculations (i.e. the present day value of a series of costs and revenue(s) that occur over time). This is one way to compare alternative investments that can be used at the forest level by valuing the incremental timber supply as it occurs against the investments made to deliver these gains. This often can look more attractive than stand-level assessments because investments made today can produce harvest volume increases quickly through an allowable cut effect (i.e., that solve pinch points).

6.1 Stand-level

The following assumptions were applied to calculate stand-level NPVs:

- 2% discount rate and a net economic benefit to the crown of $25/m^3 on the additional volume realized.[9] The economic benefit to the licensee would be additional but is not included here as the investor (crown) would not realize this benefit directly. The $25/m^3 value provides a basis for relative comparisons between treatments – site specific values should be used to evaluate actual investment opportunities.
- Multiple Fertilizations (including Single Fertilization)
    - 10-year harvest delay from time of last fertilization application

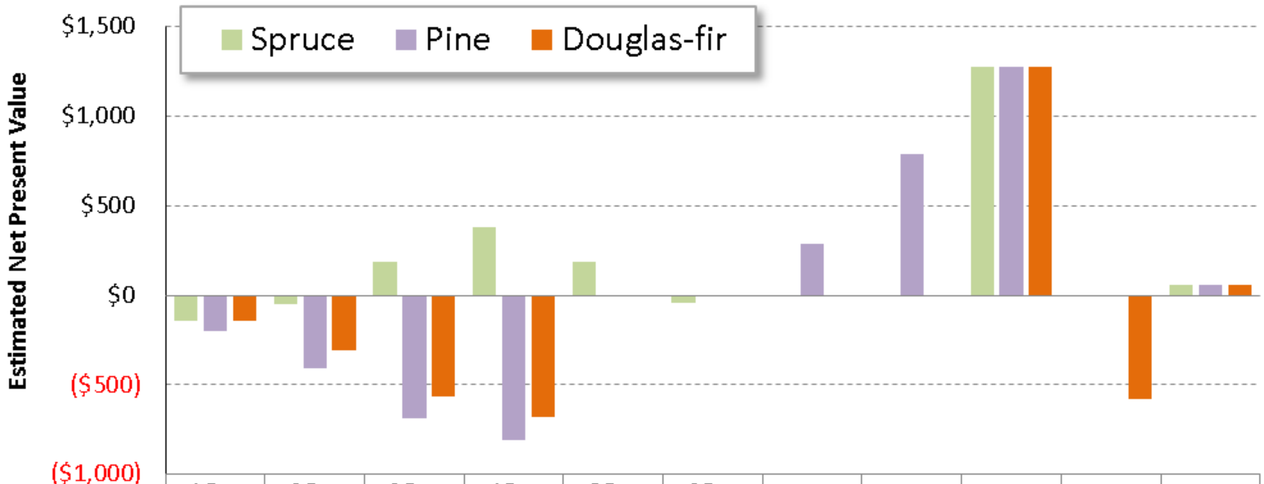
[9] $25/m³ was used as a generic value for all situations for this exercise and is meant to reflect the economic benefit to the crown (the investor) through stumpage, taxes and fees collected as the cubic meter moves through the economy.

Source - (Unpublished report prepared for the Forest Sector Climate Action Steering Committee, Forest Carbon Subcommittee c/o BC Ministry of Forests, Lands and Natural Resource Operaionts, Forest Practices and Investment Branch): Forsite Consultants Ltd., EcoRessources Carbone Inc., ESSA Technologies Ltd. and Thrower, J. Implementing Forest Carbon Offset Projects at the Management Unit Level in British Columbia – Results and Recommendations from Testing on Pilot Areas in BC's Interior and Coastal Regions. June 13, 2011. 123pp.

- Pl: Treatment cost of \$450/ha; revenues of \$300/ha, \$600/ha, \$900/ha, \$1100/ha (\$25/m³ times 12m³/ha) for 1, 2, 3, and 4 applications, respectively; realized 20, 30, and 40 years from first treatment
- Sx: Treatment cost of \$600/ha applied in 5-year intervals; revenues of \$375/ha, \$1125/ha, \$2225/ha, \$3300/ha, \$3875/ha, \$4400/ha (\$25/m³ times 15m³/ha, 49m³/ha, 89m³/ha, 132m³/ha, 155m³/ha, 176m³/ha) for 1, 2, 3, 4, 5 and 6 applications, respectively; realized 10, 15, 20, 25, and 30 years from first treatment
- Fd: Treatment cost of \$450/ha; revenues of \$375/ha, \$750/ha, \$1125/ha, \$1500/ha (\$25/m³ times 15m³/ha) for 1, 2, 3, and 4 applications, respectively; realized 20, 30, and 40 years from first treatment

- Rehabilitation
  - For marginal and uneconomic sawlog recovery classes (respectively): net treatment costs (after utilizing any merchantable timber) of \$1500/ha and \$2000/ha plus additional distance costs for cycle time zones (<5 hrs @ \$0/ha, ≥5 & <7 hrs @ \$50/ha, ≥7 hrs @ \$250/ha); revenue of \$5000/ha (\$25/m³ times 200m³/ha) realized 60 years from treatment
- Partial Cutting in Constrained Areas
  - Incremental treatment cost of \$7.50/m³ for partial cutting on slopes <40% and \$12.50/m³ on slopes ≥40% (90%/10%); revenue of \$1875/ha (\$25/m³ times 75 m³/ha); realized when harvested immediately.
- Spacing Dry-Belt Douglas-fir
  - Treatment cost of \$1100/ha for PCT and \$450/ha for fertilization; revenue of \$500/ha (\$25/m³ times increased initial entry harvest volume 20 m³/ha (10% of average Fd stand volume 200 m³/ha); realized 55 years from treatment
- Enhanced Reforestation
  - Treatment cost of \$500/ha for incremental activities; revenue of \$1500/ha (\$25/m³ times 60 m³/ha); realized when harvested after 50 years

Using these assumptions, Figure 57 shows the stand-level NPVs calculated for each silviculture strategy. At a 2% discount rate, favourable NPVs were calculated for multiple-fertilization of spruce stands and rehabilitating MPB-killed stands. Spacing dry-belt Douglas-fir stands and fertilization of pine stands led to negative NPVs; mostly due to small volume response and long intervals between investment and return.



	1 Fert 10 years prior to harvest	2 Fert 10 years prior to harvest	3 Fert 10 years prior to harvest	4 Fert 10 years prior to harvest	5 Fert 10 years prior to harvest	6 Fert 10 years prior to harvest	Rehab @ $2000/ha (Unecon)	Rehab @ $1500/ha (Margin)	Partial Cut 1/3 volume	Space Fd at cost of $750/ha	Enhanced Basic
Spruce	($140)	($47)	$186	$379	$187	($46)			$1,276		$57
Pine	($200)	($407)	($686)	($811)			$286	$786	$1,276		$57
Douglas-fir	($140)	($308)	($564)	($678)					$1,276	$(582)	$57

Figure 57 Stand-level net present values estimated for silviculture strategies (2% discount rate)

All treatments look less attractive when discount rates are increased but those with the longest timeframes between investment and return (e.g., rehabilitation) are the most sensitive. For example, an increase in the discount rate to 4% results in negative NPVs for rehabilitation across all sawlog recovery classes.

6.2 Forest-level

To assess investment efficiency at a forest level, NPVs were calculated for several scenarios by examining the series of silviculture investments and incremental revenue generated from improved harvest levels. This presents a conservative view of the scenarios because some investment costs made near the end of the period were included but the returns generated were not.

Timber supply dynamics make NPVs look considerably different at a forest-level compared to the stand-level. Figure 58 shows the NPVs calculated for the composite (optimized) silviculture treatments strategies at both the $3 M/yr and $5 M/yr budget levels. Both strategies begin with a negative NPV as costs are incurred and no revenue is realized. The incremental volume realized throughout the mid-term / long term contributes to positive NPVs except immediately following the mid-term (5th decade) when a lower level of incremental harvest volume is scheduled and yet costs remain the same.

Over the entire planning period, the total NPV for the $3 M/yr and $5 M/yr budget levels were $122.7 M and $182.6 M, respectively. The $5 M/yr scenario is financially more attractive because the increased annual budget leverages the most cost effective investments to achieve most of the potential harvest gains.

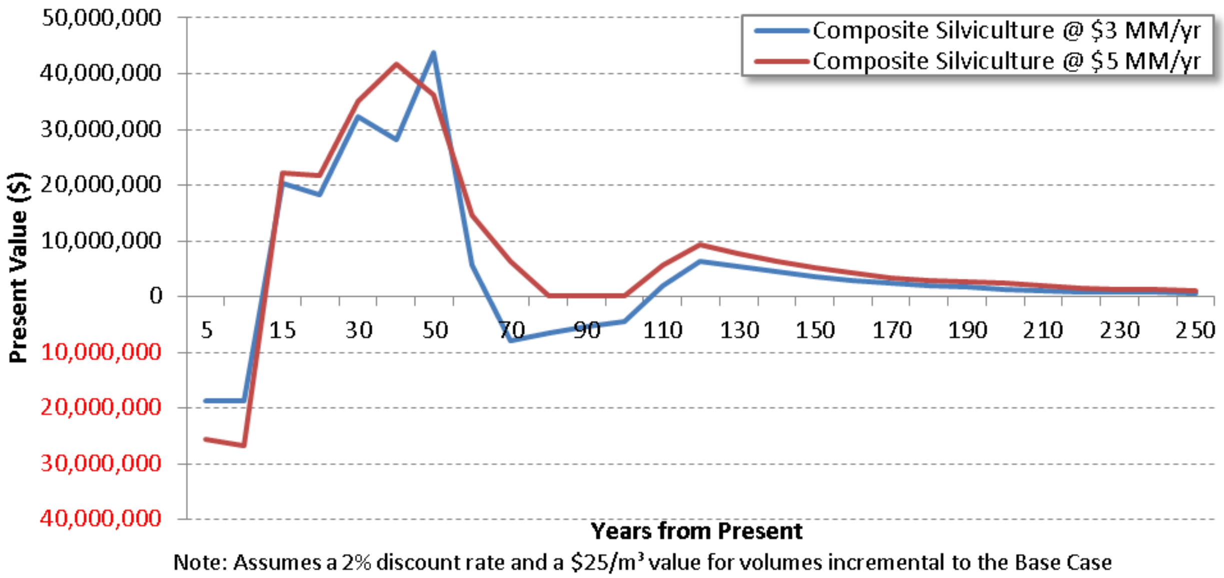
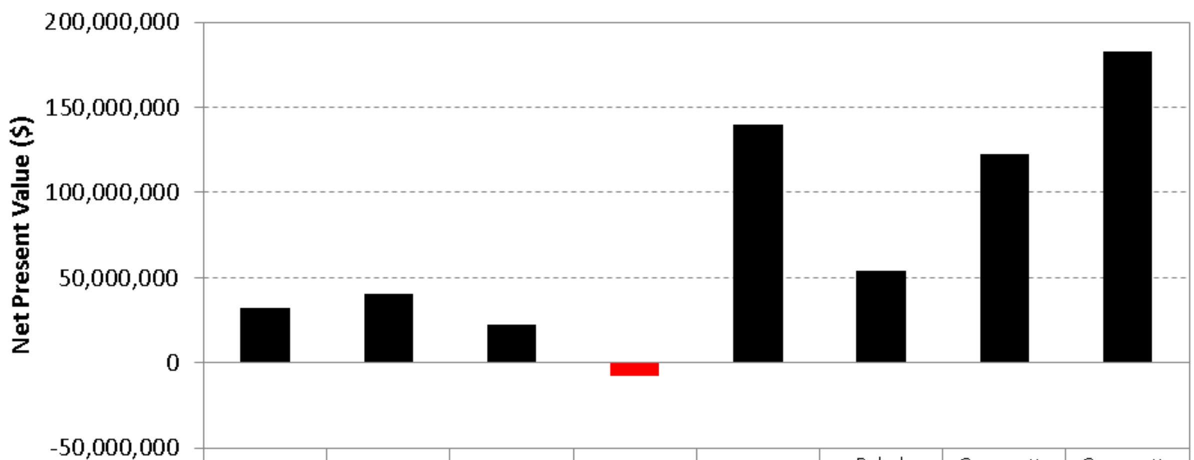


Figure 58 Present values for the composite strategies

A comparison of NPVs for all of the silviculture strategies explored (Figure 59) shows that at a 2% discount rate, both the $3 M/yr and $5 M/yr composite silviculture programs produce a positive NPV – or an internal rate of return (IRR) greater than 2%. It also shows that the partial cut from constrained areas strategy is economically very efficient since there is no delay between the time when costs are incurred and revenues are realized. Accordingly, this particular strategy is shown as favourable at both the stand and forest levels.



	Fertilization only - One Application	Fertilization only - Multi-Applications	Space Dry-belt Fd Stands	Enhanced Basic Silviculture	Partial Cut Constrained Areas (rmz)	Rehab MPB-impacted Stands	Composite Silviculture @ $3 MM/yr	Composite Silviculture @ $5 MM/yr
NPV ($)	32,096,173	40,341,797	22,662,666	-8,092,028	139,604,676	53,922,190	122,654,498	182,554,122

Figure 59 Net present values for each silviculture strategy relative to the Base Case

7 Discussion

The WLT4 Base Case applies the most current information available for forest tenures, inventories, MPB impacts, and managed stand site index estimates for the Williams Lake TSA. Compared to recently published forecasts these updates, including a revised approach for addressing dead pine degeneration (shelf-life), result in a significantly lower initial growing stock and faster degeneration of the dead pine. This produces a much faster drop, and a deeper mid-term trough.

Shelf-life assumptions play a significant role in determining the timing and level for the mid-term harvest period. In this analysis, dead pine volumes steadily diminish to 0%, 15 years after the YOD assigned to the stand (2006). This assumption is based on suggestions that much of the volume killed early in the infestation has already degraded too much to be economically viable to process.

The harvest forecast and harvest attributes imply the period of salvaging dead stands is virtually over. Consideration of an immediate reduction in harvest levels (or partitioned cuts) may be required to meter out existing green stand volumes and reduce the mid-term trough.

Many of the non-timber resource constraints were immediately violated in the model because heavily MPB-impacted stands were set to age 0 at the YOD.

Harvesting (or more properly, rehabilitation) of stands that have lost MPB-killed volume and are now below the minimum volume threshold for harvest will increase the mid and long term harvest levels.

The WLT4 Base Case provides a reasonable benchmark to assess potential silviculture strategies aimed at improving timber and non-timber outcomes in the Williams Lake TSA. Some general ways that mid-term harvest levels may be increased:

A. Defer harvesting in the short-term (e.g., avoid salvaging stands with sufficient green volume)
B. Increase volume of immature stands with current ages between 40 and 60 years (e.g., single, late rotation fertilization; partial cutting)
C. Shift available volume from the transition period to the midterm by increasing volumes of young stands with current ages between 10 and 40 years (e.g., multiple fertilization)

Table 3 summarizes the harvest flow improvements, relative to the Base Case, resulting from the silviculture strategies modelled. The strategy that best alleviates the mid-term trough was the combined silviculture treatment strategy that allows the model to select from the full suite of treatments with an annual budget of $5 M/yr.

Table 3 Summary of harvest flow differences for silviculture strategies relative to the Base Case

Scenario Type	Scenario	Short-Term		Mid-Term		Rise to Long-Term		Long-Term	
Base Case Sensitivities	80m3 pre/post SL	336,000	12%	363,000	21%	359,000	13%	188,000	5%
	110m3 pre/post SL	(114,000)	-4%	(159,000)	-9%	(23,000)	-1%	(214,000)	-6%
	Revised Shelf-Life	426,000	15%	4,000	0%	639,000	23%	182,000	5%
	Harvest sequence (1)	(234,000)	-8%	143,000	8%	2,000	0%	-	0%
	Harvest sequence (2)	(744,000)	-27%	251,000	14%	(1,000)	0%	-	0%
Silviculture Scenarios	Single Fertilization	1,000	0%	39,000	2%	128,000	5%	193,000	5%
	Multiple Fertilization	(14,000)	-1%	149,000	8%	185,000	7%	248,000	7%
	Spacing dry-belt Fd	(4,000)	0%	50,000	3%	15,000	1%	-	0%
	Rehabilitation	(3,000)	0%	147,000	8%	353,000	13%	463,000	13%
	Enhanced Basic Reforestation	(4,000)	0%	83,000	5%	69,000	2%	433,000	12%
	Partial cut in constrained areas	(4,000)	0%	241,000	14%	(8,000)	0%	(2,000)	0%

	Mix Strategies ($3 M/yr)	(54,000)	-2%	397,000	22%	59,000	2%	400,000	11%
	Mix Strategies ($5 M/yr)	(44,000)	-2%	501,000	28%	284,000	10%	600,000	17%

Note: Short-term = years 0-10; Mid-term = years 11-50; Rise to Long-term = years 51-110; Long-term = years >110

This modeling and analysis work explored opportunities to improve timber quantity, timber quality and non-timber values. The following points summarize some of the key trends learned from this exercise:

- The Williams Lake TSA will begin experience a severe shortage of available volume in 30 years (33.4 M m³; ~36% of current) lasting 3 decades.
- The approach applied in this analysis was to first develop a base case scenario that reflects a realistic harvest forecast. We learned from this, and other analyses[10], that the harvest flow is very sensitive to assumptions involving salvage effort, shelf-life, and minimum harvest criteria.
- Fertilization is an important strategy but not as time-sensitive as others. There are several decades before any of the managed stands will be harvested so there's plenty of time to treat them. First, the model selected treatments that offer more immediate and/or larger gains; then fertilization increased as treatment windows closed.
- Single-fertilization treatments are best carried out closer to harvest to maximize the NPV and minimize risk – but this approach should be used to fully utilize available budgets to ensure the benefit is captured. While there may be more opportunities for multiple-fertilization treatments sooner, risk of investment loss are increased as costs are carried longer.
- Cumulative gains from multiple-fertilization of spruce stands make this treatment the most favourable approach. Still, fertilization of pine stands should not be overlooked given the relative abundance of these stands.
- Because of the 30-year response period, spacing dense thickets of dry-belt Douglas-fir must be carried out early on to provide harvest level gains at the end of the mid-term.
- Rehabilitation provides the largest opportunity to improve harvest flows and warrants significant investment. This treatment accesses wood throughout the mid-term from MPB-impacted stands that are otherwise assumed to be ineligible for harvesting. It also adds to the long-term harvest by putting these stands back into production.
- The area eligible for rehabilitation is largely dependent on access, market prices for fibre and innovative funding mechanisms to promote rehabilitation. This treatment should initially focus on treating younger or burned stands and those with lower merchantability while deferring stands with live volumes that can rehabilitated in the mid-term.
- The enhanced basic silviculture strategy (planting at higher densities with improved genetic stock) makes some treated stands available for harvest within 35 years. This results in significant timber supply gains near the end of the mid-term (30-50 years from now), as well as, in the long-term (110+ years). Given the current elevated harvest levels, significant opportunities exist for this strategy. While licensees may be able to shift towards this strategy, this strategy requires administrative changes that provide incentives for excellence (vs. regulating minimums).

[10] Forsite Consultants Ltd. (2013). Quesnel TSA - Type IV Silviculture Strategy, Data Package. Technical Report.
Forsite Consultants Ltd. (2013). Lakes TSA - Type IV Silviculture Strategy, Data Package. Technical Report.

- Partial harvesting within constrained areas is the only strategy identified to help fill in the front of the mid-term. Provided forest cover and ecosystem functions remain intact, or improve, this strategy can borrow volume that is otherwise available later in the forecast (i.e., no extra volume).
- Both Composite Scenarios ($3M and $5M budgets) are similar in treatment selections and proportions. Using a 2% discount rate, they both provide positive NPV at the forest level.
- Regardless of the budget allocated to alleviate the mid-term timber supply shortage, a combination of scheduled activities produces the highest overall gains in timber supply and return on investment.

This analysis utilized an inventory that is largely un-verified given the recent MPB impacts. Uncertainty around existing volume estimates leads to uncertainty with mid-term harvest levels. If the current inventory overestimates growing stock, then the mid-term harvest levels presented in this analysis will be substantially lower. While the current forest inventory is disconcerting, it should not detract from the results and learning from this analysis. Instead, our focus should be on the relative differences between the Base Case and modeled strategies rather than absolute harvest flow values.

This analysis does not attempt to provide a comprehensive assessment of the full range of treatments available to mitigate mid-term timber supply shortages. The silviculture treatments investigated in this analysis were selected based on expectations that they might: a) increase the productivity of the landbase, b) increase volumes at final harvest, or c) enhance the quality of harvested products to maximize economic contributions from this fibre. While assumptions were made to reflect the cause and effect relationships expected, existing knowledge gaps and the possibility of unforeseen circumstances (i.e., wildfires, outbreaks of forest insect and disease) must also be considered.

It is clear that no single treatment will solve the forecasted mid-term timber supply shortage. Rather, a diverse suite of scheduled strategies is required that consider the costs, benefits, risks and temporal aspect of forest dynamics.