Quesnel TSA – Type 4 Silviculture Strategy

Modeling and Analysis Report

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Prepared by:

Forsite Consultants Ltd.
330 – 42nd Street SW
PO Box 2079
Salmon Arm, BC V1E 4R1
250.832.3366

Prepared for:

BC Ministry of Forests, Lands and Natural Resource Operations
Resource Practices Branch
PO Box 9513 Stn Prov Govt
Victoria, BC V8W 9C2

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1 Introduction

The BC Ministry of Forests, Lands and Natural Resource Operations initiated a Type 4 Silviculture Strategy for the Quesnel Timber Supply Area (TSA). A timber supply review (TSR) was recently completed and an allowable annual cut (AAC) was determined at 4,000,000 m^3 per year effective January 11, 2011. The Quesnel TSA TSR Technical Report provides a good base from which to pursue strategy development and/or more fully explore critical issues such as shelf-life, mountain pine beetle (MPB) related salvage strategies, priorities, and post-beetle timber supply. For many years, the Quesnel Mitigation Committee has been an active group and has compiled an extensive library of analyses, documents and information that were integrated into the Type 4 Silviculture Strategy.

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 –provides modeling outputs and rationale for choosing a preferred scenario.**
- Silviculture Strategy –provides treatment options, associated targets, timeframes and benefits.

The purpose of this Type 4 Silviculture Strategy is to understand what status quo management is expected to deliver in the future and provide direction on how changes to management could impact future outcomes. It will also provide – through a tactical plan – general direction on where and when to invest in incremental silviculture activities to meet TSA goals in the future.

The background assumptions to this analysis are documented in the Data Package published simultaneously with this report. Within it, several key assumptions are identified and flagged as sources of significant uncertainty (e.g., shelf-life, current live/dead volumes, managed stand site productivity, MPB impacts in young stands).

2 Base Case

The results presented in this section describe outcomes for three broad areas: 1) timber quantity 2) timber quality and 3) non timber value outcomes.

2.1 Timber Quantity

The following sections discuss characteristics on the amount of timber associated with the Base Case harvest forecast for the Quesnel Type 4 Silviculture Strategy (QT4).

2.1.1 Harvest Flow

Figure 1 shows the QT4 Base Case harvest forecast resulting from the modeling work and assumptions documented in the Data Package (Forsite 2013) compared with the harvest forecast from the Mid-Term Project (MFLNRO 2012). Volumes reported include conifer-leading stands only (incidental deciduous volume in the conifer-leading stands is included). The initial harvest level reflects the current AAC – 4 million m³/yr – maintained for just 5 years, then drops sharply to 1.7 million m³/yr. The harvest remains at this level for 4 decades then climbs up to the long-term harvest level in the 4th and 5th decades from now. A long-term harvest level of 2.73 million m³/yr is achieved after 65 years. Section 2.4 (page 11) provides a discussion of the differences between harvests flows.

Key assumptions behind this forecast include the use of new inventory data (LVI), a salvage focus for the next 5-6 years (beyond which shelf-life is exhausted), and consistently successful regeneration of managed stands using SIBEC site index estimates.

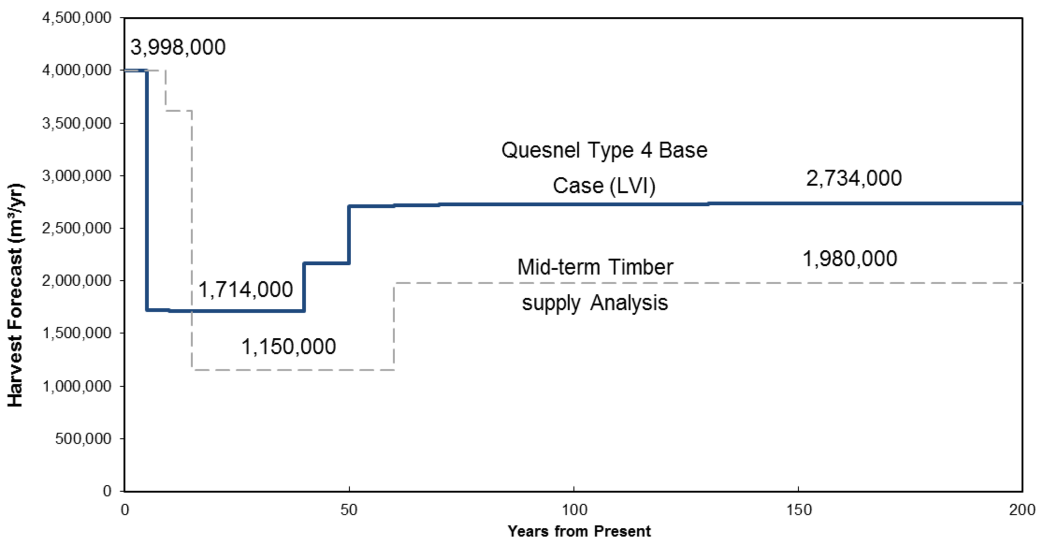


Figure 1 Harvest flow: Base Case compared to the Mid-Term Project

2.1.2 Harvest Flow Details

Figure 2 provides the harvest flow themed by species group and condition – dead pine, live pine, other conifers (mostly spruce and Douglas-fir), and deciduous. This graph was compiled from a report that accounts for individual species (as opposed to leading species) and does not show harvest in deciduous leading stands. During the first five years (2011-2015), dead pine makes up 52.5% of the total harvest and drops to only 14% during the next 5-year period (focused in years 6 and 7). The dead volume that does not get salvaged within the 14 yr shelf-life is assumed to be non-merchantable.

The harvest of non-pine species increases to 46% at the beginning of the mid-term, reflecting a sharp decline in merchantable pine. Afterwards, stand replacement begin to adopt a more cyclical pattern.

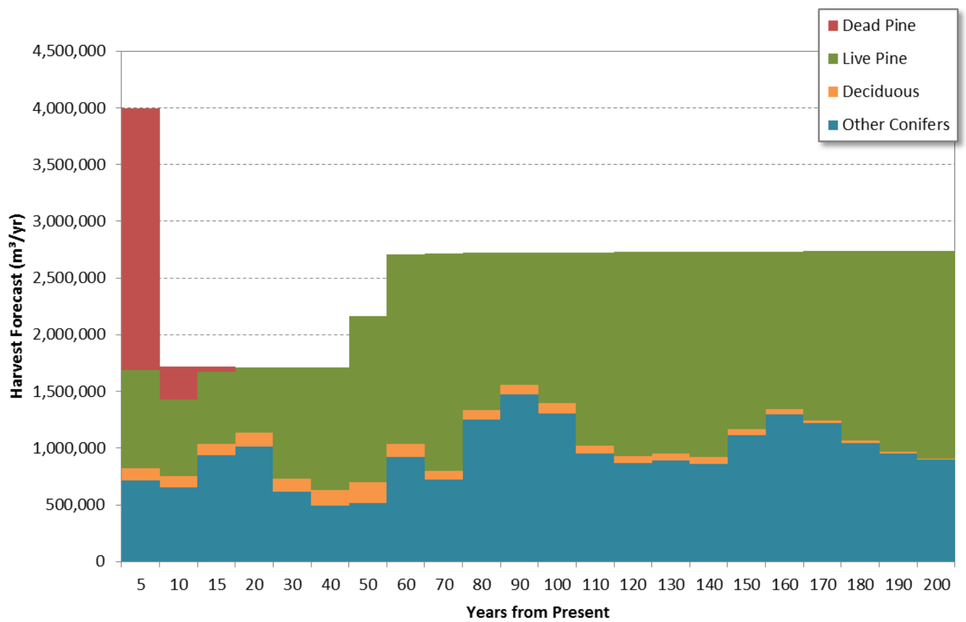


Figure 2 Harvest forecast by individual species group

Natural and managed stand contribution is included with the harvest flow in Figure 3. Harvesting of existing managed stands begins as early as 25 years from now. After the 4rd decade, managed stands - both future and existing - make up the majority of the harvest. Harvesting natural stands persists over time because of selection harvests (UWR and caribou) and impacted Pl stands eventually becoming eligible for harvest as understory regeneration reaches merchantable ages.

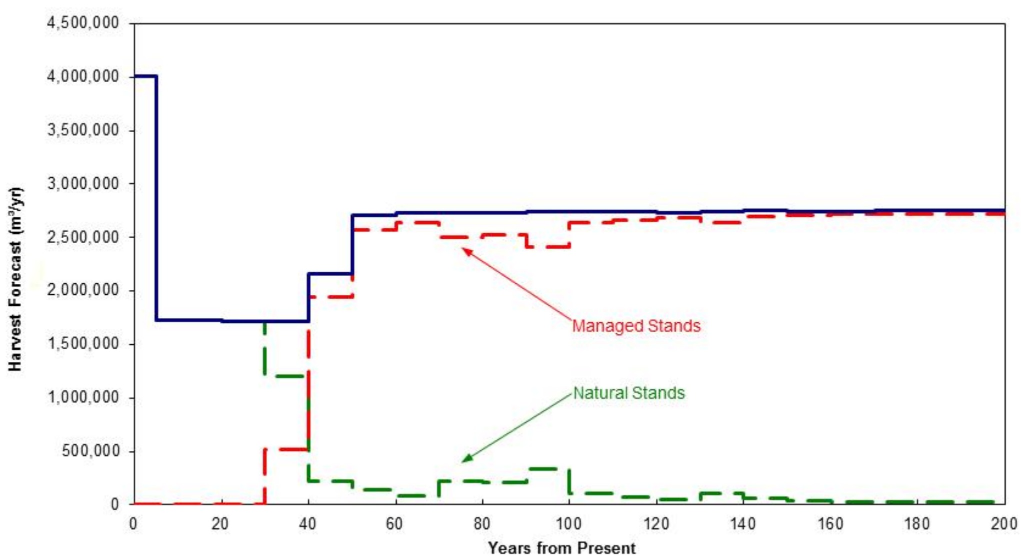


Figure 3 Transition of natural stands to managed stands

Figure 4 shows the deciduous <u>leading</u> stand harvest volume over time (not included with the harvest flows shown above). Harvesting these stands was not directly controlled in the model so harvest levels tend to fluctuate. The modeling priority for harvesting dead pine in the first 5 years influenced the harvest of dead pine within the deciduous-leading stands. All deciduous stands were assumed to come back as deciduous and thus show up again later the in forecast shown below.

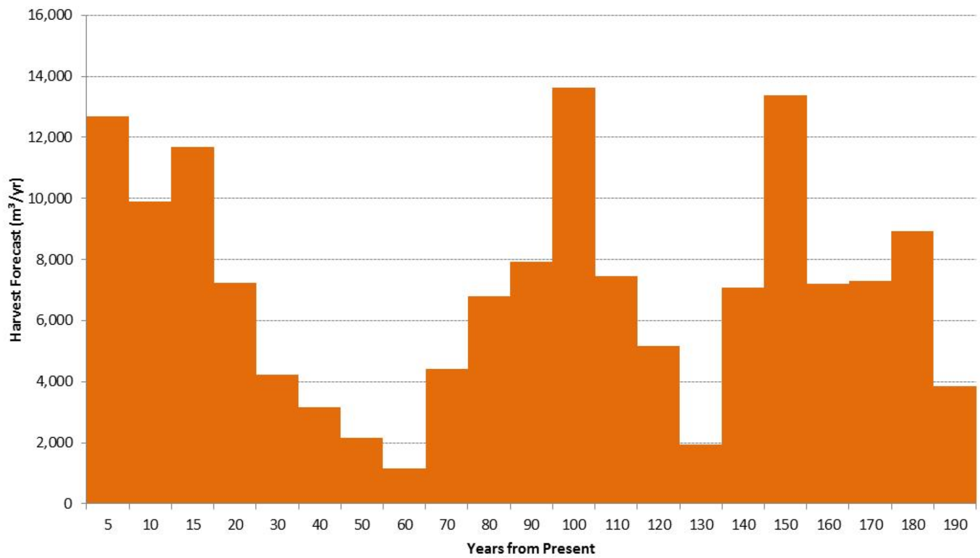


Figure 4 Harvest forecast of deciduous leading stands

The TSA was grouped using landscape units, to illustrate the harvest contribution from three regions (West, Center, East – see Figure 5). The harvest proportion from the Center is quite consistent at 44% throughout the forecast. Initially, the harvest proportion from the West matches the Center region, then decreases to 37% throughout the mid- and long-terms while harvest from the East region increases slightly. Harvesting economics were not considered or controlled in the model (i.e. hauling distance, product values, harvesting costs etc.).

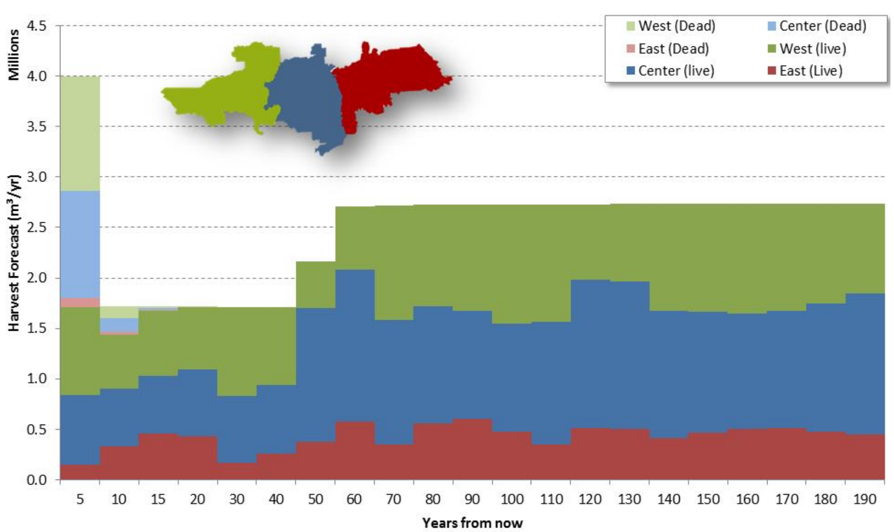


Figure 5 Harvest forecast by region

2.1.3 Growing Stock over Time

The total and merchantable growing stock is shown in Figure 6. The initial growing stock is approximately 115.2 million m³ of which approximately 102 million is considered eligible for harvest (i.e. has at least 120 m³/ha sawlog volume).

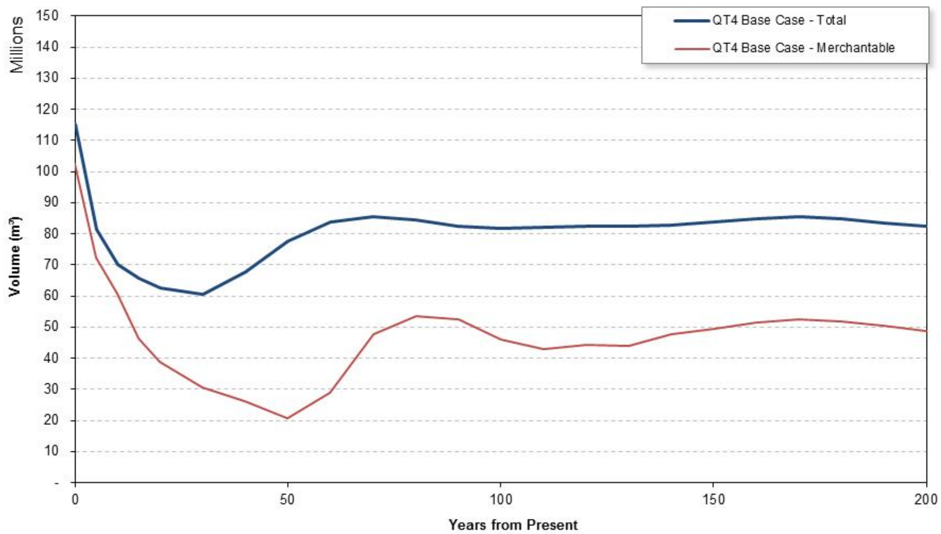


Figure 6 Merchantable and total growing stock on the THLB

Over the first 30 years of the forecast, harvesting depletes the growing stock on the THLB to nearly half (60 million m³) of the current volume. The lowest level of merchantable growing stock (20 million m³) occurs after 50 years in the last decade of the mid-term. The growing stock begins to recover once stands harvested or killed earlier on, begin adding significant volume. Both total and merchantable growing stock reaches essentially stable levels 70 years from now.

The same growing stock themed by condition, percent dead class, and post-succession origin is shown in Figure 7. Initially, 38.6 million m³ (14% of total growing stock – red and pink in the graph) is considered to be dead and merchantable. Of this dead volume, approximately 24 million m³ is harvested (63% of the initial dead volume) over the first two decades. The remaining un-harvested volume (~25.1 million m³) is assumed to decline according to the shelf-life rules. Stands that contain non-merchantable pine shift to become light brown and tan in the graph. To be eligible for harvest once again, these stands must first meet minimum harvest volumes from just the live component (mature and regenerating) of the stand.

A significant amount of MPB impacted stands are unsalvaged and their live volume continues to persist for the entire planning horizon (i.e. never gets harvested). The persistence of this volume occurs for one of two reasons (or both): stand growth assumptions never recover to reach minimum harvest volumes or the model selects these lower volume stands to satisfy cover constraints (i.e. caribou, ungulate winter ranges, and mature+old constraints) thereby minimizing timber supply impacts.

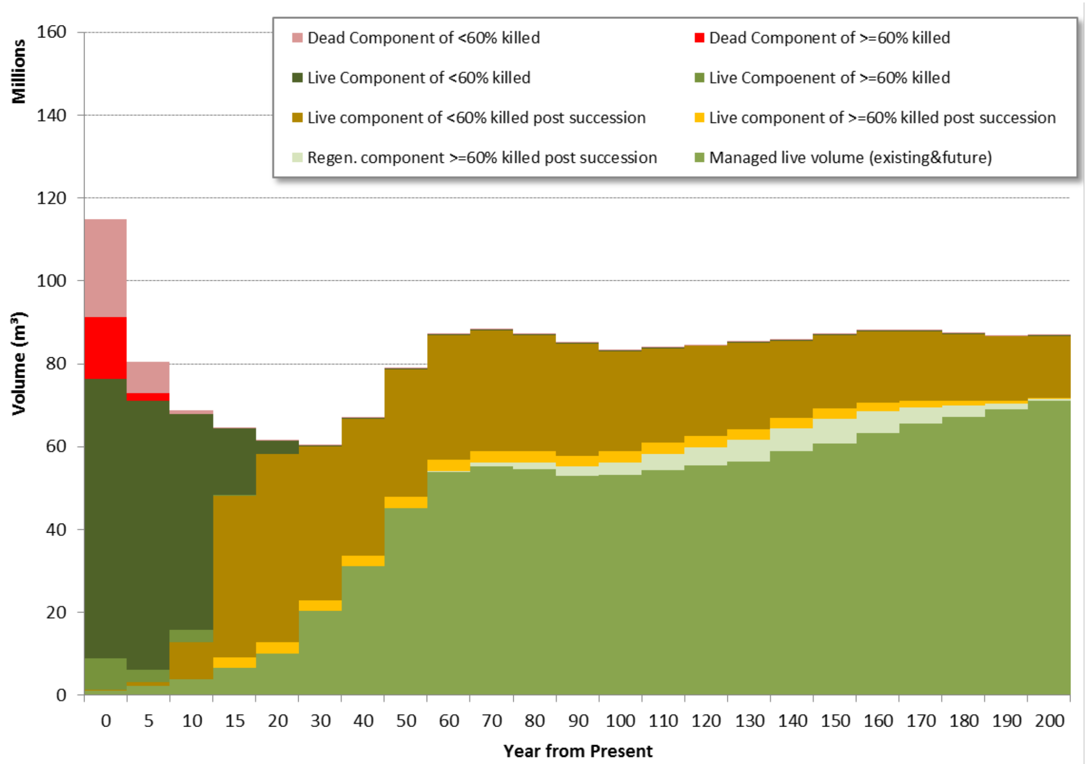


Figure 7 Total growing stock by stand condition

2.2 Timber Quality

The following sections discuss characteristics on the quality of timber associated with the Base Case harvest forecast.

2.2.1 Average Harvest Age, Volume Yield, and Area

The average volume yield (m^3/ha), annual area harvested, and average harvest age are shown in Figure 8. While the minimum harvest age was set to the age at which stands achieve 120 m^3/ha of sawlog volume, the average harvest yield throughout most of the planning horizon is above ~200 m^3/ha. The lowest average yields occur within the next 5-15 years, because lower volume stands in the western portion of the TSA contribute a significant portion of the forecast in the early periods and also because of the reduced volumes salvaged from deteriorating pine stands. The transition to second growth (managed) stands begins in the 4th decade while the youngest harvest profile occurs in the 6-7th decade (Figure 9). Average harvested volume continues to increase until the 9th decade when harvested stands are the oldest of the second growth stands. This also marks the end of the cohort of regenerating Pl stands passing through the harvest queue. The average long-term harvest volume is 225 m^3/ha.

The average harvest age is artificially low at the beginning of the planning horizon as harvesting is concentrated in severely impacted stands (>=60% impact), which had ages set to 0 at time of attack. Average harvest age peaks 20 years from now when the harvest is largely composed of older non-pine stands in the Center portion of the TSA. The lowest average harvest age occurs in the 6th decade with an average of 69 years.

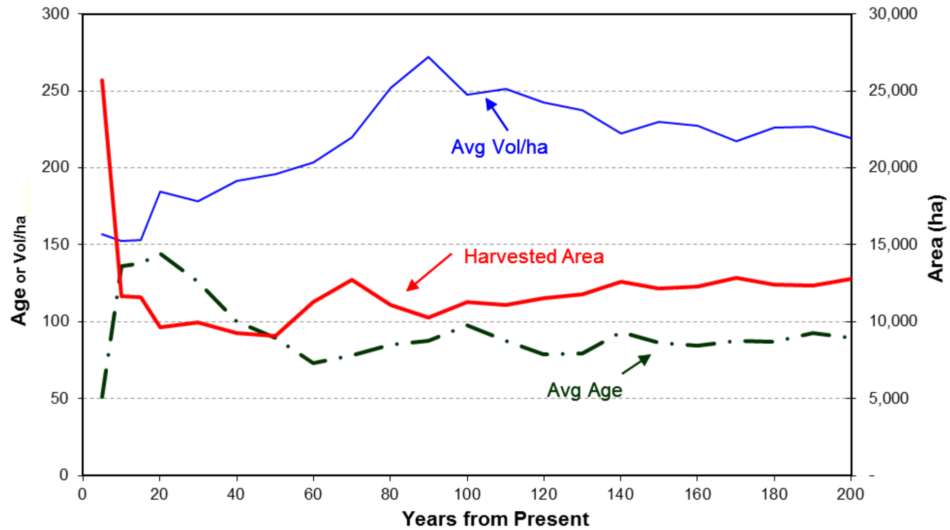


Figure 8 Average harvest age, harvest area, and volume yield

For additional insight into the harvest treatment ages, Figure 9 provides the area harvested by age range. Again, the stands initially harvested with treatment ages <20 indicate severely impacted stands (>=60% impact) whose ages were set to 0 at time of attack. In the 6th decade, the harvest relies heavily on stands between 50-59 years.

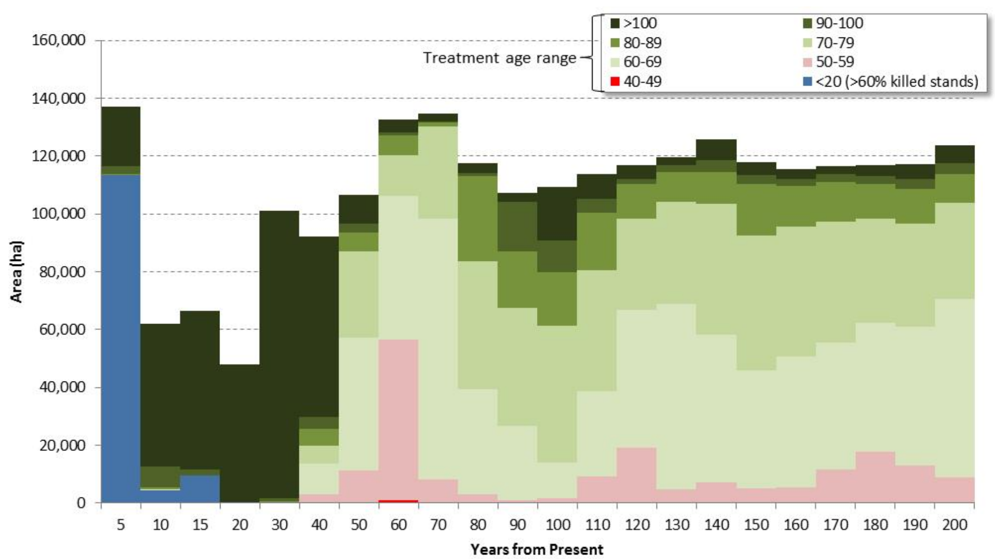


Figure 9 Harvest treatment area by age range

2.2.2 Product Profiles

Harvest operability assumptions apply a minimum stand volume (m^3/ha) that reflects the smallest logs that mills (communities) will need in the mid-term. Once stands reach the age considered economic to harvest, they become eligible for harvest in the model. During final decades of the mid-term (50-80 yrs from now) then, the model harvested considerable areas of young stands aged 40-70 years (Figure 9) that are relatively dense (1000 stems/ha), relatively low in volume (120-150 m^3/ha), and yield relatively small piece sizes (0.12 m^3). During this time, few larger diameter products such as peelers and house logs will be available.

2.3 Non Timber Value Outcomes

The following sections describe the outcomes of the non-timber and environmental considerations that were incorporated in the model. In most cases, only examples are provided since the full detail of these considerations is very lengthy and cumbersome.

2.3.1 Age Class over Time

Figure 10 shows the age class distributions for both the THLB and non-THLB, 0, 50, 100, and 200 years from now. Because ages of stands with >=60% MPB mortality were initially set to 0, a large area of the forested land base is currently identified in the 0-10 year age class. Fifty years into the future, however, the age class distribution begins to concentrate within the 0-70 year age classes. By year 100, a normalized forest develops with relatively even age classes less than 80 years (average harvest age = ~95). At this time, stands in the 100 year age class reflect poor performing post-MPB succession stands with extended minimum harvest ages or recent fires where regenerating yields are modeled using pre-existing natural yields (using VDYP). Some of these stands remain throughout the planning period while most of the THLB is below 70 years of age.

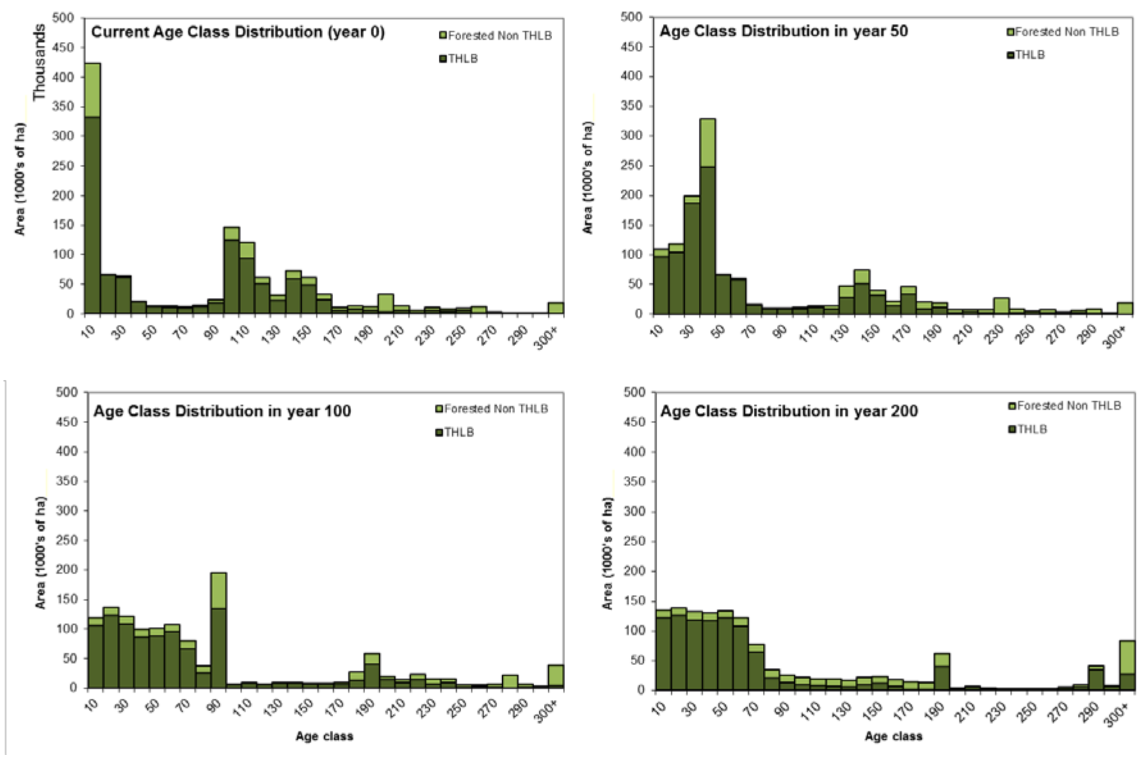


Figure 10 Age class distributions projected to 0, 50, 100, and 200 years

2.3.2 Visual Landscape Management

Figure 11 shows the visual disturbance targets and levels for two example visual landscape management units. Since the significant MPB mortality was assumed to reset stand ages, many of these units begin well above the target levels but the applied constraints then limit harvesting in these units so that they recover generally by the 2nd or 3rd decade.

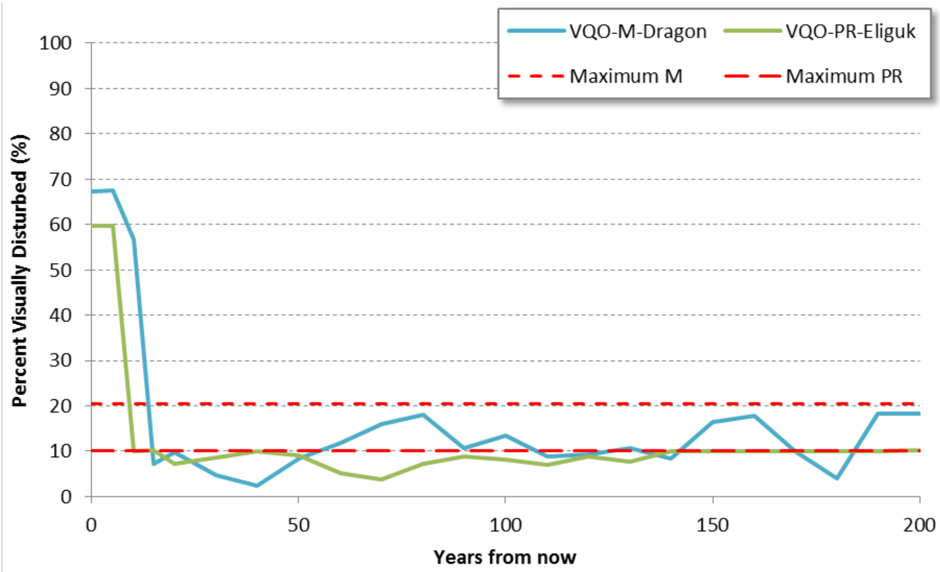


Figure 11 Example scenic and visual performance

2.3.3 Caribou and Ungulate Winter Range

Figure 12 shows the forest cover targets and levels for Caribou Wildlife Habitat Areas (WHA) and Deer Ungulate Winter Ranges (UWR). These were constrained the same way in the model (i.e. minimum of 33% <140 years). Again, some units initially violate the target condition due to the MPB mortality assumptions but these units soon recover due to the constraints applied. Further in the future, these constraints limit harvest opportunities to maintain older stands across the land base as cover and protection for ungulates. The Caribou WHA #5-086 units clearly limit harvesting throughout the entire planning horizon. The other two units do not appear to limit harvest in the mid- and long-terms.

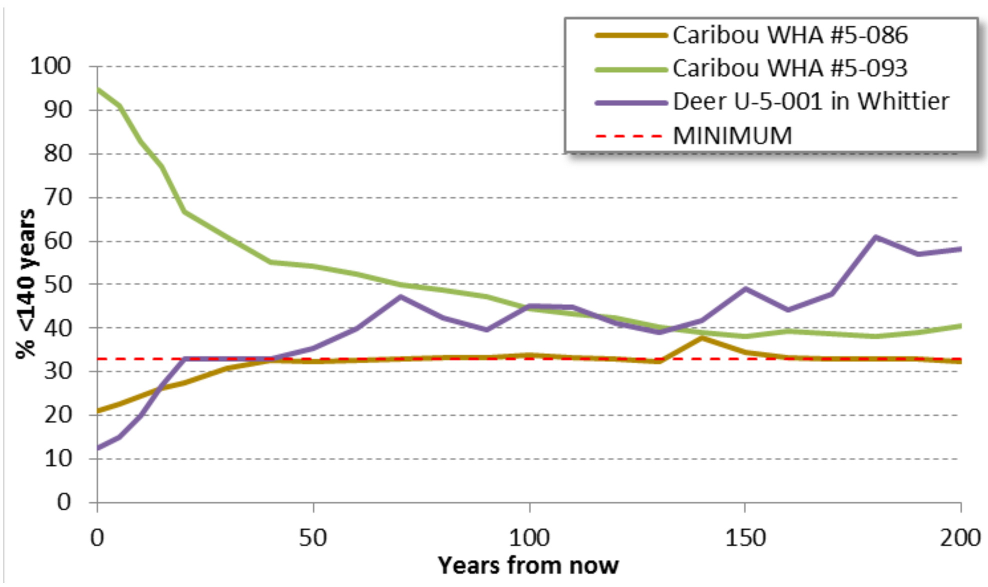


Figure 12 Example Caribou and Ungulate Winter Range performance

2.3.4 Landscape Level Biodiversity

While Old Growth Management areas were excluded from the THLB, Mature+Old (M+O) seral stage objectives were modelled as forest cover constraints. Figure 13 shows examples of the targets and levels for two larger units. The M+O constraints in Baker landscape unit within the SBPSmk and high Biodiversity Emphasis Option (BEO) appear to limit harvest opportunities as the condition is at or near the minimum target for much of the planning horizon. Harvest opportunities within the Pelican example are more variable.

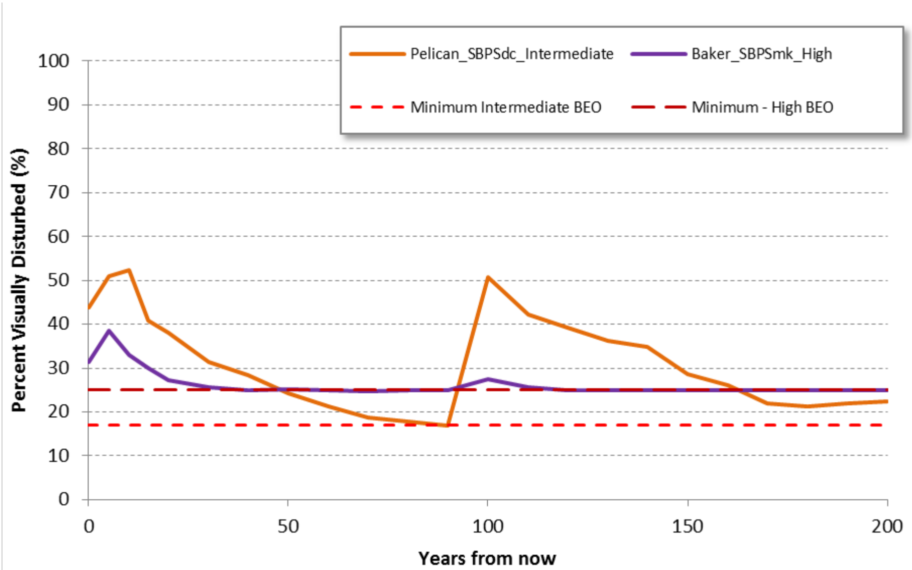


Figure 13 Example Mature+Old forest cover constraints

2.3.5 Watershed Equivalent Clear Cut Areas

Figure 14 reports disturbance levels (equivalent clearcut areas or ECAs) over time for three example watersheds. Salvaging impacted stands in the first five-year period creates the highest ECAs in the second five-year period. As no ECA constraints were implemented, a cyclical trend emerges with each rotation throughout the planning period. ECAs for some watersheds reach over 40% several times over the planning horizon. Placing ECA constraints after the salvage period (i.e. Max. 33%) would likely prolong the mid-term trough as these constraints would reduce the availability of eligible treatments.

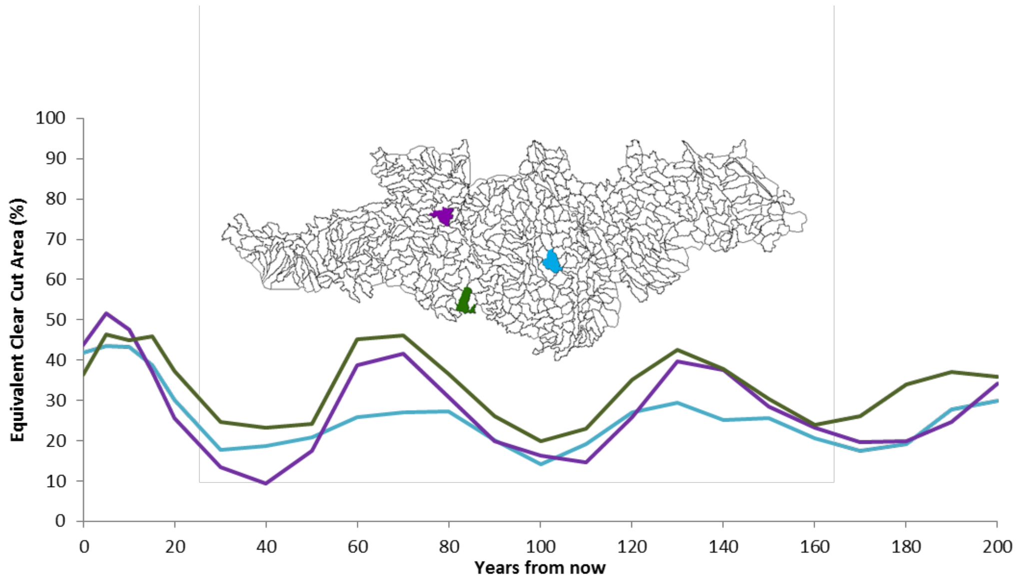


Figure 14 Equivalent clear cut area over time for example watersheds

2.4 Comparison to the Mid-Term Project

This section compares the Base Case results for this QT4 analysis with results from the Mid-Term Project. This benchmark is used to assess assumptions and results to check that the Base Case for this analysis provides a solid foundation from which to assess silviculture strategies. This section identifies and discusses differences between the two harvest flows.

Figure 15 shows that the THLB for the Base Case is approximately 2.2 % (or 23,900 ha) smaller than the THLB used in the Mid-Term Project.

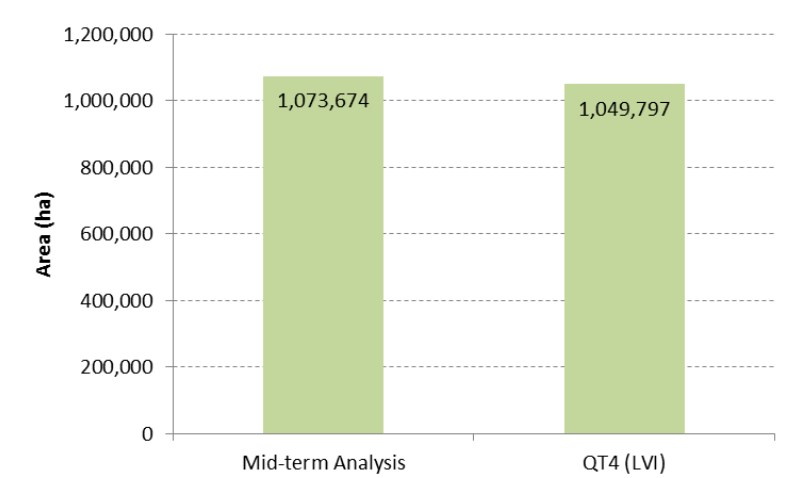


Figure 15 Base Case THLB area compared to the Mid-Term Project

Figure 16 compares the harvest flow for the Base Case to the Mid-Term Project. The initial harvest rate is essentially the same but due to the reduced shelf-life modelled in this analysis, the harvest rate drops much sooner. The mid-term level for this analysis is 33% (564,000 m^3/yr) higher than in the Mid-Term Project. The long-term harvest level is also substantially higher than by 27% (750,000 m^3/yr). Reasons for these differences are discussed below.

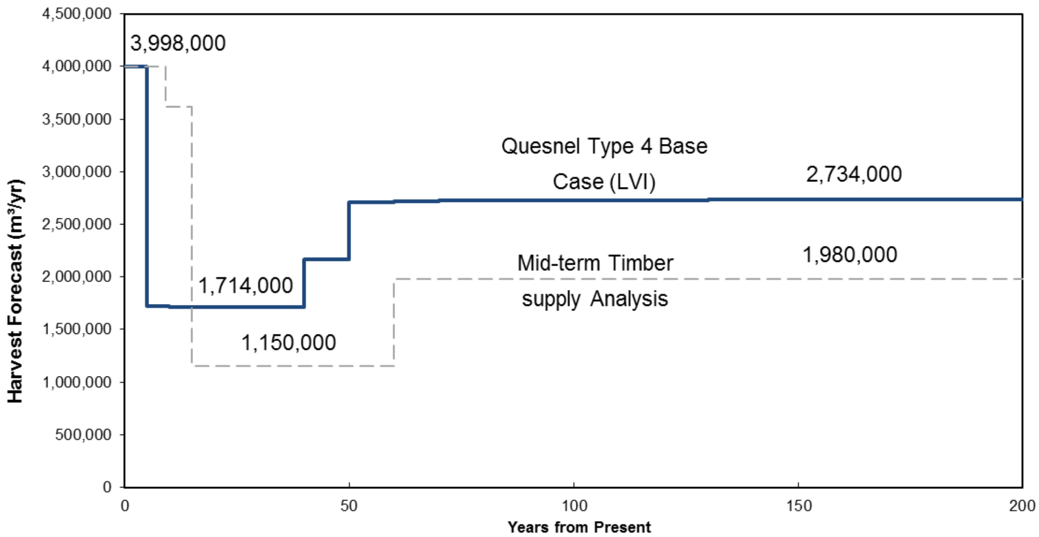


Figure 16 Harvest flow: Base Case compared to the Mid-Term Project

Figure 17 compares the growing stock over time between the two analyses. Initially, the raw inventory for this QT4 analysis is much higher (approximately 11.3 million m³) than the VRI inventory used in the Mid-Term Project. To account for the significant volumes of dead pine that have already been lost, the inventory was reduced according to the shelf-life assumptions. For this QT4 analysis then, the total starting inventory is approximately 7.5 million m³ less than the Mid-Term Project but the live volume remains higher.

The growing stock decreases much faster in this QT4 analysis which corresponds with the earlier drop in harvest level (again due to the modeled shelf-life). The growing stock in the Mid-Term Project reaches a much lower level in the 3rd decade because it has: 1) less live volume initially than the QT4 (LVI) inventory projected, 2) higher levels of MPB mortality in both older and younger Pl stands, and 3) lower site productivity in regenerating stands (high managed stand site indices in QT4).

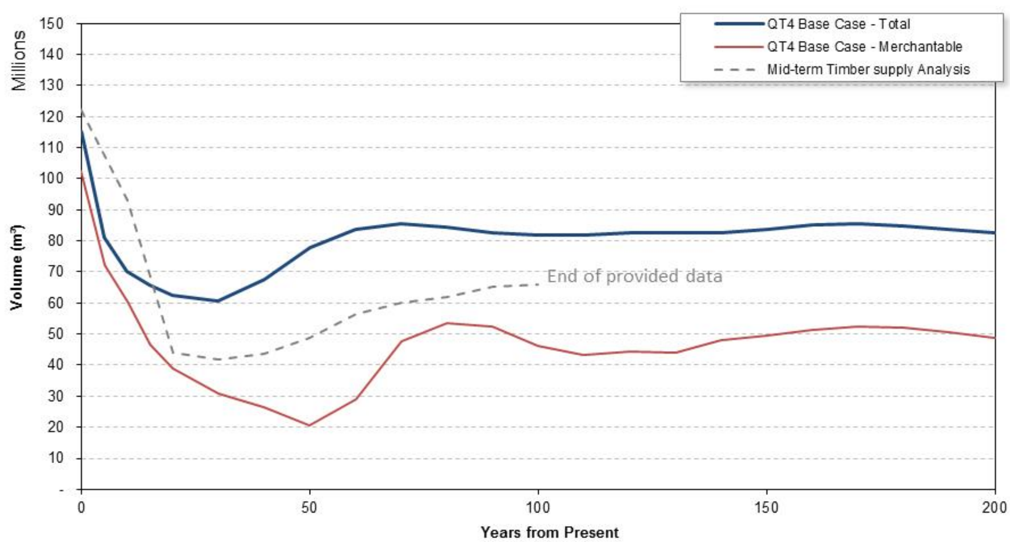


Figure 17 Growing stock: Base Case compared to the Mid-Term Project

In this QT4 analysis, the higher growing stock (live volume) present in the 3rd decade supports the higher mid-term harvest level. Long-term harvest levels are higher in this QT4 analysis because of the higher growth rates assumed for managed stands (SIBEC-derived SIs) and differences in regeneration assumptions (see bullets below for more details).

The major drivers that explain the significant differences between this QT4 analysis and the Mid-Term Project include:

- **Initial Inventory** – A new inventory (Landscape Vegetation Inventory – LVI) over a significant portion of the TSA was incorporated into the QT4 analysis. As a result, the initial (raw) standing volume was approximately 11.3 million m^3 higher than the Mid-Term Project but due to the modeled shelf-life, the adjusted starting inventory was 7.5 million m^3 lower. Overall, the LVI has more green (live) volume than in the Mid-Term Project which provides more harvesting options in the mid-term.
- **Young stand mortality assumptions** – Relative to the Mid-Term Project, the young stand mortality assumption for QT4 Base Case is considerably lower. These are based on Lorraine MacLauchlan's survey work for MPB impacts on young Pl stands (age 21-30= 13% loss, age 31-40= 23% loss, age 41-52= 40% loss). These differences contributed to the mid-term growing stock.
- **Regeneration Assumptions** – The QT4 applies more detailed assumptions to model growth for regenerating stands. These are not expected affect harvest outcomes significantly but they do provide additional stand types and attributes for exploring silviculture strategies.
- **Site Index Estimates** – Managed stand site indices for this QT4 analysis were generated from the latest provincial managed stand site index layer (SIBEC) while the Mid-Term Project applied estimates from a site index adjustment project. The area weighted-average managed site index in this analysis is 18.3m compared to 15.5m in Mid-Term Project. This increase in productivity means that managed stands yields are significantly higher. As a result, these higher site indices contribute more volume late in the mid-term and support a much higher long-term harvest level.

2.5 Base Case Summary

The Base Case for this analysis applies the most current available information for inventories, MPB impacts in both old and young stands, and managed stand site index estimates. The combined effect of these updates results in a faster drop in harvest levels but overall, a significantly more optimistic mi-term harvest level for the Quesnel TSA than published in recent forecasts. Still, the problem of addressing the impending mid-term trough persists.

Figure 9 demonstrated that the harvest level near the end of the mid-term trough is largely supported by young stands (50-70 yrs old at time of harvest) so it is critical to ensure that these expected volumes actually emerge over time. This includes careful consideration of the product profile expected from these stand types as the harvest level during this period is dependent on minimum harvest operability assumptions.

The shelf-life assumptions applied in this analysis (pre-attack dead pine volumes steadily diminish to 0%, 14 years after attack) were developed from suggestions that much of the volume killed early in the infestation (between 2003-2005) has already degraded too much to process. The rise out of the mid-term trough relies on these stands being salvaged early so that they can be harvested again near the end of the mid-term trough and throughout the long-term. Accordingly, it is critical that harvesting focuses on salvaging significantly dead stands rather than stands with higher proportions of green timber that will still be available after dead volumes exceed their shelf-life.

Harvest billing reports show that over the last few years the annual harvest has been approximately 3.5 million m³/yr when the current AAC is 4.0 million m³. This may translate into more stands becoming unmerchantable as shelf-life assumptions are applied, plus fewer stands being converted from stagnating MPB impacted stands with poor regeneration to young thrifty and faster growing managed stands.

The Base Case for this QT4 analysis provides a reasonable benchmark to assess potential silviculture strategies aimed at improving timber and non-timber outcomes in the TSA.

3 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.

3.1 Lower 1st Period Harvest

The purpose of this sensitivity is to examine the effect on mid-term harvest levels from an immediate reduction in the current AAC uplift. The harvest request for the first period remained the same (4,000.000 m³/yr) but the weighting assigned to achieve the target was reduced. This essentially prioritized the mid-term harvest over the short-term and allowed the model to select a short-term harvest level that best achieves a higher harvest level in the mid-term.

Figure 18 shows an immediate harvest level reduction to just below 2.95 million m³/yr resulting in an increased mid-term harvest level of approximately 103,000 m³/yr compared to the Base Case. Essentially, 5.25 million m³ is deferred in the first 5-year period and 3.98 million m³ of this is harvested over the following 40 years. Of the 5.25 million m³, 52% is considered dead volume indicating that the model avoided some harvesting of mixed stands. Overall, this sensitivity leaves more green volume for the mid-term at a cost of losing some dead volume with an immediate drop in harvest levels. From an optimal financial (NPV) perspective, leaving the existing uplift is preferred.

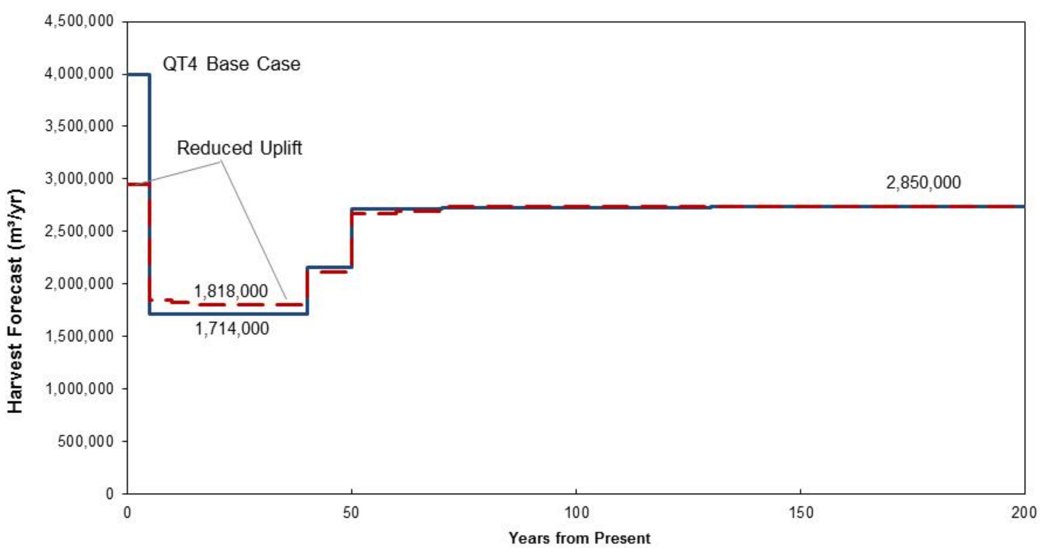


Figure 18 Harvest flow: Base Case compared to lower first period harvest level

A comparison of the growing stock over time is shown in Figure 19. The lower harvest in the first period resulted in a slightly higher growing stock at the start of the mid-term. Near the end of the mid-term, 50-70 years from now, this sensitivity produced slightly lower growing stock levels than the Base Case. This is due, in part, to a slower recovery of the land base (fewer impacted stands harvested in first period), as well as higher harvest levels in the mid-term.

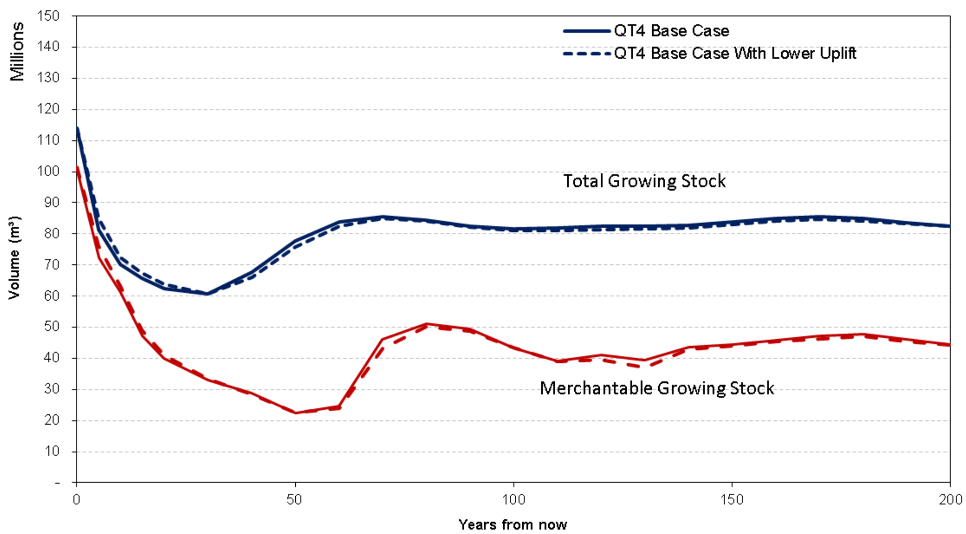


Figure 19 Growing stock: Base Case compared to lower first period harvest level

3.2 Longer Minimum Harvest Ages

The Base Case employed a mid-term strategy to gain access to timber sooner by generating minimum harvest ages (MHAs) for future managed stands based on a minimum volume criteria (>=120 m^3/ha) resulting in an weighted-average MHA of 61 years for future managed stands.

This sensitivity explores the effects of applying MHAs based on the achievement of maximum culmination age (biological rotation), or the age when volume increment is the greatest. This approach maximizes the long-term harvest level and increases the weighted-average MHA to 88 years – a 27-year (44%) increase. For context, the area-weighted average total volume yield at the CMAI derived MHA is about 305 m^3/ha (vs. 120 m^3/ha in the base case).

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

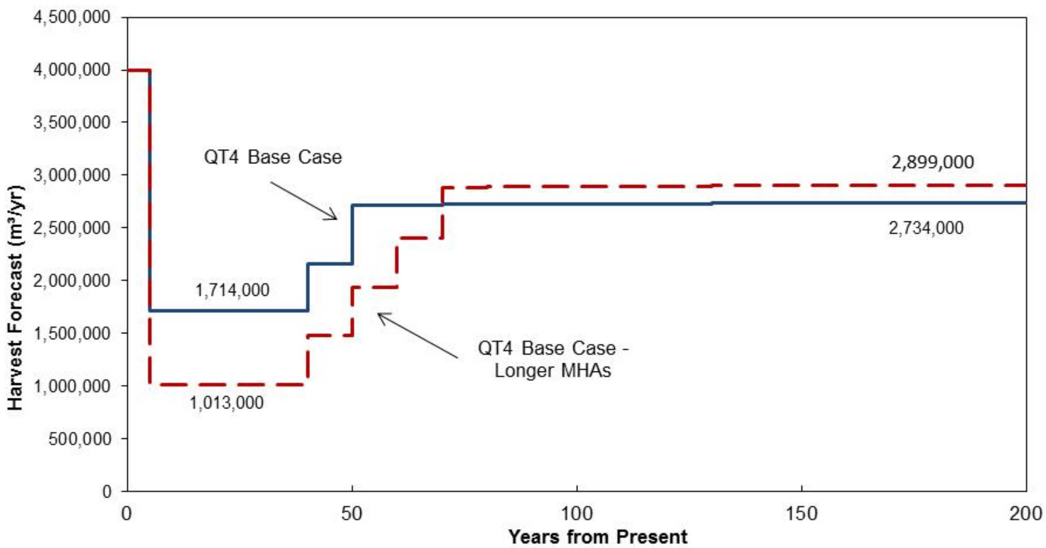


Figure 20 Harvest flow: Base Case compared to longer MHAs

Figure 21 shows the growing stock over time and the resulting age class structure 200 years from now. The extended period to access stands killed by MPB combined with the resulting lower mid-term harvest level supports the recovery of growing stock levels to almost pre-MPB epidemic levels within 80 years from now. The age class distribution at the end of the planning horizon is more or less evenly distributed between 0-90 years old rather than 0-70 years in the Base Case.

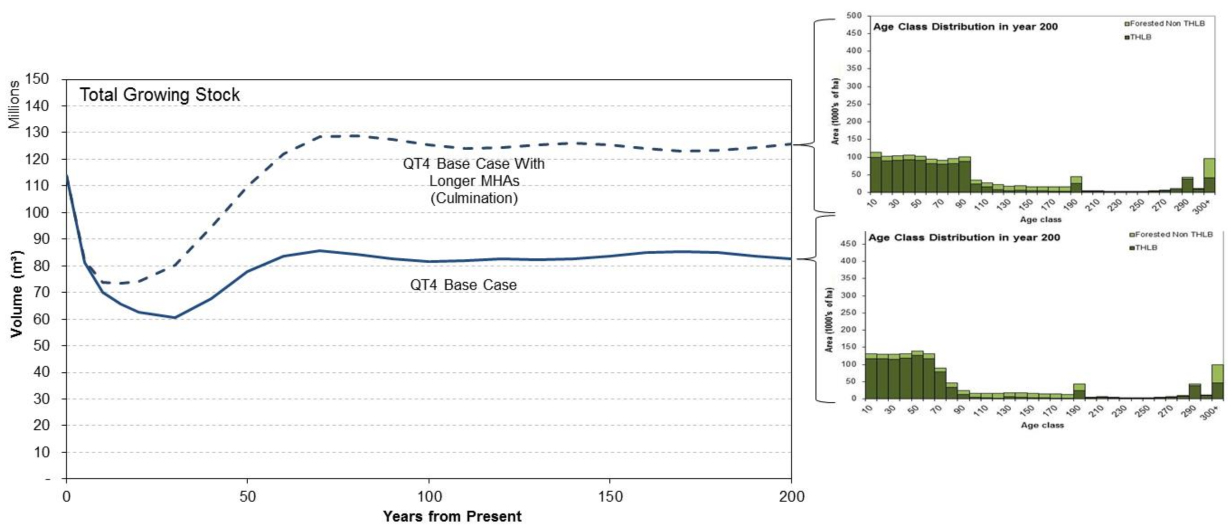


Figure 21 Growing stock and age class distribution: Base Case compared to longer MHAs

Figure 22 compares the area harvested by the age class for the longer MHA sensitivity. During the 6th decade, the weighted average harvest ages are 67 years in the Base Case compared to 132 years in the longer MHA sensitivity (nearly double).

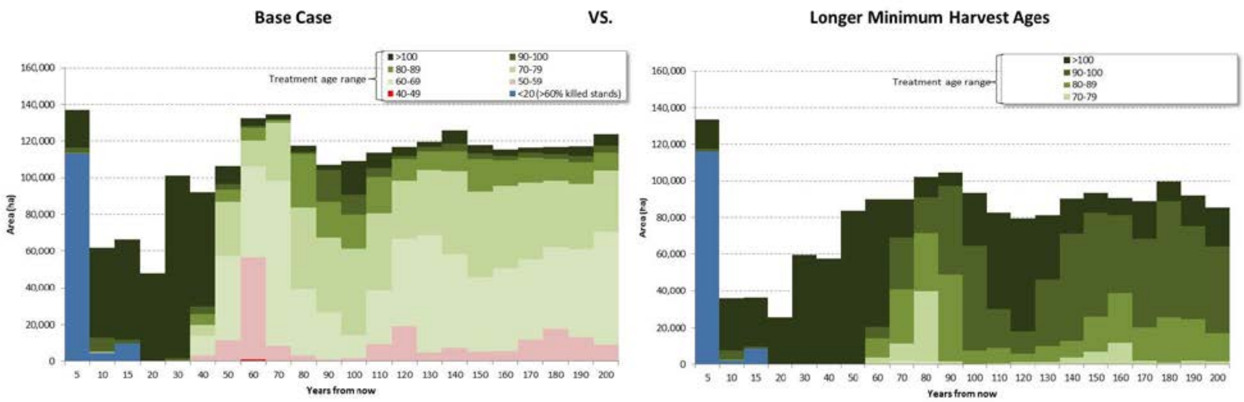


Figure 22 Harvest area by age class: Base Case compared to longer MHAs

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. To illustrate this, Figure 23 compares merchantable volumes (m³/ha) by diameter at breast height class (cm) for a 67 year old stand and a 132 year old stand. The sawlog volume per ha produced is much higher in the longer MHA sensitivity and diameter's are significantly larger.

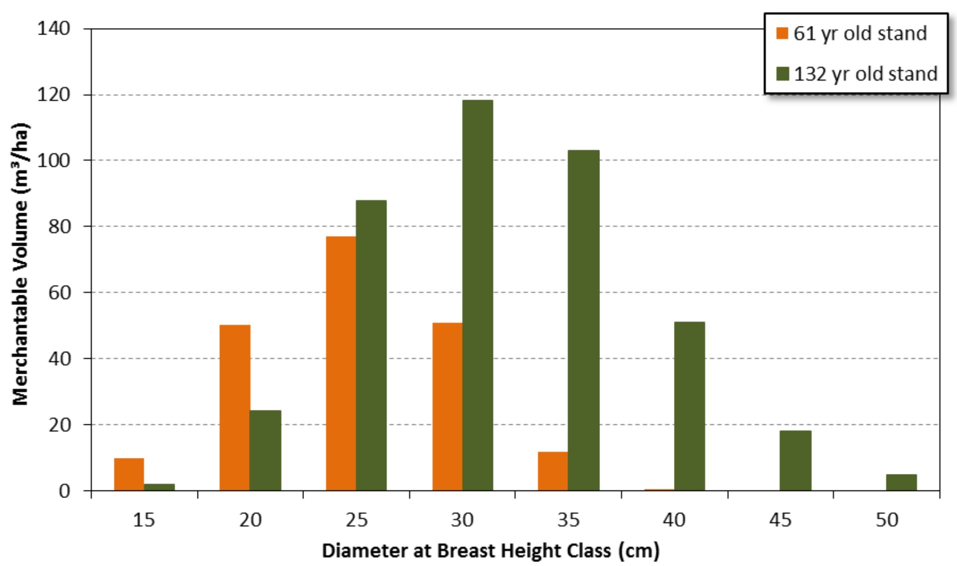


Figure 23 Diameter class distribution of merchantable volume: 61 and 132 year old stands

Thus, holding managed stands longer before harvesting has a major negative impact on midterm harvest levels, but has a numerous benefits in the longer term (higher AAC, better product profile, higher vol/ha leading to lower harvesting costs and fewer ha harvested/yr, more area in mature stands).

3.3 Longer Minimum Harvest Ages with Commercial Thinning

The longer minimum harvest age sensitivity showed that older harvest ages produced more favourable product profiles, but at a heavy cost to the amount of volume available over the next 40 years. This sensitivity examined a potential compromise that introduces commercial thinning to gain early access to some volume while maintaining longer MHAs for the final harvest entry (clear cut). This strategy gains access to some of the merchantable volume that was logged in the base case 60-80 years from now, but was left to grow in the extended MHA scenario. It does this by removing a portion of the volume from many stands (commercial thinning) instead of clearcutting this volume from fewer stands (i.e. expensive logging used to access volume in order to allow stands to continue on to culmination). This treatment was only eligible on better sites once stands attained 120 m³/ha of sawlog volume.

The harvest forecast for this sensitivity is shown in Figure 24. It shows that the mid-term harvest levels can be increased by accessing stands earlier on the eligible portion of the land base. Because commercial thinning is not eligible over the entire land base, the mid-term harvest does not reach the same level as in the Base Case.

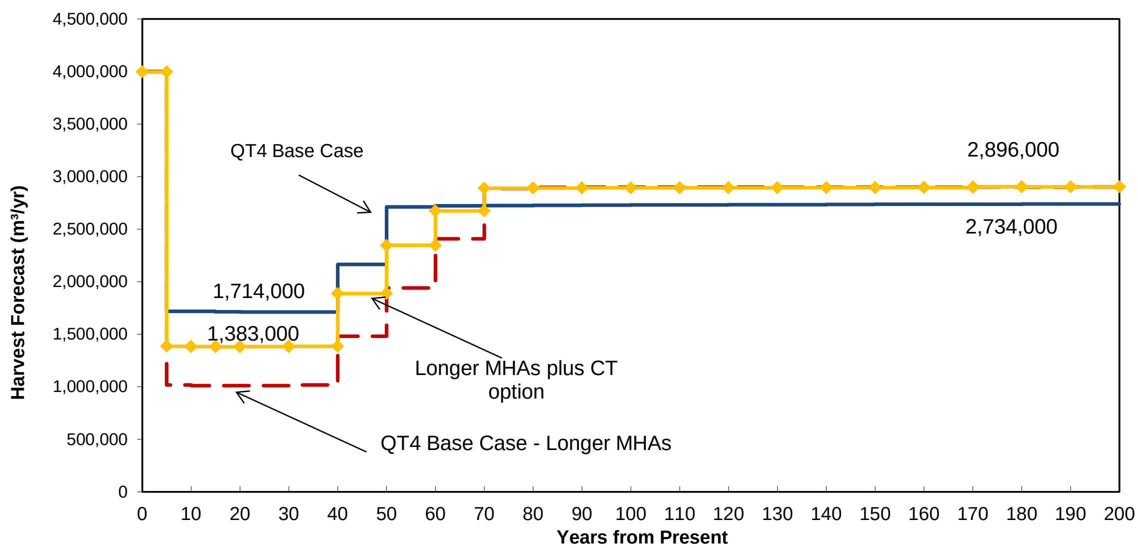


Figure 24 Harvest flow: Base Case compared to longer MHAs and commercial thinning

The volume (Figure 25) and area (Figure 26) harvested through commercial thinning is only required as stands transition from natural to managed stands (mid- to long-term), which occurs between the 4th and 8th decades. The commercial thinning treatment only removes 30% of the stand volume so the area treated during this time is considerably higher than clear cut harvesting. In this sensitivity, commercial thinning becomes the dominant harvesting method during the transition out of the midterm (accounts for 60-80% of the harvested area).

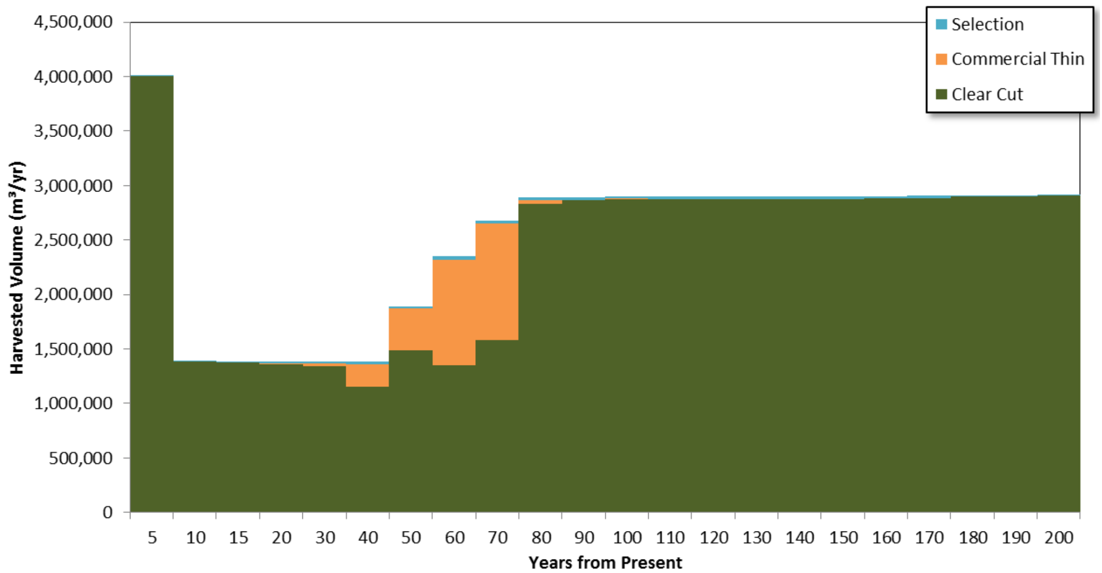


Figure 25 Harvest volume by silviculture regime - Longer MHAs with Commercial Thinning

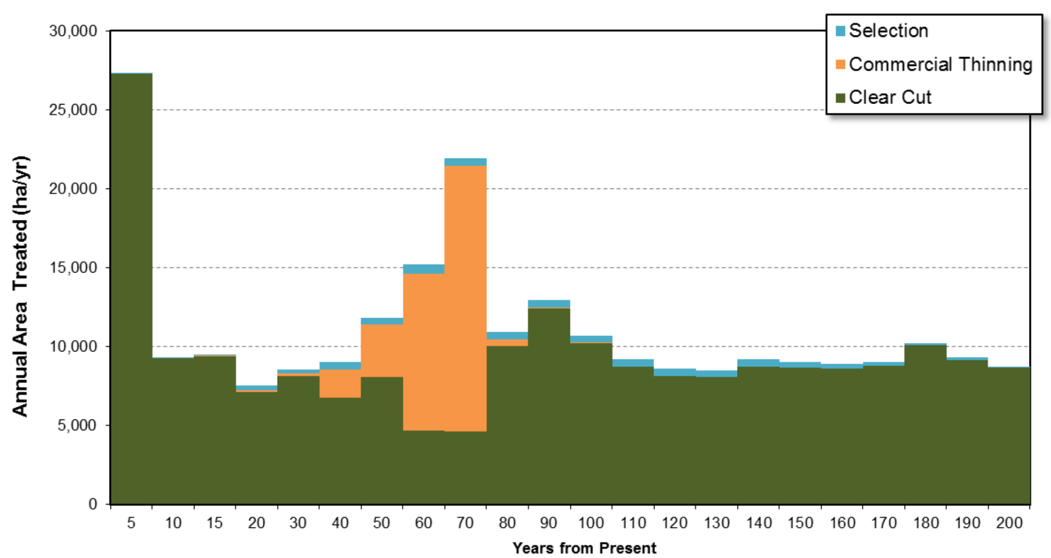


Figure 26 Harvest area by silviculture regime - Longer MHAs with Commercial Thinning

4 Silviculture Strategies

The following sections present the results of applying alternative modeling assumptions, as silviculture strategies, relative to the Base Case. These sections highlight the key forest metrics affected by the strategies and provide rationale for observed differences from the Base Case. Each strategy below begins with a high-level overview of how the strategy was modelled, but a more complete discussion of the specific modeling details are provided in the data package (Forsite 2013).

4.1 Single-fertilization

Fertilization is a silviculture treatment intended to increase the merchantable yield and value of stands by adding nutrients that are limited on sites and improving the growth of individual trees. This strategy is expected to improve the mid-term harvest level because the additional volume, on stands harvested in 40-60 years, reduces the age that these stands become eligible for harvest (MHA) so that the existing volume does not have to be metered out as long.

In this particular strategy, stands were only fertilized once. The stand-level cost for this treatment was assumed to be $450/ha and the model was given a maximum budget of $5 million/yr – or up to 11,110 ha/yr. No minimum expenditure budget was specified to allow the model flexibility to determine when and how much area to fertilize throughout the planning horizon.

The area by species (Figure 27) and expenditures (Figure 28) fertilized throughout the planning horizon show that fertilization is directly influenced by the land base profile. With a single-fertilization treatment, the allotted $5 million/yr budget is never fully utilized. In the near-term, relatively little area is fertilized due to the limited number of eligible stands and the many timing options that ensured each eligible stand was treated once before harvest. In time, however, more stands become eligible for treatment. Virtually all of the eligible areas were treated in the model.

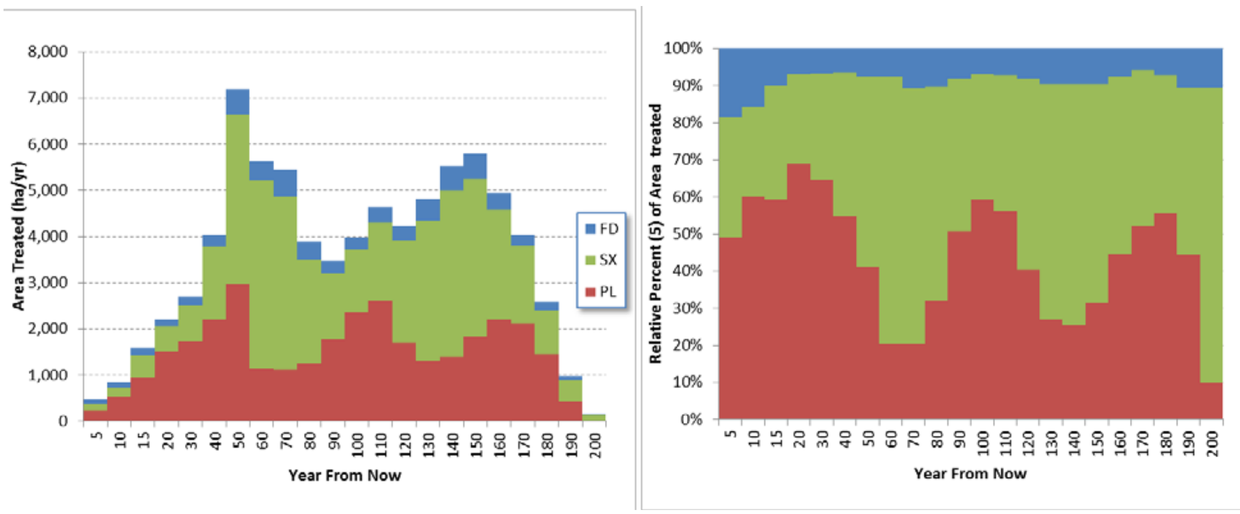


Figure 27 Total and percent area by leading species treated over time under the single-fertilization strategy

The model appeared to show a tendency to fertilize Sx and Fd before Pl because of the higher volume response achieved with these species – however, Pl stands make up a very large portion of the landbase so they still make up a majority of the treated ha's in many periods.

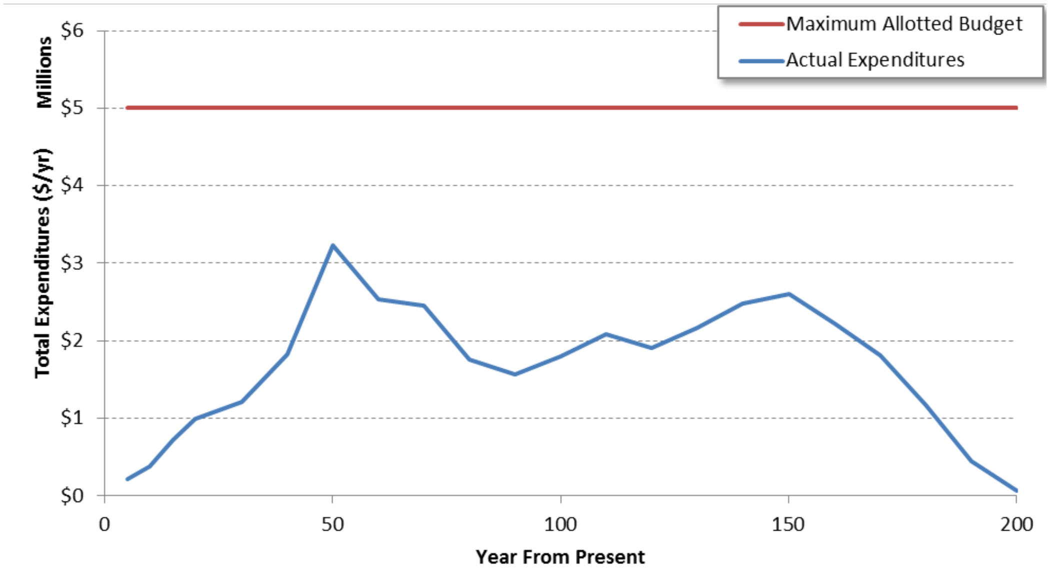


Figure 28 Expenditures over time for the single-fertilization strategy

The harvest flow resulting from the single-fertilization strategy is shown in Figure 29. Relative to the Base Case, the mid-term harvest level increases by 56,000 m³/yr while the long-term harvest level increases by 104,000 m³/yr. The additional volume was harvested while maintaining a growing stock over time (Figure 30) that is nearly identical to the Base Case.

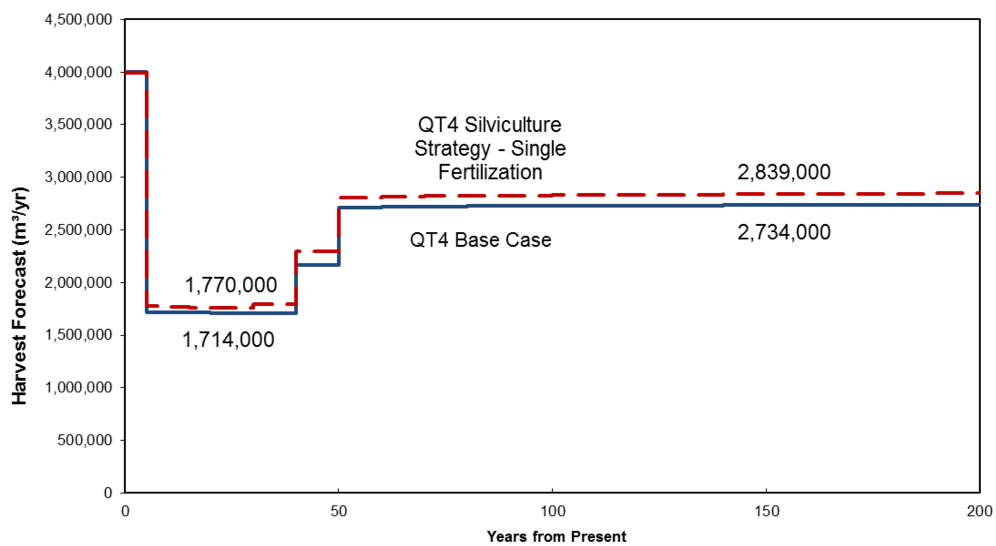


Figure 29 Harvest flow: Base Case compared to single-fertilization strategy

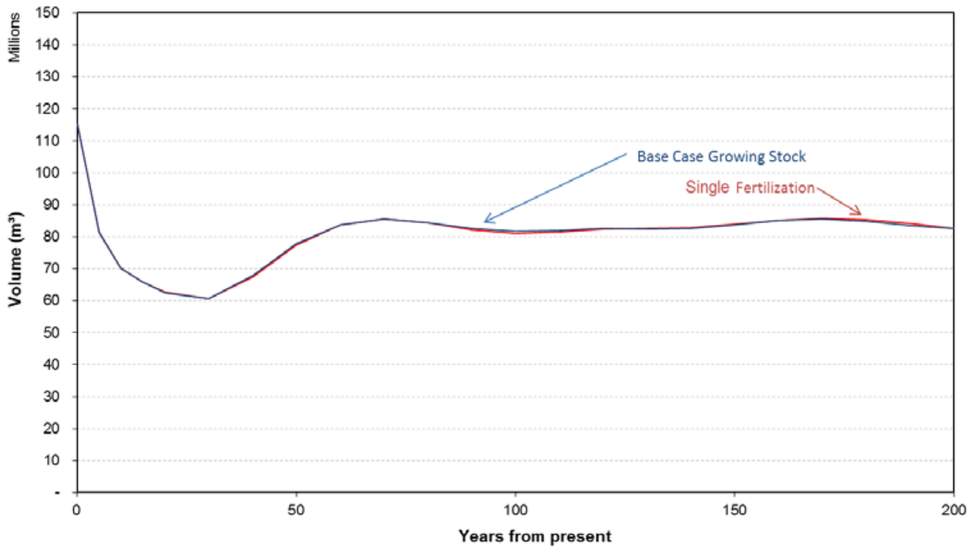


Figure 30 Growing stock over time: Base Case compared to single-fertilization strategy

4.2 Multiple-Fertilization

The multiple-fertilization strategy investigates the effect on harvest flow when the stands are fertilized 4 times prior to being harvested. Like the single-fertilization strategy, an annual budget of $5 million was available (no minimums) allowing the model flexibility to choose when and how much to fertilize.

Figure 31 shows the area fertilized over time under the multiple-fertilization strategy (1, 2, 3, or 4 applications). Again, due to a lack of eligible stands, relatively little area is fertilized over the next 5 years. In time, however, more stands become eligible for treatment. Near the end of the planning horizon, the treated area dwindles down because the model does not consider treatments beyond the planning horizon and there is no incentive to continue fertilizing.

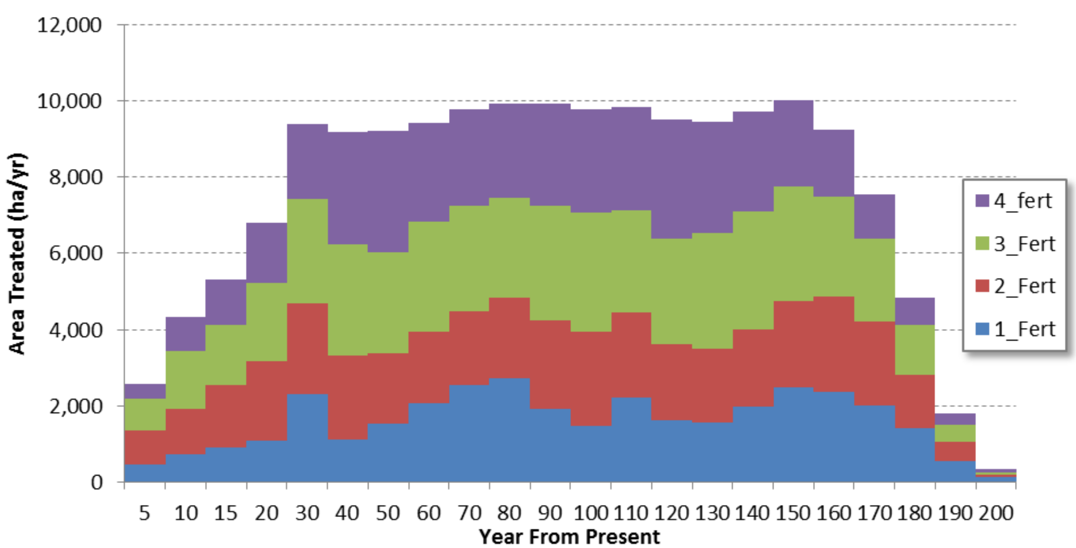


Figure 31 Total area fertilized by frequency regime under the multiple-fertilization strategy

Figure 32 shows that the model takes advantage of the highly attractive gains associated with multiple-fertilization treatments on spruce by fertilizing a disproportionate amount of spruce leading stands relative to the amount of spruce leading profile on the landbase. As well, the many pine stands that are recovering post MPB become eligible for treatment 10-30 years from now. The cyclical pattern of pine fertilization reflects the amount of pine on the land base resulting from the recent MPB epidemic.

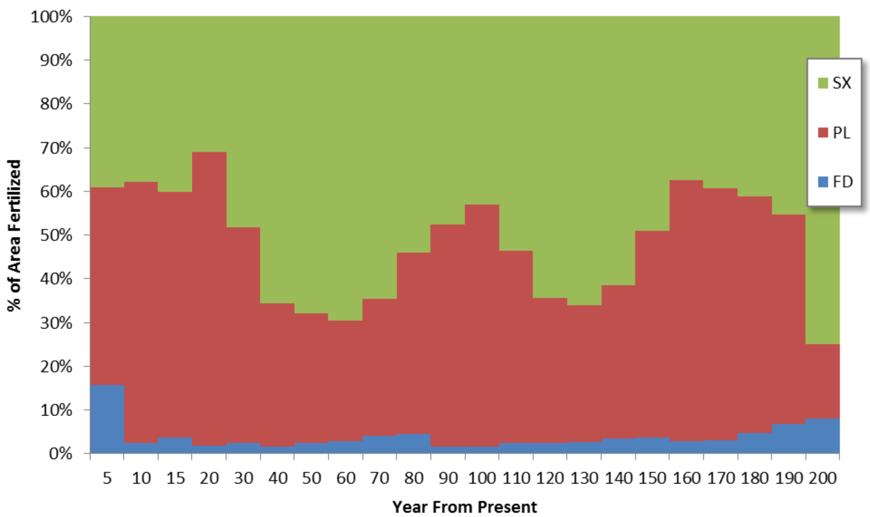


Figure 32 Percent area by leading species treated over time under the multiple-fertilization strategy

Figure 35 shows that, due to the lack of eligible stands, the budget for this strategy steadily increases until the 3rd decade when the entire budget is utilized.

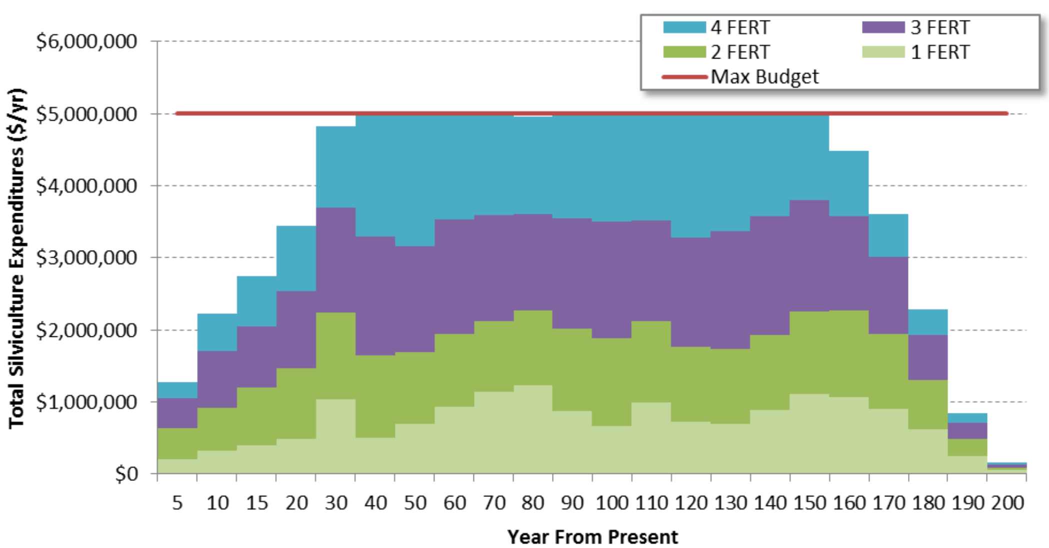


Figure 33 Fertilization expenditures by frequency regime under the multiple-fertilization strategy

Figure 34 shows a significantly improved harvest flow with the multiple-fertilization strategy; increasing harvest levels in the mid-term by 169,000 m^3/yr and 203,000 m^3/yr in the long-term. Besides the incremental volume, these fertilization treatment assumptions enabled the model to access to stands sooner. This strategy improves the mid-term harvest level because the future harvesting can rely on harvesting this additional volume sooner. Consequently, the existing volume does not have to be metered out as long and can be harvested sooner.

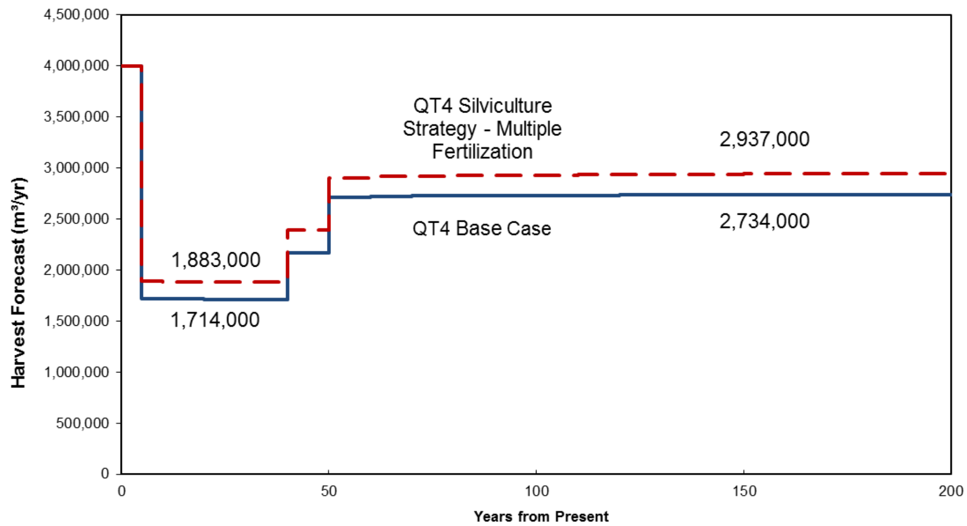


Figure 34 Harvest flow: Base Case compared to multiple-fertilizations strategy

Figure 35 compares the relative contributions of natural and managed stands. The multiple-fertilization strategy shows more harvesting from managed stands in the 4th decade because the natural stand volume has been removed more quickly in earlier periods.

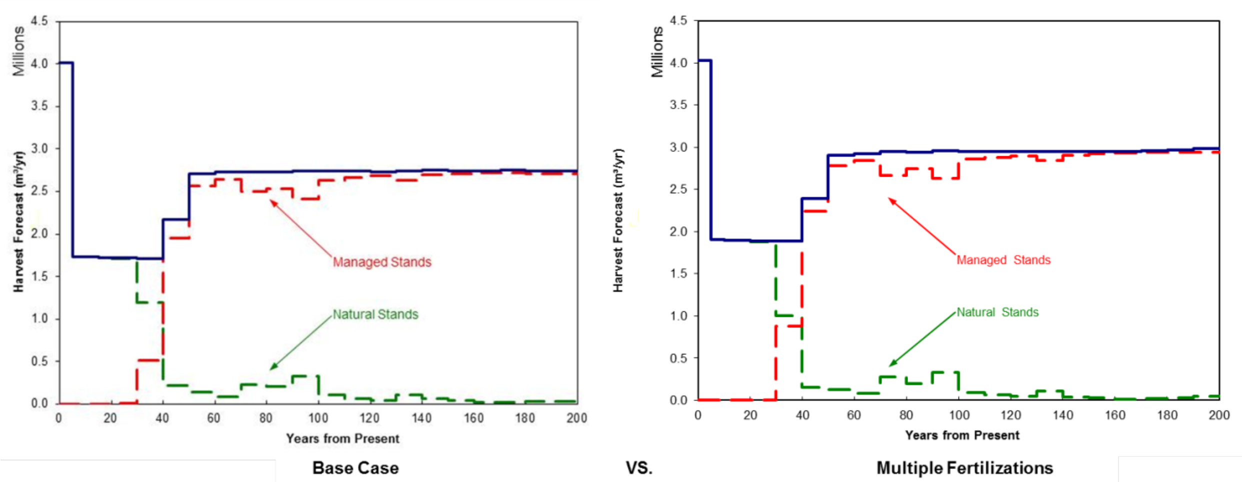


Figure 35 Harvest flows for existing and managed stands: Base Case compared to multiple-fertilizations strategy

4.3 Rehabilitation

Many stands are never harvested throughout the planning period because they have insufficient volumes post MPB - effectively reducing the contributing landbase. This occurs when marginal or young stands with a poorly-regenerating understory do not achieve the minimum merchantability requirements. Figure 36 shows an example of the post MPB yields associated with such an unmerchantable stand, compared to the projected rehabilitation response.

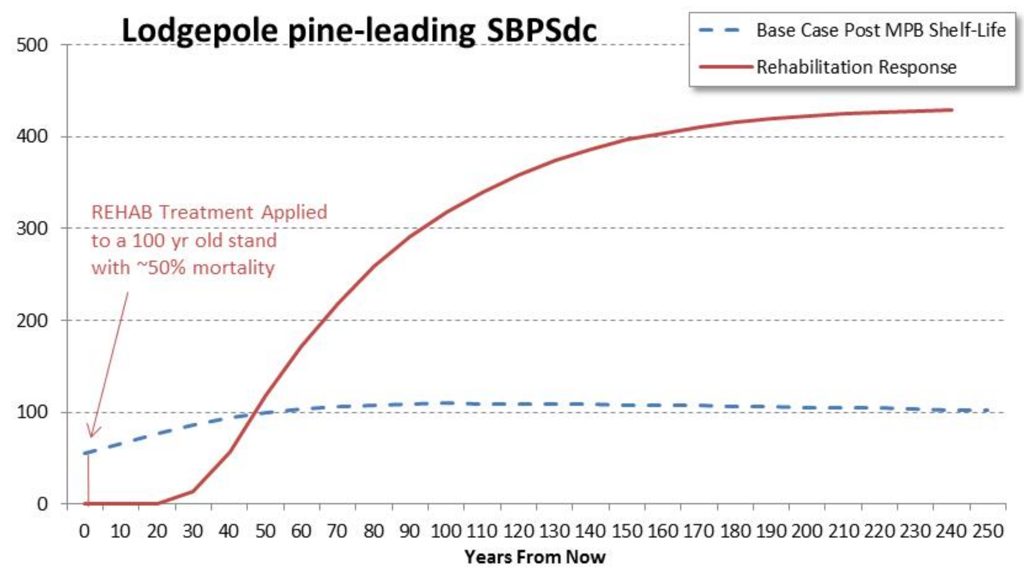


Figure 36 Stand yields: post MPB stand recovery compared to a rehabilitated stand

The rehabilitation strategy examines the effects of regenerating these unmerchantable stands and establishing improved forest crops. This strategy delivers volume at the time of rehabilitation (that would not have otherwise entered the marketplace) and improves long term harvest levels by ensuring productive managed stands come online in the future.

Figure 37 shows the area treated over time for three rehabilitation regimes. A total of 6,200 ha were treated over the first 5 decades representing expenditures of $6.3 million. The model salvages most of the high percent pine stands so many of the post-MPB stands selected under this rehabilitation strategy are low volume mixed stands. In fact, the vast majority of the rehabilitation treatments was done on stands with live volumes ranging between 75 m^3/ha and 120 m^3/ha.

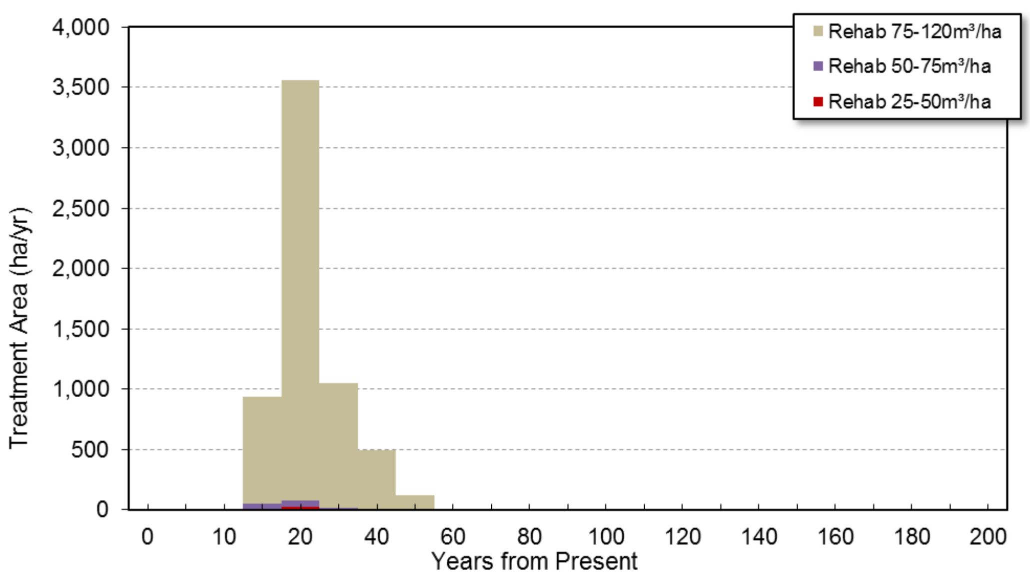


Figure 37 Area treated by merchantability class under the rehabilitation strategy

Figure 38 shows a moderately improved harvest flow with the rehabilitation strategy. The mid-term increases by 53,000 m^3/yr while the long-term increases by 101,000 m^3/yr. Modeling assumptions cause rehabilitation treatments to begin 15 years from the start of the planning horizon; immediately following the salvage period where eligible stands must first deteriorate under the shelf-life assumptions. In reality, some of these stands are already beyond the salvaging window, so rehabilitation treatments can actually be done sooner. Furthermore, licensees have reported that post-MPB attack stand break up and blow down is already occurring, which suggests that candidate stands for rehabilitation are already present on the ground within the Quesnel TSA. Challenges can exist with identifying these stands today because market conditions can cause stand treatment eligibility to fluctuate. For example, higher lumber prices can make new stands, particularly close to towns, economically viable for salvage (which has a far lower cost to the crown the rehabilitation).

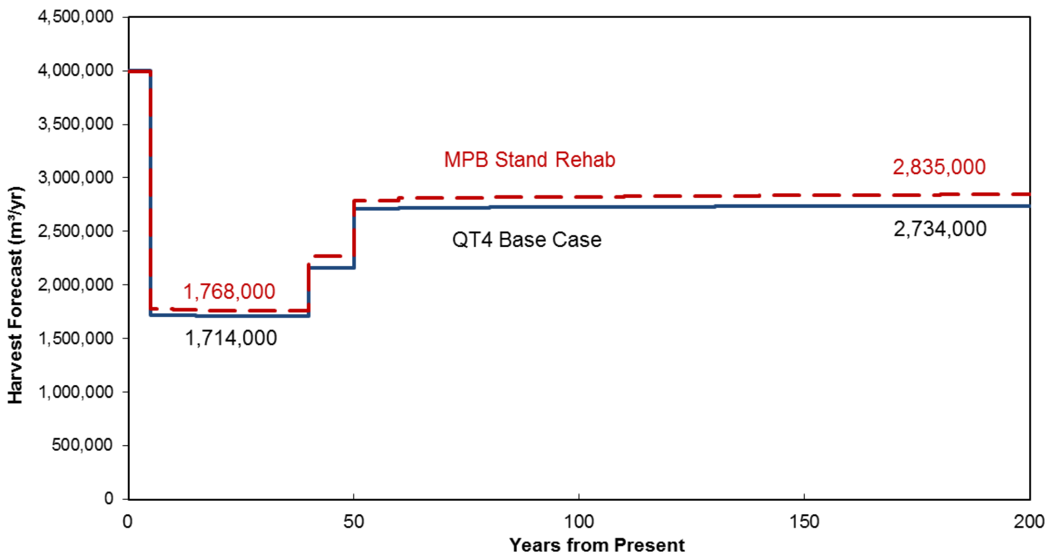


Figure 38 Harvest Flow: Base Case compared to rehabilitation strategy

4.4 Pre-Commercial Thinning

This pre-commercial thinning (PCT) strategy investigates the effect on harvest flow when the stand density is controlled to remove the least desirable trees to make room for potential crop trees. In some cases, the PCT treatments were combined with fertilization. Approximately 5,000 ha were identified as candidate stands for the PCT/fertilization treatment. Only existing stands were considered because the Base Case post-harvest regeneration assumptions do not reflect the full variability of stand density conditions likely to occur. Stands with more than 10,000 stems per hectare (sph) were considered for PCT. After treatment, these stands then became eligible for fertilization.

Figure 39[1] shows the treatment response for a high density (10,000 sph), naturally-regenerated stand that undergoes a PCT treatment to 2500 sph. It compares stand density, merchantable volume, and average diameter at breast height for the top 250 crop trees (factor by 10 on the secondary axis). The diameter of the largest 250 trees is shown to reflect a biological change from the treatment rather than the mathematical difference of removing the smaller stems. In this example, a significant change in stand density results in relatively little change in volume. Specifically, a $1100 investment at year 15 produces an extra 15-20m^3/ha at rotation (60 yrs) – thus we are investing $1100 for 45 yrs to get 15-20m^3 and larger stand diameters (trees are no taller so taper is increased).

[1] Generated by TIPSY 4.3 - GEOGRAPHY: Southern Interior/Quesnel/SBPS/10% Slope, ESTABLISHMENT: Regen delay = 0; Target Density = 10000 trees/ha (Natural), SPECIES: 100% LODGEPOLE PINE; Site Index = 18.10, TREATMENT: Pre-commercial thinning to 2500 trees/ha

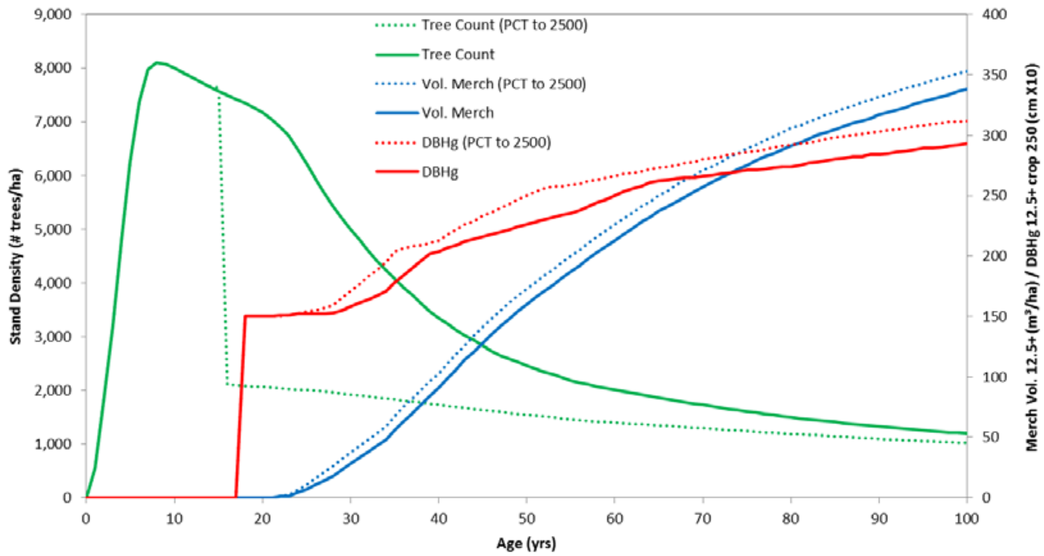


Figure 39 Stand-level treatment response over time for a natural stand example thinned from 10,000 to 2500 sph

Figure 40 shows the treatment area selected by the model under the pre-commercial thin strategy. The model treated 4,056 ha; approximately 80% of the candidate areas for this treatment.

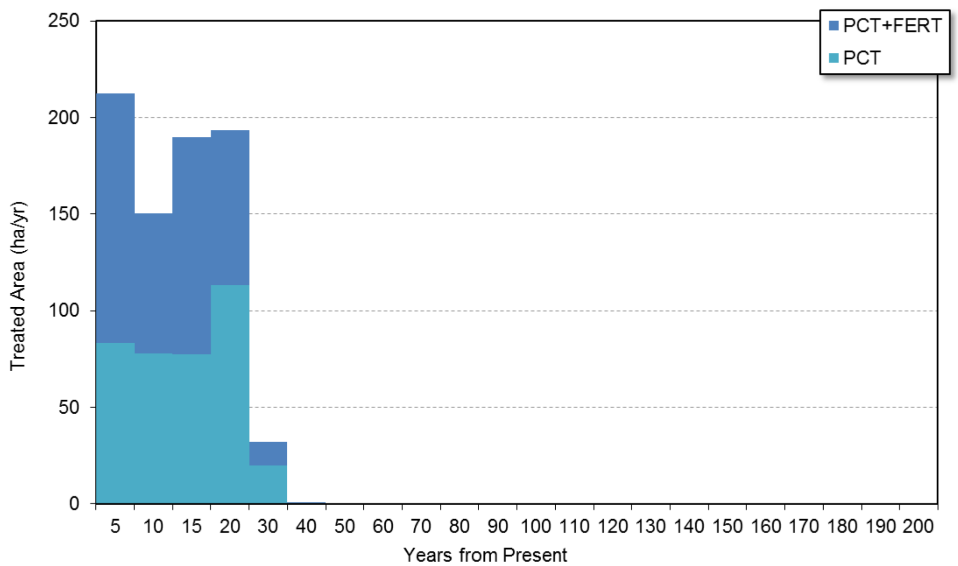


Figure 40 Area treated under the pre-commercial thin strategy

Figure 41 shows a slightly improved harvest flow with the PCT and fertilization treatment. The limited opportunities combined with marginal volume gains suggest that this treatment is a poor choice if harvest volume is the only metric considered (and particularly poor if return on investment is considered). In practice however, this treatment may be regarded as a cleaning treatment that prepares stands for other treatments such as fertilization (i.e., volume gains over fewer stems). When viewed as a cleaning treatment, costs are often less and the outcomes appear to be more attractive.

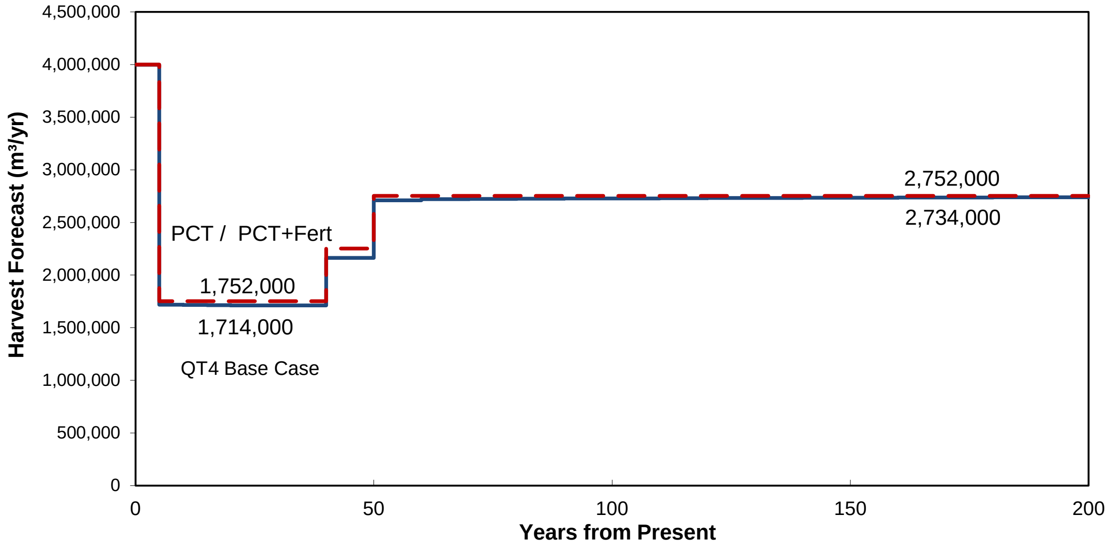


Figure 41 Harvest flow: Base Case compared to pre-commercial thinning strategy

4.5 Enhanced Basic Silviculture

The enhanced basic silviculture strategy investigates the change in harvest flow when regeneration practices are implemented that aim to maximize stand productivity (vs just meet minimum legal requirements). Modeled stand reforestation assumptions are revised accordingly: rely more on planted regeneration with genetic gains, plant at higher densities, and plant sooner after harvesting. The use of planted stock also provides an increase in yield through genetic gains in primary traits such as height and in turn, volume growth. In reality, this strategy could also include practices such as brushing, planting with fertilizer (teabags), etc. Silviculture foresters would be assumed to have the resources to optimize outcomes on eligible sites. Administrative changes[2] would clearly need to occur to make this practical but the point of the scenario is to clarify what could be gained by pursing these changes.

Figure 42 compares stand-level yield curves generated from Base Case assumptions and enhanced silviculture assumptions. While the differences appear small, the volume is concentrated in fewer stems and the MHA is reduced slightly under the enhanced assumptions. If the natural ingress assumed to occur in the base case was also captured in the enhanced regeneration assumptions, the volume difference would be even larger.

[2] Ideas such as allowing companies to select from a tiered set of stand target densities and species mixes that are linked to increasing stumpage credits may be worth exploring.

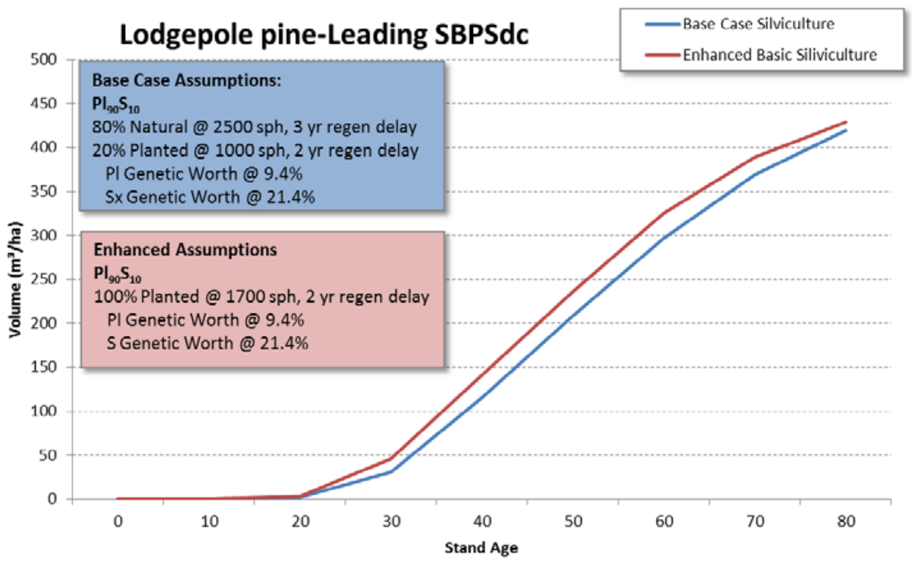


Figure 42 Stand-level treatment response over time comparing Base Case and enhanced basic silviculture assumptions

The incremental cost for this treatment over Base Case regeneration assumptions was modelled at $500/ha, so a $5 million/yr budget can treat up to 10,000 ha/yr. Figure 43 shows the treatment area selected under the enhanced basic silviculture option. The model utilized the full budget allotment over the first 15 years. Afterwards, this budget was not fully utilized.

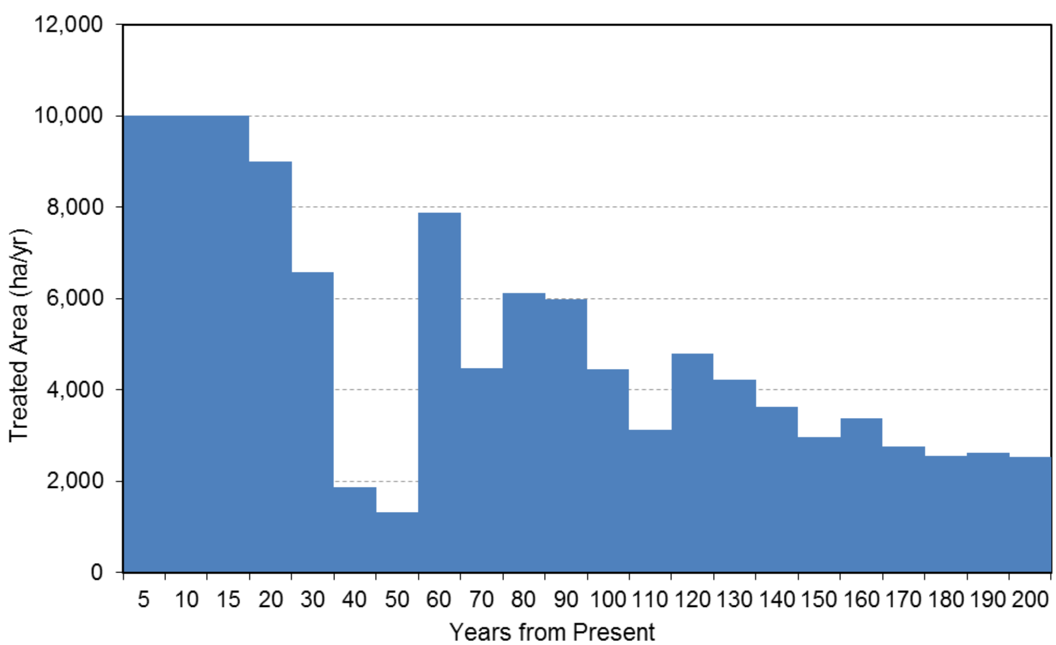


Figure 43 Area treated (harvested and subsequently regenerated) under the enhanced basic silviculture strategy

Figure 44 shows a moderate improvement in harvest flow under the enhanced basic silviculture strategy. The mid-term increases by 52,000 m³/yr while the long-term increases by 213,000 m³/yr. The increased harvest levels are primarily a result of planting trees from select seed which increases yields and shortens rotation lengths.

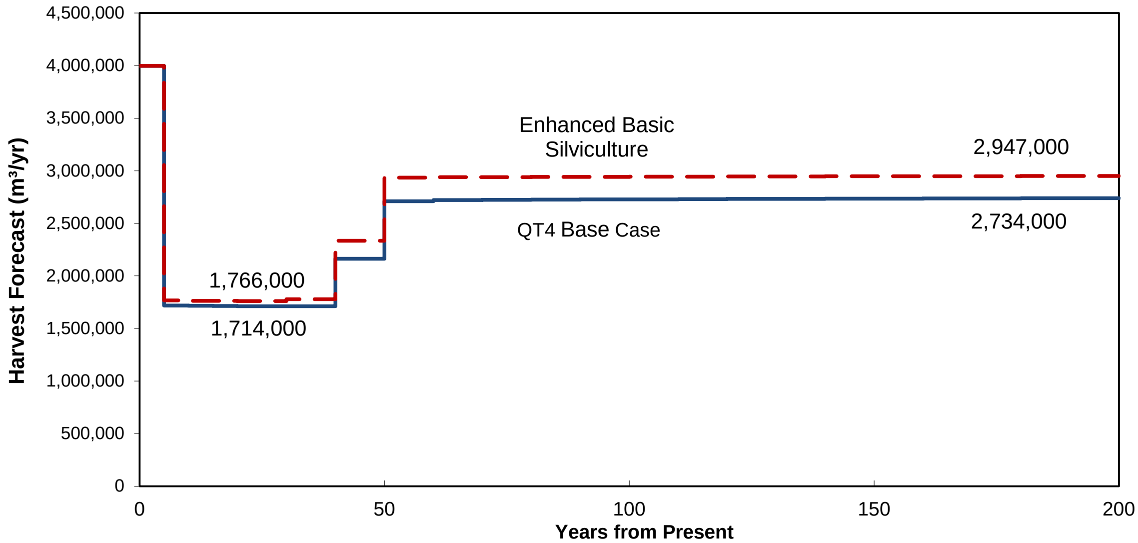


Figure 44 Harvest flow: Base Case compared to enhanced basic silviculture strategy

4.6 Partial Harvest within Constrained Areas

The partial harvest strategy investigates the change in harvest flow from accessing volume from areas that are otherwise constrained (mature seral, visuals, caribou, watershed ECAs). The partial harvest treatments are assumed to not affect forest cover constraints (treatment can occur and stand still satisfies the objective). The treatment was setup for existing natural stands only after the salvage period is complete. It is meant only as a short term strategy to help improve the midterm.

Figure 45 shows the area treated under the partial harvest strategy. This treatment begins 20 years from the present and peaks at a rate of ~2400 ha/yr during the mid-term 40 years from now.

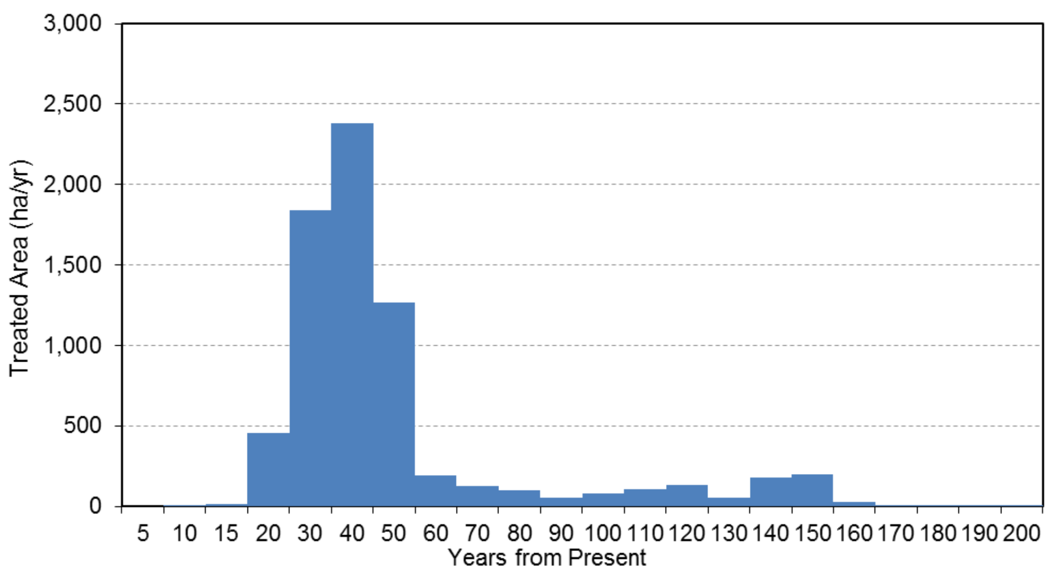


Figure 45 Area treated under the partial harvest strategy

Figure 46 shows the area harvested in the partial harvest strategy compared to the Base Case. The additional area harvested between the 2nd and 7th decade largely reflects the partial harvesting treatment where the post-harvest stand condition does not compromise modeled forest cover constraints.

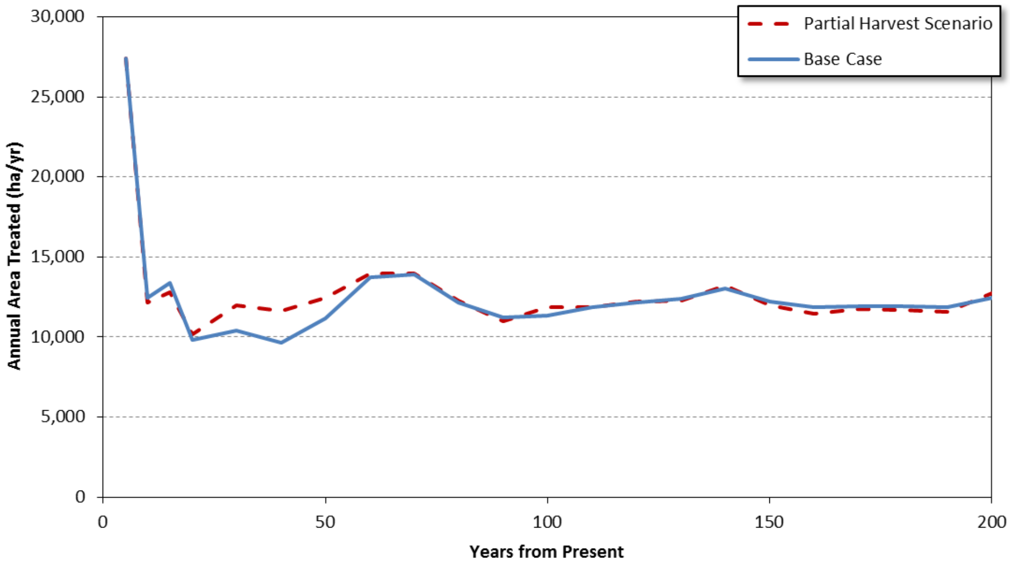


Figure 46 Area harvested over time: Base Case compared to the partial harvest strategy

Figure 47 shows a slightly improved harvest flow with the partial harvest strategy; with the most significant increase occurring at a critical point in the planning period, during the 4th decade as the availability merchantable wood approaches is lowest level (Figure 17). The timing of this increase also coincides with periods when some non-timber forest conditions are considered "tight" relative to their targets (Figure 11, Figure 13 and Figure 14).

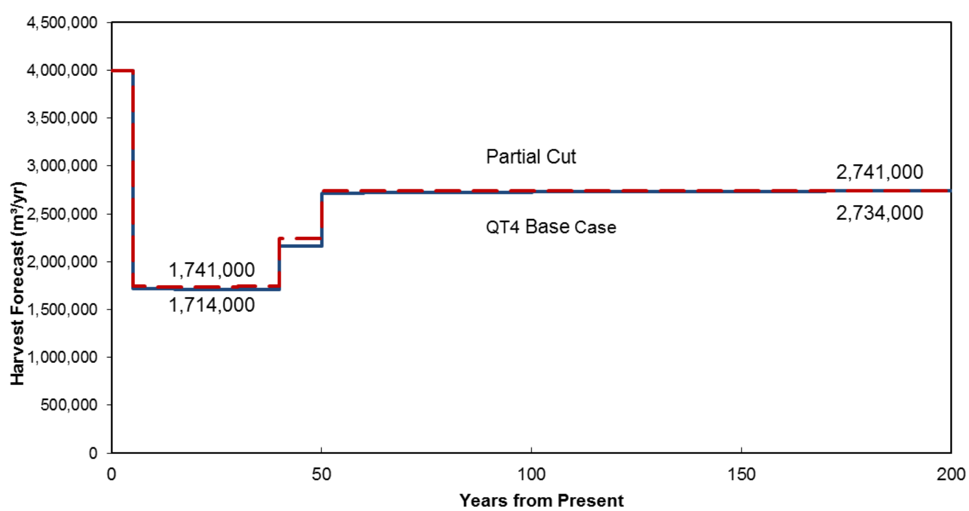


Figure 47 Harvest flow: Base Case compared to the partial harvest strategy

4.7 Combined Silviculture Treatments (Budget of $5 million / year)

In this strategy, all of the above-mentioned strategies were available to the model with the same $5 million/yr budget. It is intended to explore what, when, where and how much each silviculture treatment might contribute to best mitigate the forecasted mid-term timber supply shortage.

Figure 48 shows silviculture treatment areas selected by the model over the next 100 years on the left; corresponding expenditures are shown on the right. For the first 5 years, 74% of the allotted budget is spent on enhanced basic silviculture treatments ($3.7 million/yr), while the rest of the budget is applied to fertilization (18%; $0.9 million/yr) and pre-commercial thinning (8%; $390,000/yr) treatments.

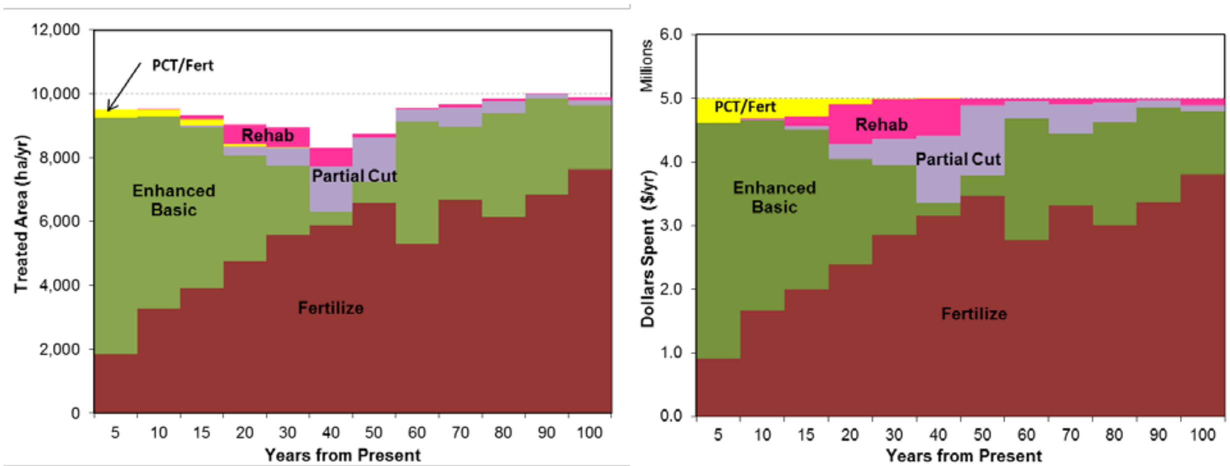


Figure 48 Area treated and budget spent by silviculture treatment under the combined silviculture treatment strategy with a budget of $5 million/yr

Later in the planning period, as more stands reach ages within the fertilization eligibility window, a greater proportion of the budget is spent on fertilization. By the 3rd decade, most of the budget is spent on fertilization treatments (~$3.0 million/yr).

Both rehabilitation and partial harvest treatments begin after the salvage harvesting phase when stands have completely deteriorated from MPB attack (15-20 years from now). The rehabilitation strategy contributes to available volumes in long term while the partial harvesting strategy contributes to the mid-term volumes.

Figure 49 shows a significantly improved harvest flow by combining all silviculture strategies. The mid-term harvest level increases by 16.2% (277,000 m^3/yr) over the Base Case while the long-term harvest level increases by 9.4% (258,000 m^3/yr).

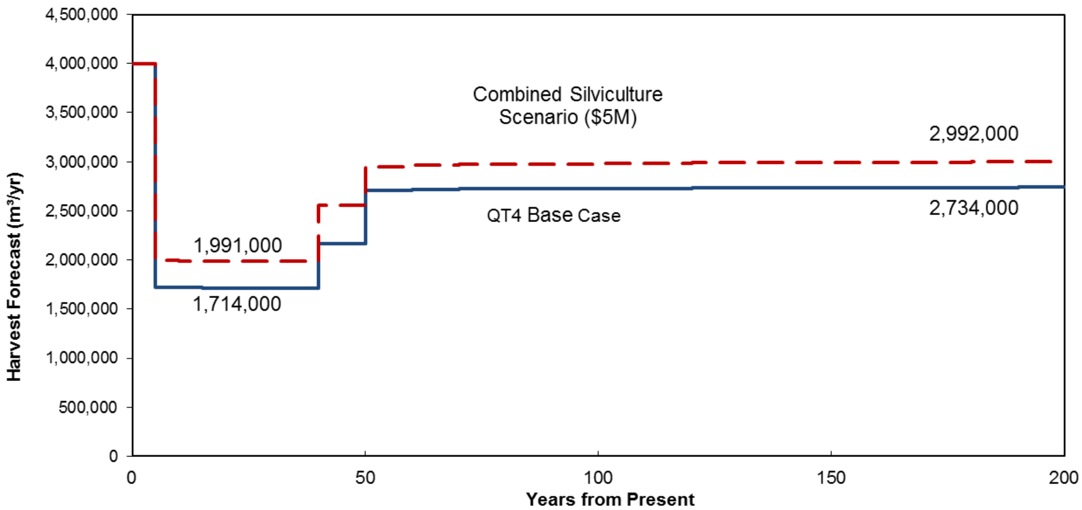


Figure 49 Harvest flow: Base Case compared to combined silviculture strategy (Budget $5 million/yr)

4.8 Combined Silviculture Treatments (Budget of $2 million/year)

Similar to the previous combined silviculture strategy, all of the above-mentioned strategies were available to the model, except the budget was reduced $2 million/yr to reflect a more realistic funding level. Again, this strategy is intended to explore what, when, where and how much each silviculture treatment might contribute to best mitigate the forecasted mid-term timber supply shortage.

Figure 50 shows silviculture treatment areas selected by the model over the next 100 years (left) with corresponding expenditures (right). For the first 5 years, 83% of the allotted budget is spent on enhanced basic silviculture treatments ($1.65 million/yr), while the rest of the budget is applied to fertilization (12%; $250,000/yr) and pre-commercial thinning (5%; $94,000/yr) treatments.

Relative to the combined silviculture scenario at a $5 Million/yr budget, the distribution of budget allocated to silviculture activities changed slightly. In the first 5 year period, more money was focused on enhanced silviculture (83% versus 74%) and less budget was focused on fertilization and pre-commercial thinning (13% versus 18% and 8% versus 6%, respectively). The higher reliance on enhanced silviculture is largely due to the disproportionally higher harvest target request 50 years from now relative to the rest of the planning horizon. The higher request in this one period intentionally focuses treatments in the near-term towards meeting the target harvest level in this period.

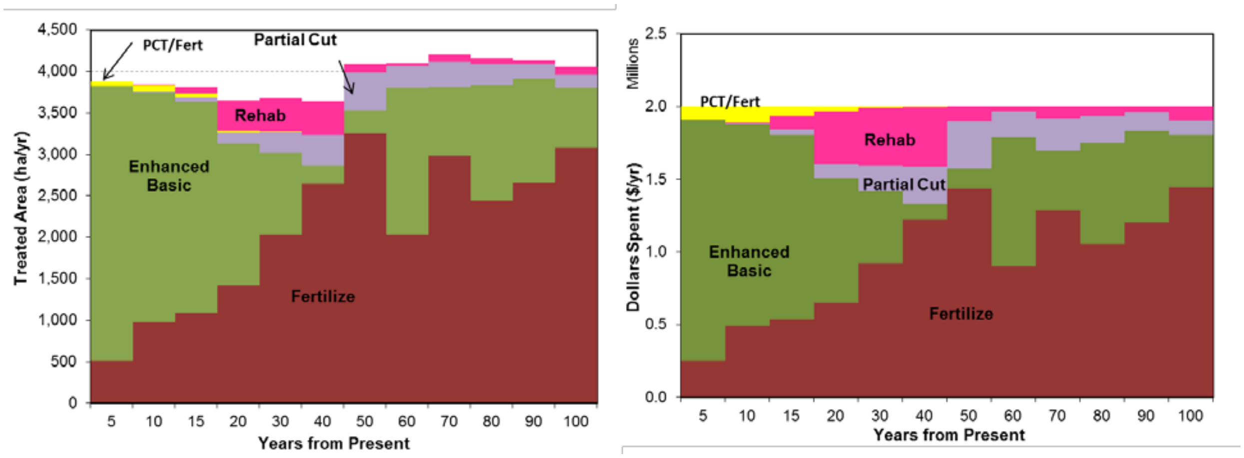


Figure 50 Area treated and budget spent by silviculture treatment under the combined silviculture treatment strategy with a budget of $2 million/yr

Figure 51 shows a considerably improved harvest flow by combining allowing all silviculture strategies at a reduced budget of $2 million/yr. The mid-term harvest level increases by 10.2% (175,000 m^3/yr) over the Base Case while the long-term harvest level increases by 3.1% (86,000 m^3/yr).

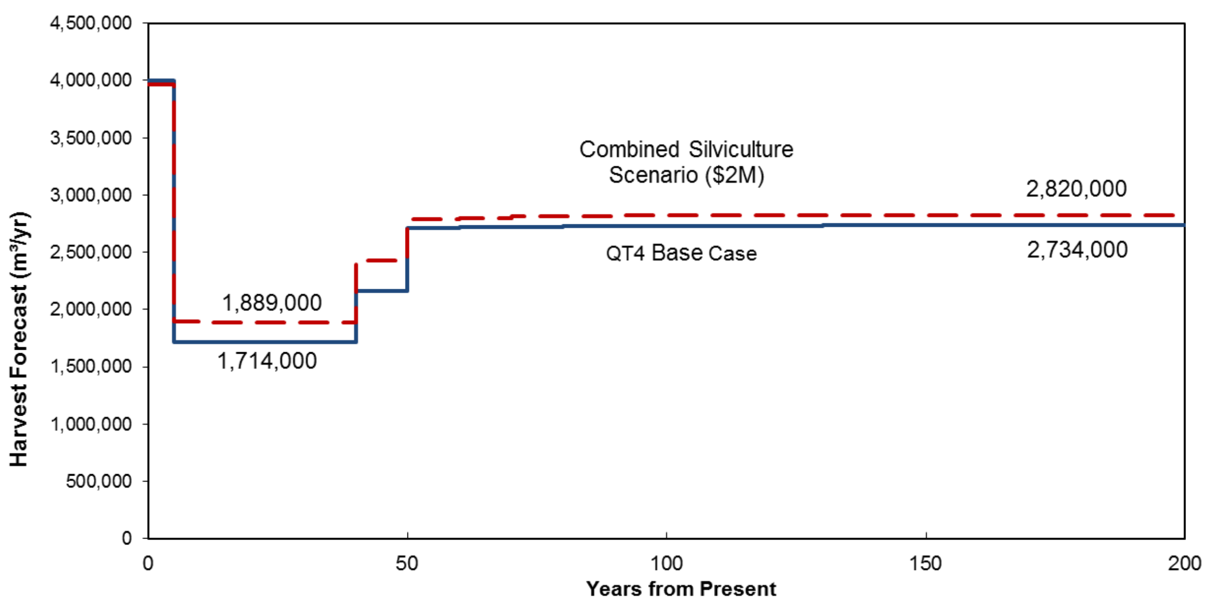


Figure 51 Harvest flow: Base Case compared to combined silviculture strategy (Budget $2 million/yr)

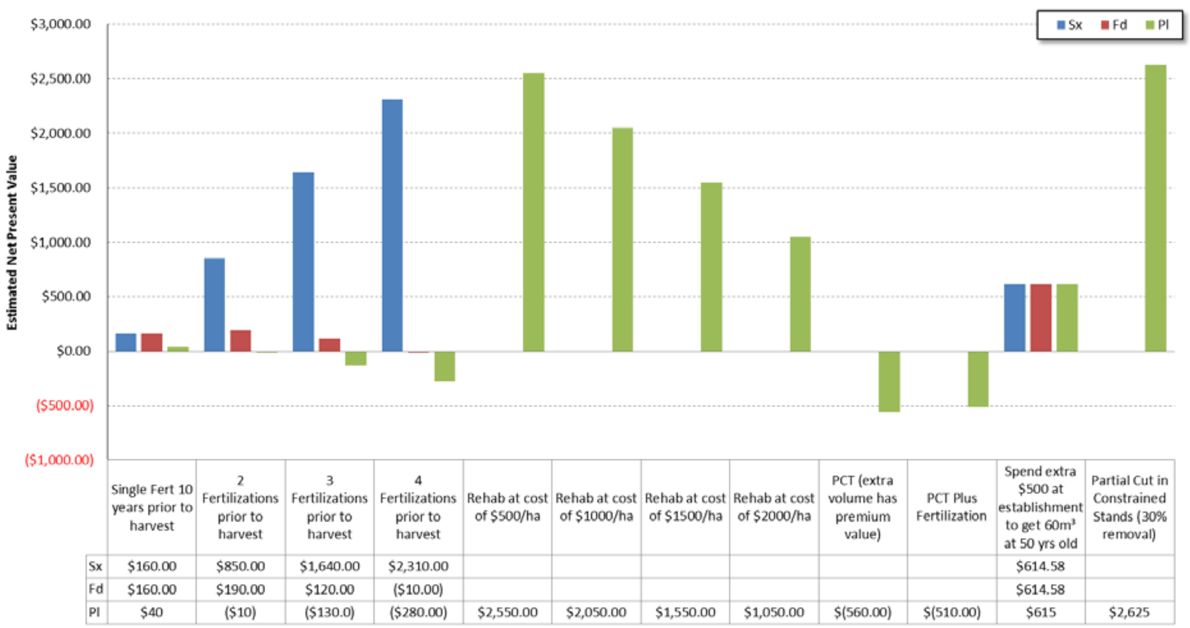
5 Economic Considerations

The following section presents the results of the silviculture strategies considering both stand- and forest-level economic criteria. These economic considerations are intended to provide simple evaluations to compare results for each silviculture strategy.

The investment efficiency of alternative silviculture treatments at the stand level can be assessed based on the net present value (NPV) of its series of costs (investments) and resulting future returns. This is one way of comparing alternative investment choices that produce different future outcomes in terms of revenue scale and timing. Where stand treatments can combine to create synergistic improvements in timber supply (e.g. solve pinch points in timber supply), investment efficiency needs to also be considered at the forest level as well. Both of these approaches are examined below.

5.1.1 Stand-level

Figure 52 shows stand-level NPVs by treatment type (and species type where appropriate). The best stand-level NPVs can be seen to come from multiple-fertilization of spruce stands, rehabilitating pine stands and partial cutting – while pre-commercial thinning and multiple fertilization of pine stands lead to negative NPV's due to little volume response and long periods of time between investment and revenue realization. With higher discount rates, all treatments would look less attractive, but those with long times between investment and return (rehab/enhanced regeneration) would be impacted disproportionately. For example, at 8%, rehabilitation with a cost of $1000/ha had a NPV of -$900/ha.



	Single Fert 10 years prior to harvest	2 Fertilizations prior to harvest	3 Fertilizations prior to harvest	4 Fertilizations prior to harvest	Rehab at cost of $500/ha	Rehab at cost of $1000/ha	Rehab at cost of $1500/ha	Rehab at cost of $2000/ha	PCT (extra volume has premium value)	PCT Plus Fertilization	Spend extra $500 at establishment to get 60m³ at 50 yrs old	Partial Cut in Constrained Stands (30% removal)
Sx	$160.00	$850.00	$1,640.00	$2,310.00							$614.58	
Fd	$160.00	$190.00	$120.00	($10.00)							$614.58	
Pl	$40	($10)	($130.0)	($280.00)	$2,550.00	$2,050.00	$1,550.00	$1,050.00	$(560.00)	$(510.00)	$615	$2,625

Figure 52 Stand-level net present values for silviculture activities using a 2% discount rate.

Stand Level NPV Calculation Assumptions:

Assuming a 2% discount rate and a net economic benefit of \$50/m^3 on the additional volume realized.[3]

- **Single Fertilization** 10 years prior to harvest
  - Sx or Fd: Treatment cost of \$450/ha, 15m^3 realized in 10 years (\$750/ha)
  - Pl: Treatment cost of \$450/ha, 15m^3 realized in 10 years (\$750/ha)
- **Multiple Fertilizations** prior to harvest where harvest occurs as soon as possible after last fertilization application.
  - Sx: Treatment cost of \$600/ha applied in 5 year intervals, 49^3/yr, 89^3/yr, and 132^3/yr, for 2nd, 3rd, and 4th application respectively (\$2450/ha, 44500/ha, and \$6600/ha).
  - Fd: Treatment cost of \$450/ha, 15m^3/application realized in 10 years (\$1500/ha, 2250/ha, and \$3000/ha)
  - Pl: Treatment cost of \$450/ha, 12m^3/application realized in 10 years (\$600/ha)
- **Rehabilitation**
  - Rehab costs provided for 4 levels of cost (\$500, \$1000, \$1500, and \$2000/ha). The idea being that stands with some merchantable value will offset the establishment silviculture cost. All values provided assumed 200m^3/ha of sawlog volume produced within a 60 year time frame. NPV of \$10,000 revenue 60 years out at a 2% interest rate = \$3.047.82. Initial investment cost already in present terms deducted from this potential future revenue provided the stand level NPVs.
- **Pre Commercial Thinning**
  - Incremental volume of 18 m^3/ha with an incremental product value of \$30/m^3 for a total future revenue of \$1440/ha realized 50 years from now for a future revenue of \$535.00/ha expressed in today's terms minus \$1100.00 initial treatment cost = -565.66/ha
- **PCT Plus Fertilization**
  - Incremental volume of 18m^3/ha from PCT and 12m^3/ha from fertilization 20 years from initial PCT treatment with an incremental product value of \$30/m^3 for a total future revenue of \$1440/ha realized 50 years from now or \$535/ha expressed in today's terms (@2% discount rate) minus \$1100.00 initial treatment cost minus fertilizer application 20 years from now at cost of \$450/ha (\$302.84/ha Present value) = -\$511.176./ha)
- **Enhanced Reforestation**
  - Spend an extra \$500 at establishment to get an extra 60m^3 50 years from now (when harvested) at a value of \$50/m^3 = \$3000/ha future value expressed at \$1114.48/ha - \$500/ha treatment cost = NPV of \$614.58/ha
- **Partial Cutting**
  - Get 30% of stand volume within a constrained area at an incremental cost of \$15/m^3. In this case, (75m^3/ha realized from treatment * \$50/m^3) + (-\$15/m^3* 75m^3/ha)= NPV of \$2625.00/ha

[3] This value was selected to provide an example. Only the variable costs of logging/hauling the additional volume would be considered as the fixed costs would still be incurred at time of logging without the investment occurring. Economic benefit meant to consider both revenue to crown (stumpage/taxes/fees) and that realized by the tenure holder.

5.1.2 Forest-level

To assess forest level investment efficiency, NPV's were calculated using the series of investments made over the planning horizon and the revenue associated with any improvement in harvest yields over the same timeframe. This presents a somewhat pessimistic view of each of the scenarios because some investment costs made near the end of the period in question will be included but the returns they generate are not. When the cumulative investments and returns are considered over time for treatments, the potential economic benefits can look considerably different at a forest-level relative to stand-level due to timber supply dynamics. This is partially attributed to an "Allowable Cut Effect"[4].

Figure 53 shows the series of annual present values realized for the combined (optimized) silviculture treatments strategies at both the \$5 Million/yr and \$2 Million/yr budget levels. Both strategies begin with a negative NPV because costs are incurred with no revenue (harvest remains at current AAC - 4.0 million m^3/yr). When higher harvest levels occur during the midterm/longterm, the net economic benefit of this volume is greater than the ongoing investment in silviculture so annual present values are positive. Throughout the 200 year planning period, the total NPV for the \$5Million/yr and \$2 million/yr budget levels are \$343 Million and \$211, respectively. A 60% reduction in budget resulted in only a 39% reduction in NPV because it is able to focus on the most cost effective investments – however the higher level of spending still achieves a higher overall NPV because the additional \$'s invested still produce positive contributions to the NPV. The spike 50 years from now is a result of the extra harvest request in the transition period from the mid-term to the long-term.

This analysis suggests that a 2% discount rate, the silviculture program will produce a positive NPV – or in other words - an internal rate of return (IRR) greater than 2%.

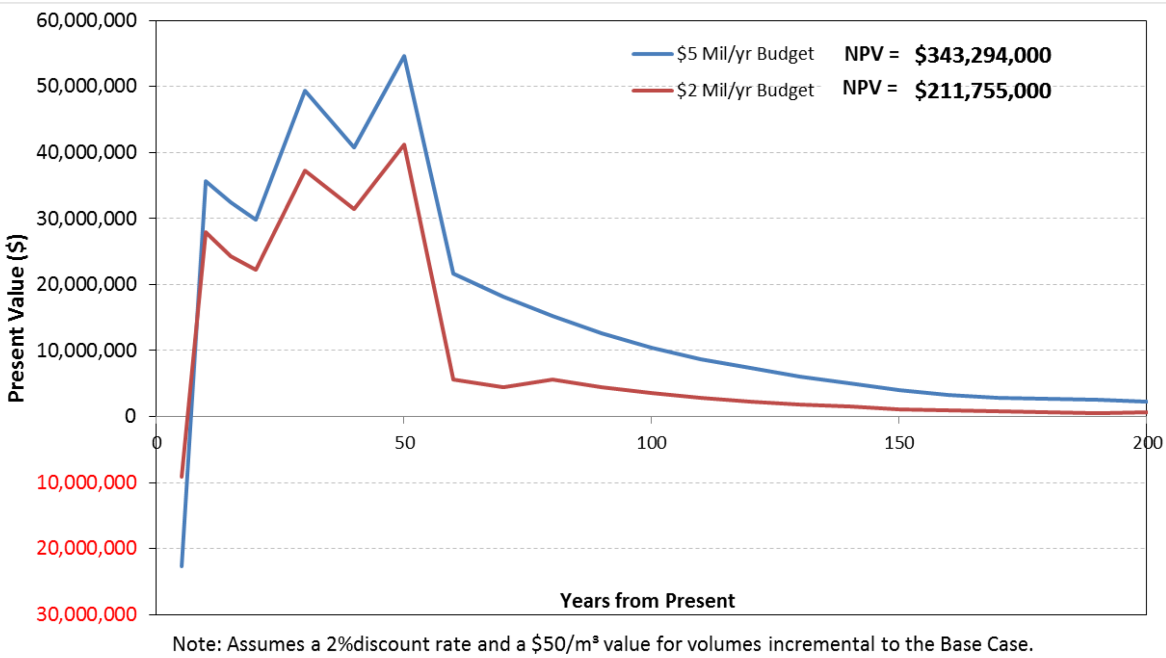


Figure 53 Present values for the combined silviculture treatment strategies

Figure 54 shows the total NPV's for each silviculture strategy relative to the Base Case.

[4] An immediate increase in timber supply resulting from expected future gains. This occurs because incremental volume in the future takes the place of existing stand volume that would otherwise be needed at that time. This effectively allows existing stand volumes to be harvested at a faster rate over the intervening time period.

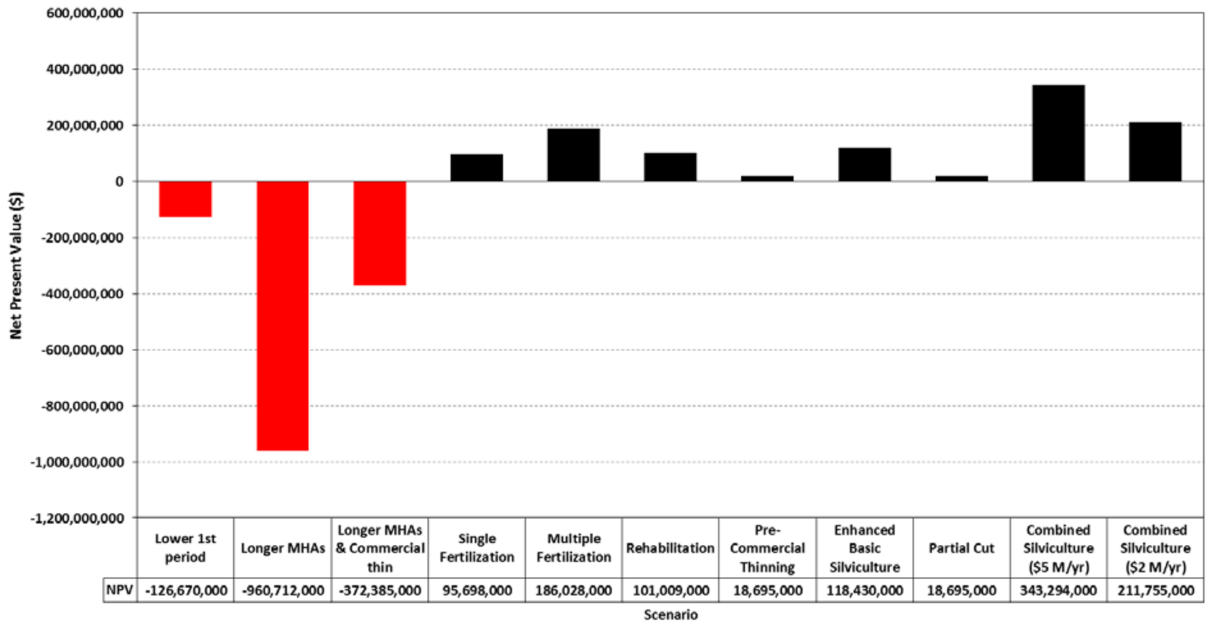


Figure 54 Net present values for each silviculture strategy relative to the Base Case

The three base case sensitivities (section 3) present negative NPVs as the opportunity cost associated with reduced harvesting. However, these figures assume that each cubic meter harvested is worth the same amount ($50/m^3). It is more likely that these NPVs are much better because the product profile associated with these sensitivities should be much better than the Base Case. On the other hand, the longer rotation ages also extend the time required to attain these improved product profiles so the NPVs are diminished due to the time value of money.

According to these total NPVs, the most favourable strategy is the combined silviculture treatments strategy at the $5 million/yr budget level. It was most attractive because this strategy produces the highest incremental harvest flow relative to the Base Case and these gains are realized relatively quickly.

6 Preferred Silviculture Strategy

The forest estate model used in this analysis applied a goal-seeking approach that scheduled numerous activities across time and space to arrive at the best solution that met the defined targets. Consequently, for any given funding level, the combined silviculture treatments strategy should produce a preferred silviculture strategy.

In this analysis, the model results suggest that combined strategy with the higher budget level ($5 million – section 4.7) is the preferred strategy. Compared to all other strategies explored, this strategy produced the:

- Highest increase in the mid-term harvest level (277,000 m^3/yr or 16.2%)
- Highest increase in the long-term harvest level (258,000 m^3/yr or 9.4%)
- Highest total NPV over the planning horizon

It is not appropriate to simply adopt the modelling output from the preferred strategy as the tactical plan. Rather, the treatment schedule produced must be considered in light of other factors and information learned from this analysis. This tactical plan, informed by this preferred scenario, is presented in the final Quesnel Silviculture Strategy document.

7 Summary

Table 1 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 million.

Table 1 Summary of harvest flow improvements from silviculture strategies relative to the Base Case

Scenario Type	Scenario	1st 5 year period Change relative to Base Case (m³/yr)		Mid-term relative to Base Case (m³/yr)		Mid-to-Long-Term Transition relative to Base Case (m³/yr)		Long-term relative to base case (m³/yr)	
Base Case Sensitivities	Lower 1st period	-1,049,000	-25.9%	103,000	5.8%	-49,000	-2.2%	6,000	0.2%
	Longer MHAs	-93,000	-2.3%	-701,000	-39.8%	-684,000	-30.9%	165,000	5.8%
	Longer MHAs & Commercial thin	-3,000	-0.1%	-332,000	-18.8%	-276,000	-12.5%	162,000	5.8%
Silviculture Scenarios	Single Fertilization	-3,000	-0.1%	56,000	3.2%	134,000	7.8%	104,000	3.7%
	Multiple Fertilization	-2,000	0.0%	168,000	9.5%	226,000	1.8%	203,000	7.3%
	Rehabilitation	-3,000	-0.1%	53,000	3.0%	108,000	6.0%	101,000	3.6%
	Pre-Commercial Thinning	2,000	0.0%	53,000	2.1%	89,000	4.9%	18,000	0.6%
	Enhanced Basic Silviculture	0	0.0%	168,000	2.9%	172,000	10.2%	213,000	7.6%
	Partial Cut	-1,000	0.0%	37,000	10.5%	39,000	4.0%	2,000	0.1%
	Combined Silviculture ($5 M/yr)	-4,000	-0.1%	277,000	15.7%	394,000	17.8%	258,000	9.3%
	Combined Silviculture ($2 M/yr)	-33,000	-0.8%	174,000	10.2%	262,000	11.9%	86,000	3.1%

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:

- Reducing salvage immediately leaves more green timber on the landbase that can be harvested throughout the mid-term. However, this approach comes at some cost of deteriorating volumes according to shelf-life assumptions plus the economic loss of a reduced short-term harvest level.
- Waiting longer to harvest managed stands (i.e., age based on culmination of MAI versus the minimum stand volume criteria of > 120 m³/ha) significantly lowers and prolongs the projected mid-term but improves the long-term harvest level, product profile, and harvest costs (also reduces hectares harvested per year and increases age classes distribution).
- Commercial thinning 50-70 years from now (transition to harvesting managed stands) could be considered to produce better stands in the long term while still accessing some harvest volumes near the end of the midterm. However, during this period, nearly half of the harvest area must be commercial thinning to achieve the results presented section 3.3. This is a relatively expensive harvest method so technological advances and use of smaller equipment is likely required to make this more economically viable.

- Despite the number of times stands can be fertilized, there are limited opportunities for fertilization in the short-term (next 20 years). This is due, in part, to the current lack of stands in suitable age classes (20-60 year old stands) and forest health conditions for this treatment. Fertilization opportunities increase 20-40 years from now.
- Single-fertilization treatments are best carried out closer to harvest to maximize the NPV and minimize risk – but government budgets should be utilized when ever they are available to ensure the benefit is captured.
- While more opportunities for multiple-fertilization treatments are available 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 treatment. Still, fertilization of pine stands should not be overlooked given the relative abundance of these stands.
- Rehabilitation of marginally-economic stands as the salvage period expires (towards the end of shelf-life) should provide some harvest volume at the time of treatment while also producing regenerated volume at the end of the mid-term (50-60 years from now) and into the long-term (80+ years). The eligible area for this strategy is largely dependent on market prices for fibre plus innovative funding mechanisms available.
- Given some uncertainty with regenerated stand densities, there are limited opportunities for pre-commercial thinning in the short-term (next 20 years) and future opportunities are difficult to predict. While this treatment provides little direct benefit to timber supply, it can contribute by improving timber quality and preparing suitable stands for other treatments, like fertilization.
- The enhanced basic silviculture strategy (planting at higher densities with improved genetic stock) results in significant timber supply gains near the end of the mid-term (50-60 years from now) and into the long-term (80+ years). With elevated harvest levels in the short-term (next 5-10 years), significant opportunities exist for this strategy. While licensees may be able to move more toward target stocking levels, administrative changes that incent excellence (vs regulate minimums) will be required to get significant engagement from forest companies.
- The partial harvesting within constrained areas strategy is most opportune throughout the mid-term while available merchantable volumes are low. Provided forest cover and ecosystem functions remain intact, or improve, this strategy can provide access to volume within areas otherwise constrained by non-timber values such as landscape biodiversity, visuals, wildlife habitat and watersheds.
- 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. Some work has been done to verify the volume estimates but licensees have reported large discrepancies when comparing cutting permit cruise data. Uncertainty around existing volume estimates results in uncertainty around mid-term harvest levels. If the current inventory is overestimating growing stock, then the mid-term harvest levels presented in this analysis could be substantially lower. However, this should not detract from the results and learning that this analysis provides. The focus should be on the relative differences between the Base Case and modeled strategies as opposed to 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 of their ability to increase the productivity of the landbase, increase volumes at final harvest, access volumes from constrained areas, or 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. future fires, potential future outbreaks of forest insect and disease) must 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.

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