Interim Guidance for Commercial Thinning – Interior British Columbia

Office of the Chief Forester Division

British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development

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Acknowledgements

Produced in partnership with project team members from the:

Forest Industry (West Fraser Mills, Carrier Lumber, Canadian Forest Products, BC Timber Sales, Western Forest Products, BC Council of Forest Industries, the BC Pulp and Paper Coalition), FP Innovations, the University of British Columbia, Natural Resources Canada, the Office of the Chief Forester Division, and the Timber Pricing Branch, with support from the late Terje Vold, Jim Hackett and Bryce Bancroft.

Cover Photo: Google Earth image of commercial thinning interior Douglas-fir near Quesnel, 2019

Executive Summary

This document provides the principles behind the use of commercial thinning (CT) as a tool to achieve timber management objectives. It provides guidance on where and how to apply CT based on operational experience and growth and yield model projections as well as implement operationally under the *Forest and Range Practices Act* (FRPA). Deviation from this guidance should be based on dialogue between industry and government forest professionals, and as provided in this guidance, utilizing a structured adaptive management approach.

This document provides guidance on:

i. The principles that guide the use of CT within the Interior of British Columbia (BC),
ii. Examples on where and how CT should be applied at the stand level,
iii. Examples on how it can be incorporated in timber supply analysis to support Forest Landscape Planning pilots (FLP) and operational decisions, and
iv. Example stocking standards.

A Stand Level Decision Aid is included for lodgepole pine, white spruce and to a limited extent interior Douglas-fir.

This guidance document builds on the 1999 *Guidelines for Commercial Thinning* prepared by the then BC Ministry of Forests. If an element of CT advise is not contained here, please refer to that document.

The document is structured with three main themes as chapters:

1. Vision and Principles behind CT
2. Stand selection criteria, including the growth and yield and economic modelling assumptions and operational implementation suggestions
3. Planning at both stand and landscape levels, including legislation and policy

The Appendices go into more detail on five topic areas:

1. Stand Level Decision Aid
2. Literature Review Executive Summary
3. Landscape Level GIS Analysis of potentially suitable areas
4. Forest Health Considerations
5. Economic Analysis of CT

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Chapter 1 - Vision and Principles for Commercial Thinning

Introduction

The timber supply in the BC Interior has shifted markedly in the last two decades from a legacy of mature and old forest to a substantial composition of managed or second growth forests across many management units. This shift has resulted largely from nearly two decades of extensive salvage harvesting of mountain pine beetle (MPB) damaged lodgepole pine, losses from wildfire, ongoing mortality losses from other conifer bark beetles and disease, and ongoing reductions to the Timber Harvesting Land Base (THLB) for other land use objectives.

Commercial thinning (CT) may help offset short- and mid-term timber supply shortfalls experienced in some Interior management units (e.g., Timber Supply Areas and Tree Farm Licences) by providing redistribution of timber flow at the landscape level by breaking up large areas of THLB in similar age classes. There is also a societal focus on the health, condition, and overall resilience of our forests and CT may contribute to this goal.

This CT guidance focuses on timber objectives for the BC Interior and has been developed with input from West Fraser Mills, Carrier Lumber, Canadian Forest Products, Western Forest Products, BC Council of Forest Industries, the BC Pulp and Paper Coalition, FP Innovations, the University of British Columbia, the Ministry of Forests, Lands, Natural Resources Operations and Rural Development and Natural Resources Canada.

This document provides guidance on:

i. The principles that guide the use of CT within the BC Interior,
i. Examples on where and how CT should be applied at the stand level,
ii. Examples on how it can be incorporated in timber supply analysis to support Forest Landscape Planning (FLP) pilot projects and operational decisions, and
iii. Example stocking standards for retention during operations and to provide opportunity in the future.

This guidance does not replace or preclude legal requirements or other sources of guidance that have been previously issued by the Ministry[1]. It builds on the *Guidelines for Commercial Thinning* (Ministry of Forests, 1999). If an element of CT advise is not contained here, please refer to that document.

This guidance provides input to landscape level planning and associated timber supply analysis. They are intended to support operational decision-making for candidate stands for CT treatment.

This document is version 1 of intended guidance focused on managing for timber production in the BC Interior. Exploring the use of CT for managing timber in Coastal forests (version 2) and using CT or partial harvest as a tool for managing other non-timber resource values such as: indigenous values, stand structural diversity, wildlife habitat, wildfire risk mitigation, visual quality and carbon sequestration will be addressed in subsequent guidance (version 3).

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[1] Guidance of note for the Interior of BC, includes Chief Forester Expectations for Prioritization in Response to Spruce Beetle Outbreaks (June 2020)

Vision

The application of commercial thinning will support the development of resilient future forests that optimize a steady stream of goods and services over time to meet the requirements of society. Within this framework, the province is fairly compensated for resource use. Future timber supply and other resource values are maintained and not compromised by commercial thinning.

Management Focus

The focus of this guidance is to maintain or enhance the volume and/or value of the timber from our Interior forests to help alleviate immediate and mid-term timber supply while maintaining or enhancing the many non-timber values our forests provide.

Definition

Commercial thinning is a partial cutting treatment applied to immature forests where the value to the province exceeds the cost of the treatment. Commercial thinning applies to even-aged forest stands and is an interim treatment that exists in the context of a broader stand management regime to provide for specific prescribed stand volume and value attributes over time. Value may be economic as a measure of quality and quantity of fibre in the future, providing ecological function or social in nature as a steady flow of fibre for producers.

Principles to guide commercial thinning

These principles are meant as the underpinnings to long term sustainable management. The document provides analytical work to help guide implementation. Where stands are outside of that guidance, they must achieve the principles described here. Additional simulations can be run to assess specific instances where a candidate stand is outside the guidance range yet is consistent with the principles.

1. Vigorous stand growth and site potential is maintained

- With the intent to remove some volume early and maintain vigorous growth until final harvest, the stand is younger than the culmination of the mean annual increment and final harvest is at least 15-20 years after CT operations.
- The residual stocking has tree species, quality, health, vigor, and density that allows for the residual stand to capture the site's growth potential.
- Distribution of growing space among the residual trees is a key factor that determines site occupancy and stand growth following CT operations.
- Access trails and new road clearing widths within all operations are kept as narrow as possible.

2. Stand yields are maintained for the full rotation

- Cumulative volume of CT plus final harvest is relatively equal to or greater than the volume at rotation of the untreated stand forecast from growth and yield model runs.
- The target for Volume Yield Neutral as defined in these guidelines is 95 % or greater of the volume estimated by models for clearcutting the stand at age 80 years. The variance from full yield is based on assumed uncertainty of model results and timing of final harvest.

3. Adaptive management will improve practices

- Ongoing monitoring occurs over time; metrics are established to measure the effectiveness of treatments in the short, medium, and long term.
- This guidance will be reviewed and updated annually to reflect the most recent learnings from the CT Research Sub Committee and other science-based sources.
- Prescriptions will apply the most recent learnings from various sources, E.g., the Quesnel FLP pilot, the CT Research Sub Committee, Operational learnings from BC and other comparative jurisdictions regarding timber management, operational practices, resource management priorities (wildlife, water, fish, wildfire resilience and other values);

4. Economic benefit to the public is maintained

- The net present value (NPV) of the conversion return estimate for the rotation is positive with reasonable log price, logging phase cost and discount rate estimates are used in the calculations.

5. Non-timber values are maintained or enhanced

- The intent is for the CT treatment to at least maintain the other non-timber resource values.

Management Objectives

Before embarking on any harvest or silvicultural treatment, it is essential to understand the current and future management objectives for the management unit. The following general management objectives apply to commercial thinning:

1) To alleviate immediate and mid-term timber supply concerns, by providing for sustainable levels of allowable annual cut, by addressing age class imbalances, and the redistribution of timber flow over time to support economic stability within communities.

2) To enhance the quality and attributes of merchantable timber at final harvest through a reduction in stand density that maximizes diameter and volume growth of residual trees, as well as, removes dead, damaged, and diseased trees without substantially impacting cumulative gross volume production

3) To utilize additional merchantable material produced by a stand through capturing tree mortality that would otherwise be lost to suppression or other forest health factors.

4) To maintain or enhance stand level biodiversity and ecosystem resilience by modifying stand structure and species composition to provide for wildfire risk reduction across the landscape.

Chapter 2 – Selection criteria

Guidance Assumptions

This guidance is based on current practices in BC's Interior where timber is removed on 5 meters (m) wide trails, measured bole to bole, established every 20 m (see Figure 1). The 15 m strips between trails are 'thinned from below' to enhance the volume and value of the residual crop trees at the time of final harvest. With 'thinning from below', the lower crown classes are removed to favour the most vigorous trees in the stand. Trees 'thinned from below' can also include 'quality thinning' where dead, damaged, and diseased trees are removed to utilize tree mortality losses while improving the health, resilience, and growth of the remaining trees.

Although the guidance assumptions are mechanized 'thinning from below', other thinning approaches and patterns with narrower access trails, including multiple thinning entries, may be appropriate and will yield different results than presented here. Custom stand-level modelling will be required to rationalize the operation (see "Determining Volume Yield for the Rotation").

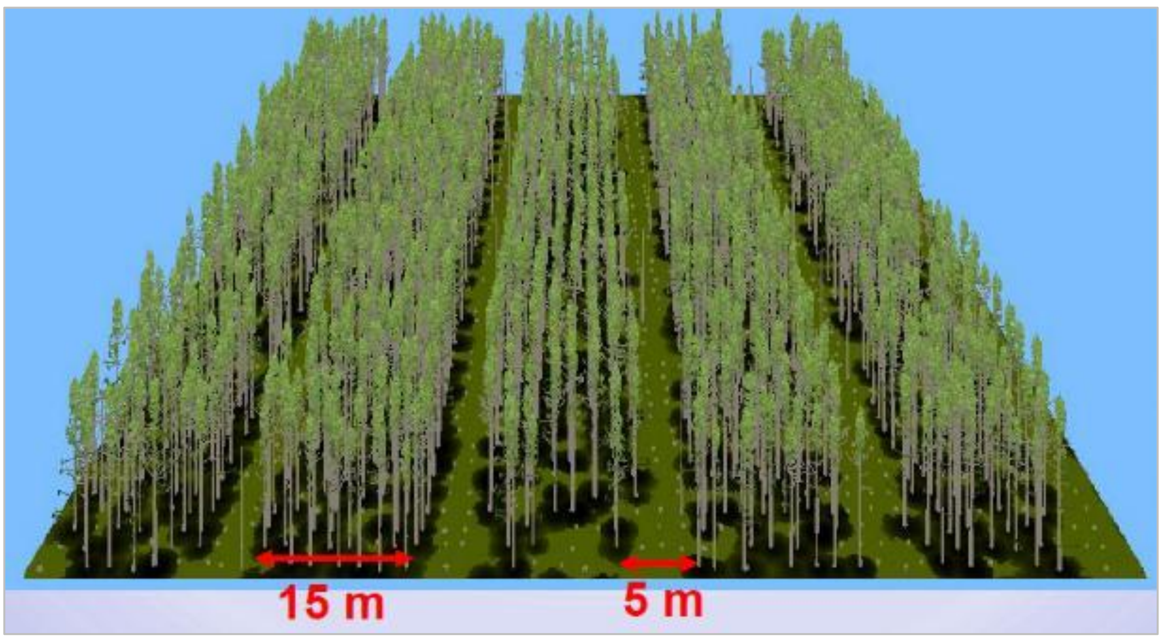

Figure 1: The type of thinning modelled is based on current practices in BC's Interior.

Stand Level Modelling Considerations

To provide operational guidance the Forest Analysis and Inventory Branch used the Tree and Stand Simulator (TASS) to predict silvicultural treatment response by modeling individual tree crown dynamics and their relationship to bole growth and wood quality. The focus on crown dynamics makes TASS particularly well suited for predicting response to treatments such as fertilization, and pre-commercial and commercial thinning.

In the stand level analysis, the following versions were used to simulate the response to CT:TASS v3.01.015W for interior lodgepole pine (Pli) and white spruce (Sw), and TASS v2.07.75WS was used for interior Douglas-fir (Fdi). These will be referred to as TASS II, or TASS III in this document. The parameters used in the TASS analysis for all three species to assess if stands met treatment suitability criteria include:

- Site Index (SI)[2]: SI 16 to 26 m at 2 m intervals
- Initial planting densities: 1000 to 2600 sph at 200 sph intervals
- Thinning intensity: 00 (control), 25, 40, 50 and 60% basal area removal
- Thinning ages: 25 to 65 years at 5-year intervals
- Final harvest ages: 60 to 120 years at 20-year intervals
- Standard Operational Adjustment Factors[3] (OAF1 = 15%; and OAF 2 = 5%)
- Utilization standards: 7.5, 12.5, and 17.5 cm dbh.

TASS simulations assume the stand contains: 100% single species, planted stems at an initial density, no natural ingress, evenly distributed stems, and no damage to residual stems from CT operations.

Forest Health Considerations

The intent of CT is to maintain a heathy and vigorous stand. CT may aid in this by removing damaged or diseased trees; however, it is important that forest health is considered before and during CT operations to promote a healthy productive stand. Proper planning and training of operators will help achieve this. Stocking standards are expected to identify the acceptable damage criteria of residual trees.

CT operations including the establishment of access trails may increase the presence and severity of certain insects, diseases, and abiotic factors. Many insects and diseases will flourish in damaged trees and can spread to adjacent forested areas. Where CT is proposed it should be remembered that pest proofing the residual stand is an important objective. To meet this objective, it is important that a systematic Forest Health survey be conducted, prior to the thinning activities, to determine intensity and distribution of damage agents (e.g., insects, disease, and potential abiotic factors).

Appendix 4 contains specific guidance related to the following forest health considerations before, during and after CT operations:

- Windthrow, including height to diameter ratio degree of slenderness and multiple thinning entries,
- Stem damage and decay, including the timing of operations,
- Drought,
- Root Disease and butt rot,
- Pine Stem Rust, including western gall, stalactiform and comandra blister rusts,
- Dwarf Mistletoe, and
- Insect pests (e.g., bark beetles, terminal weevils).

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[2] A measure of productive potential of a specific tree species expressed as potential tree height at 50 years breast height age.

[3] Operational Adjustment Factors in growth and yield modelling: OAF 1 addresses reductions or gaps in physical growing space/stem distribution. OAF 2 is a progressive multiplier that increases linearly with the age of the stand to address decay waste and breakage and losses due to forest health agents that are not static over the life of a stand.

Economic Considerations

A conventional economic analysis evaluated the CT operations developed for timber stands within the same SI, initial stocking density and age class, for both lodgepole pine and white spruce. The analysis confined itself to a log-based valuation model; an end-product valuation model was not considered. Please refer to Appendix 5 for a detailed description of this work, including the assumptions employed and the results obtained.

The economic analysis suggests that most commercial thinning treatments do not result in a higher return on investment relative to the base case scenario (i.e. no thinning treatment), when using net present value (NPV) as the economic criterion for choosing between mutually exclusive projects in the same time frame. The attractiveness of investment projects increases with the size of the NPV. High NPV projects are inherently more appealing and are preferred to lower NPV projects. Any treatment that is incapable of generating enough cash inflows to cover necessary cash outlays, when both are expressed on a present-value basis, should not be undertaken. In the case of a treatments with an NPV = 0, acceptance would neither increase nor decrease the value of the CT treatment to the landowner. The owner would be indifferent to pursuing such a project. NPV analysis of CT represents a practical application of marginal analysis, in which marginal (or incremental) revenues and marginal (or incremental) costs of projects are considered on a present-value basis. Use of NPV in the evaluation of alternative CT investments allows landowners to apply marginal analysis in a simple and clear manner. The widespread practical use of the NPV technique lends support to the view that value maximization is the prime objective pursued by landowners in the process of evaluating alternative projects.

In summary, all treatments with a positive NPV[4] are acceptable, but the treatment with the largest[5] NPV is favoured. There are likely other economic indicators in addition to NPV that need to be considered when analyzing the potential benefits of CT. At the regional and community level, the focus may be on the number of jobs lost or gained or the change in total earnings among workers. We only considered NPV, a measure of economic efficiency her. It is a widely accepted criterion for evaluating alternative investment projects.

The results presented here show that thinning responses overwhelm the present value calculations within a relevant range of rotation ages and SI classes. Regardless of the sensitivities considered for log prices, costs or discount rates, the base case provides a higher NPV than the NPV for treated stands within the Mackenzie, Prince George, and Quesnel TSAs. The NPVs are still positive for some treated stands but not as high as the NPVs for untreated stands.

It is recognized that CT is still in its infancy in the BC Interior. Further work is required to better understand the potential of this treatment. Previous work[6] advised that CT treatments be undertaken with caution since not all of them yield positive NPVs. Within this context, the following economic guidelines are provided to licensees contemplating CT operations on their management units and should be read together with other guiding principles presented in this document:

- Undertake CT operations if it can be demonstrated that conversion return estimates are positive, and

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[4] Accept all independent projects with ZERO or higher NPV discounted at opportunity cost of capital

[5] For mutually exclusive alternatives, accept alternative with the largest NPV when discounted at opportunity cost of capital

[6] See “Commercial Thinning of Lodgepole Pine: An Economic Analysis. Unpublished Working Paper 6-017 by M. Stone. September 1996.

- When estimating conversion returns, reasonable log price, logging phase cost and discount rate estimates are used in the calculations.

CT operations on Crown land are discouraged where conversion returns are forecast to be negative, unless other extenuating circumstances prevail. For this version of the guidelines, only timber (net) revenues (i.e. conversion returns) are considered. Guideline revisions may include revenues from other sources or non-market values arising from CT operations.

Landscape Level Considerations

A GIS analysis provided a spatial link to the stand level modeling using the Vegetation Resource Inventory (VRI). The VRI was designed to be a strategic management unit level inventory and is not always reliable at the stand level. Based on an examination of completed CT operations with the VRI, the VRI appears useful for age and density but not for basal area or volume. The Provincial Site Productivity Layer (PSPL) is used to address SI rather than VRI's SI value. The GIS analysis suggests using VRI for leading species, initial planting density (via link to RESULTS), and stand age. The suite of parameters provides a list of candidate stands highlighted by the Decision Key (Figure 2) for a forest-level analysis.

The GIS analysis also accounts for terrain and distance to processing facilities. It was assumed, based on operational experience, that slopes <45 percent are more suitable for CT than steeper slopes, and that economically viable CT opportunities are greater where they are located closer to a processing facility (e.g., within 50, 100 and 150km distances of the opening).

The GIS inventory analysis revealed a limited number of stands that met the eligibility requirements for the near term. The analysis indicates that treating those stands will have negligible effect on timber supply at the landscape level. Appendix 3 contains the resultant areas.

Professionals must keep sustainability in mind as the extent of CT expands across the landscape. This is essential on sites that are not identified as volume growth neutral because modelling indicates there will be less volume yield at final rotation.

Future releases of this document may include the results of including CT operations in the timber supply review (TSR), Integrated Stewardship Strategy (ISS), and FLP pilots to explore how CT could impact short- and mid-term timber supply and value relative to a base case without CT.

Determining Volume Yield for the Rotation

One of the guiding principles of CT is that the stand's volume yields are maintained for the full rotation. In other words, the cumulative volume of CT plus final harvest is relatively equal to or greater than the volume at rotation of the untreated stand forecast from growth and yield model runs. To provide guidance on this principle the stand-level Tree and Stand Simulation model (TASS) projections were run using a decision key and a decision aid was produced (Figures 2-4).

If the assumptions discussed under the "Stand Level Modelling Considerations" section are not consistent with your stand, consider contacting the Stand Development Modelling group of the Forest Analysis and Inventory Branch for custom modelling or to provide interpretation.

Decision Key

The stand level CT Decision Key shown in Figure 2 provides a methodology that identifies candidate stands. The Decision Key was applied to the stand level analysis using TASS. There are four factors that are important to consider:

1. **Stand age:** It is assumed that if the stand age exceeds culmination of the mean annual increment (CMAI), that it is eligible for final harvest and therefore not eligible for CT operations.
2. **Volume removal at CT:** The Key assumes there is a minimum of 50 m^3 per hectare of merchantable volume that is economic to be removed as a commercial thinning (i.e. that the volume harvested pays for the CT operation). The criteria for merchantability are for all species, 12.5cm dbh with a diameter inside bark (top diameter) of 10cm.

   NOTE Local experience may suggest different utilization specifications and minimum harvest volumes that are considered economic; thus, some variation should be expected on what stands are considered merchantable.
3. **Stand retention after CT:** The Key assumes that $\geq$20 m^2 of basal area (BA) minimal stocking after thinning can be retained to provide adequate stocking to achieve the site's growth potential in support of final harvest.

   Distribution of growing space among the residual trees is a key factor that determines site occupancy and stand growth following CT operations. Ideally, harvesting pattern used in CT should create narrow canopy gaps and redistribute the growing space equally to the residual trees.
4. **Volume for the rotation:** The final step in the Key assumes that the cumulative volume harvested (thinning plus final harvest) should be $\geq$0.95 of the unthinned control stand in order to maintain future timber supply. Thinning Priority 1 (Thin P1) stands, referred to as "yield positive", suggest the best potential for CT as the cumulative volume harvested is >1.05 of the control (i.e. >5% more than an unthinned stand), while Thinning Priority 2 (Thin P2) stands, referred to as "yield neutral" or "volume growth neutral", are between 0.95 and 1.05 (within 5%) of the control.

   A sensitivity analysis was completed to examine the impact of assuming that the cumulative volume harvested (thinning plus final harvest) would be >0.90 of the unthinned control stand. Government direction was not supportive of reducing the yield by more than 5% at this time.

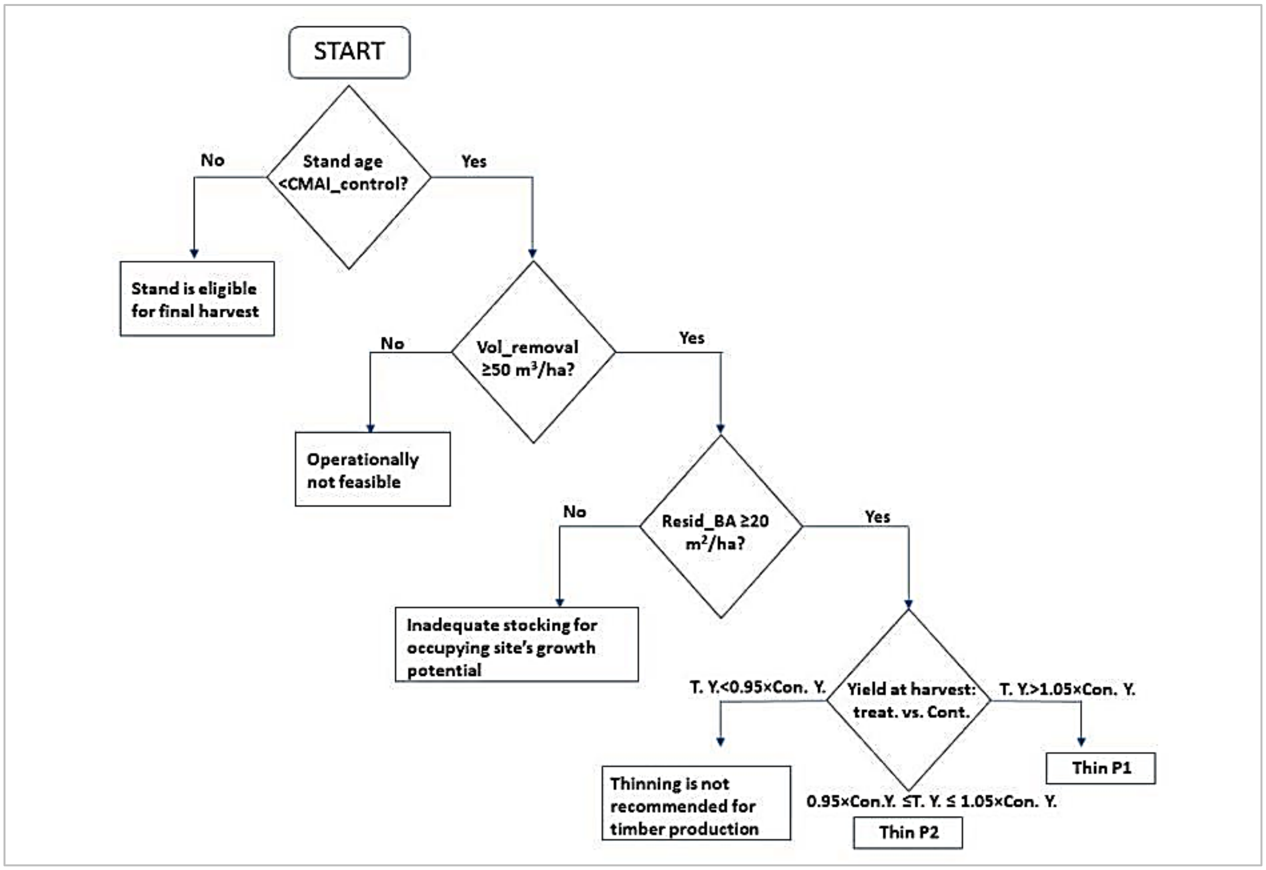


Figure 2: Stand Level Decision Key for Commercial Thinning Opportunity

Decision Aid for commercial thinning opportunity

Applying the above parameters to the Decision Key led to a user-friendly 'Decision Aid' that shows under what conditions CT (P1 and P2) opportunities exist for each of the three species. Appendix 1 provides the Decision Aid showing the opportunities. A companion set of field guides has been produced that describes the field methodology to collect the key decision variables of stand age, top height, site index, and basal area.

The importance of the field measurements:

- Tally/count plots are averaged to get the stand basal area, for use on the Field Decision Aid.
- Measured breast height age and inventory-standard top height are used to determine site index to compare the stand to the modelled parameters (record the methodology used).
- Measured stand age (with conversion from breast height age) is used to determine if the stand is below the age of CMAI, the first decision point.
- Measured height and diameter are used to calculate the height to diameter ratio, an indicator of how stable the stand will be against stem damage by wind or snow (see Forest Health section of the Guidelines document for thresholds).
- Measured height to the base of live crown is used to calculate percent live crown, an indicator for multiple reasons, including the amount of windthrow resistance, vigour and potential growth response the stand may have after CT operations.

Use the values collected and calculated above in the Decision Aid to determine the stand suitability for CT operations.

Commercial thinning for a timber quality and quantity objective: Candidate stands for CT treatment can demonstrate ahead of cutting permit approval that they will be at least volume growth neutral compared to a traditional clearcut regime and that a positive conversion return is achievable with reasonable log price, phase cost and discount rates estimates.

The candidate stand has the following characteristics measured in the field:

- Stand age less than the culmination mean annual increment,
- Current density/basal area (BA) sufficient to meet volume removal criteria approved within an FSP, and
- Site quality and density that allows for residual BA/ha to capture the site's growth potential, identified through the Decision Aids within this guidance or custom stand simulations.

The following figures indicate the decision points which create the thresholds for CT operations. These same figures are presented in larger format in Appendix 1.

There is a possibility of observing higher basal area (or a stand lying outside of Decision Aid graphic) if the stand was initiated with higher planting density (>2600 sph) or located in a better-quality site (SI>26 m) than what was modelled in the TASS simulations. The grey lines indicate the upper bounds of the TASS experimental plot data without OAF's applied.

Conversely, if your stand does not qualify based on the Decision Aid and you believe that a CT operation will provide value to the stand or fit within landscape objectives, use the field data in support of the professional rationale to the decision maker.

Interpreting the Decision Aid figures in Appendix 1:

Using the field measured variables of the **current average top height and merch. basal area (>12.5cm)**, locate your stand on the graph. If your basal area is **within or above the values in the green shading**, **and total stand age is below the culmination of MAI**, you may proceed without contacting the Stand Development Modelling group of the Forest Analysis and Inventory Branch for with site information for custom modelling or to provide interpretation

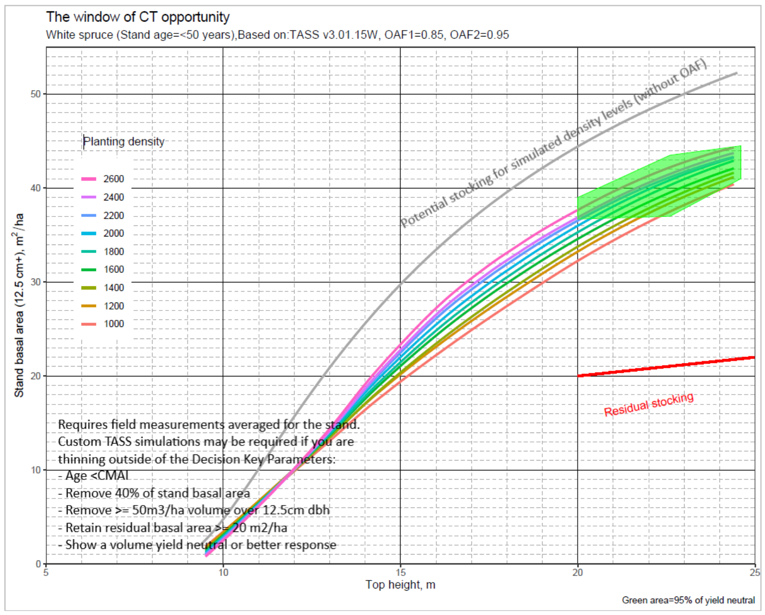


Figure 3: The window of CT opportunity for white spruce to show a volume yield neutral or better response.

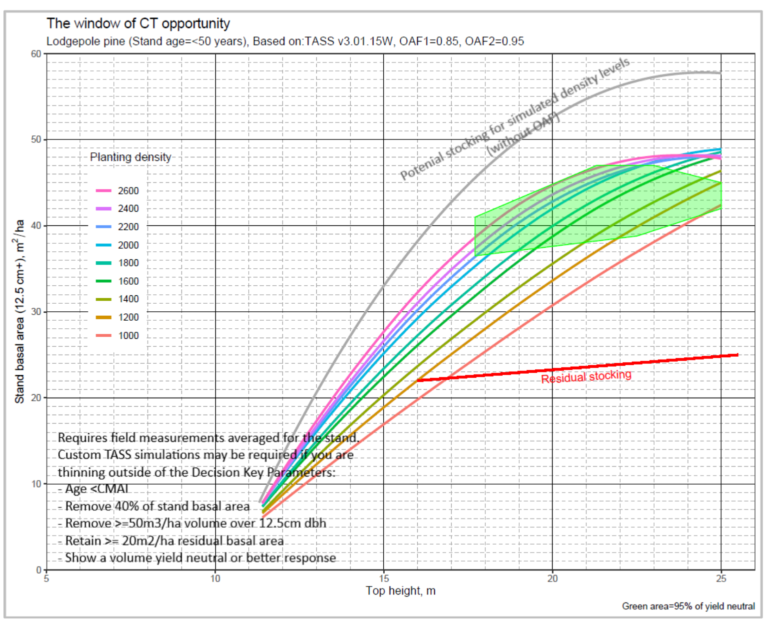
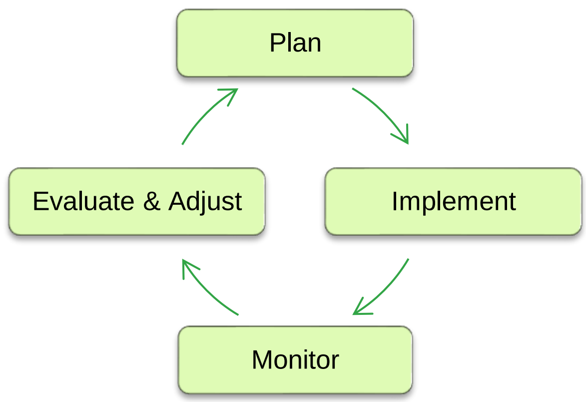


Figure 4: The window of CT opportunity for lodgepole pine to show a volume yield neutral or better response.

Adaptive Management

The stand, economic and forest level considerations in this guidance document provide information on where to find CT opportunities. Commercial thinning outside the parameters of the Decision Key assumptions may impact the stand's ability to meet timber supply projections in the future.

There may be local evidence to suggest that CT opportunities exist that do not fully align with the considerations in this guidance. A professional rationale must be provided to the decision maker where CT operations are planned on stands that, for example, are not projected to provide opportunities based on the TASS simulations. This should be followed by an adaptive management approach where we in fact 'learn by doing' by collecting key information.



One continuous improvement management process is where we:

Plan — A plan is prepared to deliver desired management goals and objective.

- Pre-treatment verification survey is undertaken to determine if the stand is suitable for CT with existing stand conditions described
- Plan is prepared to describe how the stand will be commercially thinned e.g. CT operations approach and intensity

Implement — The plan is implemented through operational actions.

- Post-treatment survey is conducted that describes actual volume removal and residual stand conditions and reported to RESULTS

Monitor — Data are collected to determine if desired results were achieved.

- Final harvest survey is completed that describes the value and volume of the timber removed

Evaluate and Adjust — The adaptive management step where the process is improved.

- Was the treatment successful based on the value and volume of timber removed during CT and final harvest relative to treatment costs?
- Industry/Ministry will monitor the effectiveness of the treatments for adherence to the principles, guidelines, and the results achieved
- Are there recommendation to modify the CT Guidelines, based on operational and scientific evidence?

Operational Implementation

The industry representatives have included some suggestions for a successful CT operation:

- Determine if the stand has received a fertilizer treatment. If the stand has recently been fertilized, consider deferring CT approximately 10 years after it was fertilized to allow the stand to fully respond to the fertilization treatment.
- FP Innovations has a stand assessment and planning tool and guidance for the supervisor and operator conducting the treatment. For more information, contact the Forest Operations department.[7]
- Determine the tree removal criteria and order of importance for selection during the treatment. This could include items such as – tree quality, species, tree size, spacing and prepare the site-level plan to meet FRPA requirements.
- Prepare plans for harvesting contractor use (i.e. treatment map, etc.) and discuss them during the pre-work meeting with the contractor.
- Allow the harvesting contractor the flexibility to locate trails and the trail spacing (they know the machines abilities the best).
- Restrict machine operations by laying out areas to prevent machines from impacting other resources, such as, streams or wildlife features. For example, a small stream with partial retention within 10m of the stream could have the Machine Free Zone (MFZ) located at 7m from the stream rather than 5m. This should ensure trails are located far enough from the stream to maintain the required protection and retention while allowing the machinery to reach in and complete the CT within the riparian management area.
- Monitor frequently during the operation to verify remove/retention levels to ensure Stocking Standards will be achieved at the end of the CT operations.

Figure 5: Harvester cutting access trails near Prince George, 2020.

[7] https://web.fpinnovations.ca/

Chapter 3 - Planning

Legislation and Policy

CT operations are a timber harvesting activity, and as such, considered a primary forest activity under the *Forest and Range Practices Act* (FRPA). CT harvest activity and road use require authorization under the *Forest Act*.

Strategic Planning Direction

Strategic planning includes regional land use plans, sub-regional Land and Resource Management Plans (LRMPs), and Sustainable Resource Management Plans (SRMPs). Some of the strategic planning outcomes have been translated into legal resource management objectives via Orders under FRPA's *Government Actions Regulation* (GAR) or the *Land Act'*s *Land Use Objectives Regulation* (LUOR). Examples include old growth management areas (OGMAs), wildlife habitat areas (WHAs) for species at risk, ungulate winter ranges (UWRs), and visual quality objectives (VQOs) for designated scenic areas.

In these cases, any CT operations must be consistent with the directions in the Order. Other aspects of strategic plans should also be considered when undertaking CT operations, for example, draft OGMAs that have not yet been legally established.

Tactical Planning

The guidance in this document may inform tactical plans of Integrated Stewardship Strategies. Integrated Stewardship Strategies (ISS) take a forward-looking approach to timber supply, generating management scenarios based on different harvesting and silviculture practices. These CT guidelines can assist in providing the recommended timing and location of potentially treatable stands and silviculture regimes to provide a commercial thinning opportunity in the future. This may also include where associated government investments (e.g. FFT fertilization activity) may augment CT.

Operational Planning

Operational planning under the current FRPA framework includes FSPs and Woodlot Licence Plans (WLPs). The intention to commence a CT program must be specified within an FSP or WLP through the initial submission or a major amendment. The plans must specify the situations or circumstances where the CT stocking standard will be applied. This initial inclusion requires information sharing with Indigenous Nations, other tenured users and public review and comment. The Delegated Decision Maker will conduct formal consultation with the Indigenous Nations prior to an FSP or WLP approval decision.

With an approved FSP, proponents must obtain harvest and road use authorization prior to conducting the CT operations. This includes ensuring requirements of FPRA are met, such as preparing a site plan; meeting FPPR objectives which include timber, water, cultural heritage, visual quality, and soils; and being consistent with Orders under GAR and the LUOR. Indigenous Information sharing, consultation and public review is also conducted at this stage, prior to cutting permit or road permit issuance. When all authorizations are in place, the operations can proceed.

Stocking Standards

A person required to prepare an FSP must ensure that the plan specifies stocking standards for areas referred to in the *Forest Planning and Practices Regulation* (FPPR) section 44 (4), and the situations or circumstances that determine when the stocking standards will be applied.

The factors relating to stocking standards for an even-aged stand are contained in the FPPR, including the:

- types of commercially valuable and ecologically suitable species to be retained on the area; and
- characteristics, quantity, and distribution of retained trees that are required to ensure the area will remain adequately stocked for the final harvest activity.

The following section contains an example of a stocking standard that may be included into FSP or WLP for CT operations. In this example, if the minimum basal area is not retained, then the proponent accepts a free growing obligation to meet the even-aged stocking standards in the FSP or WLP. The free growing stocking standards include a minimum density (such as 700 sph) which may be met with the residual trees and must be reported to the specifications in the *RESULTS Information Submission Specification for Licensees* (RISS-lf)[8].

Stocking Standard	Retained Basal area of stems ≥ 12.5 cm dbh (m^2/ha)	Incurs a Free Growing Obligation?	Assessment Methodology[9]
Commercial Thinning	>20	No	Post-Commercial Thinning Survey Procedures
Even aged	<20	Yes	Layered Survey, or Interior-Deviation from Potential Methodology

Variations to this example stocking standard may be proposed and will be reviewed for consistency with the factors related to a stocking standard and adequate site occupancy for the objective.

Example Stocking Standard

Where a stand is harvested consistent with the Forest Planning and Practices Regulation (FPPR) section 44 (4) it shall be deemed a commercial thinning for a timber quality and quantity objective where it occurs in an even-aged stand of 25-55 years of age, site index of at least 18m, removing no more than 40% of the stand's initial basal area, utilizing access trails no more than 5m wide measured bole to bole, thinning from below between the access trails to encourage a growth response in the residual stems.

The commercial thinning standard unit complies with the conditions specified below for a minimum period of 12 months following the completion of harvesting:

- Greater than 20 m^2 per hectare average basal area is retained in trees with a diameter at breast height of ≥ 12.5 cm, and
- No area > 2 ha or 10% of the Standards Units (SU) area, whichever is less, has a retained basal area less than 20 m^2 per hectare, and
- Trees contributing to the retained basal area must be the species identified as preferred, acceptable, or ecologically suitable in the even-aged stocking standards for the BEC site series in this FSP, and
- Trees contributing to the retained basal area comply with the attributes defined in the *Silviculture Surveys Procedures Manual "*Free growing damage criteria for single entry

[8] RESULTS Policies and Procedures: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/silviculture-reporting-results/business-and-policy-documentation

[9] Assessment methodology is contained in the current version of the *Silviculture Surveys Procedures Manual*.

dispersed retention stocking standard (SEDRESS) managed stands in Interior Deviation from Potential (DFP) and Layered Surveys".

The compliance assessment will be conducted using the Commercial Thinning Survey Procedures in the *Silviculture Surveys Procedures Manual*.

Where harvesting is deemed to be a commercial thinning based on the condition a minimum of 12 months following the completion of harvesting, the standard unit is exempt from the requirements to produce a free growing stand, consistent with FPPR section 44(3)(h).

If during the 12 months period following the completion of harvesting the conditions specified above are not maintained, the commercial thinning standards unit may be further stratified and the site plan amended to delineate where the licensee shall hold a free growing obligation on the harvested area and the appropriate stocking standard in the intermediate cutting or even-aged stocking standards in this FSP, including target and minimum density, shall be applied.

Future Management Regimes to set up CT opportunities

Establishment decisions set the stage for all future activities on that stand. For stands with a high productivity that are close to a processing facility, consider high planting densities (enhanced basic reforestation) to allow for CT opportunities in the future.

The Decision Aids in Appendix 1 can be used, based on young managed stand growth and yield modelling, to estimate a planting density that would provide at least a yield neutral, top height to thin at if you are planning for a single CT entry. Use of stand density management diagrams[10] or growth simulations to model the stand progression can be used to provide suitability ranges.

The site preparation technique, espacement, species and genetic worth of the planting stock, vegetation control, thinning age, fertilization after treatment and any direction for non-timber values are all decisions that the forest professional will need include in the management regime.

Example Objective: Harvest at least 50 m^3/ha through commercial thin, removing 40% of the basal area, providing at least 350 m^3/ha at final harvest age at culmination of the mean annual increment. Merchantability limits for all species are dbh >=12.5cm, dib 10cm.

Species	Site Index (m)	Planting Density (sph)	CT age (yrs)	BA retention (m^2/ha)	Final Harvest Age (yrs)
Sw	24	2000	45	22	85
Pli	22	2400	35	20	65
Fdi[11]	26	2000	65	17	121

Fertilization

The benefits to fertilize prior to and/or after CT require additional analysis. Consider the adaptive management approach so that operational information can be used to determine potential benefits.

[10] Stand density management diagrams publication (Farnden, 1996)

[11] Note due to lack of information on Fdi response to CT, treatment in areas that meet the principles can be considered

Prior to planning a CT operation, determine if the stand has received a fertilizer treatment. If the stand has already been fertilized, consider commercial thinning approximately 10 years after it was fertilized to allow the stand to fully respond to the fertilization treatment.

For interior Douglas-fir, white spruce and lodgepole pine, fertilization two or more years after CT operations appear to be an economically feasible silviculture investment.[12]

Non-Timber Considerations

While the focus of this guidance is for a timber objective, forest professionals cannot overlook the impact that a CT operation may have on other resource values and commitments made within their FSP or WLP. The key principle being to ensure that non-timber values are maintained or enhanced through commercial thinning operations and not to negatively impact these values.

References

Farnden Craig Stand density management diagrams for lodgepole pine, white spruce and interior Douglas-fir [Report]. - Victoria : Canadian Forest Service - Pacific Forestry Centre, 1996.

Ministry of Forests Guidelines for Commercial Thinning [Report]. - Victoria, B.C. : Province of British Columbia, 1999.

Ministry of Forests, Lands, Natural Resource Operations and Rural Development Managing Root Disease in British Columbia [Report]. - Victoria, B.C. : Province of British Columbia, 2018.

[12] From Guidelines for Commercial Thinning (Province of BC, 1999)

Appendix 1: Stand Level Decision Aid

Note that the assumptions are listed in the section Stand Considerations - TASS Simulations.

There is a possibility of observing higher basal area (or a stand lying outside of Decision Aid graphic) if the stand was initiated with higher planting density (>2600 sph) or located in a better-quality site (SI>26 m) than what was modelled in our TASS simulations.

Commercial thinning for a timber quality and quantity objective: Candidate stands for CT treatment can demonstrate ahead of cutting permit approval that they will be at least volume growth neutral compared to a traditional clearcut regime and that a positive conversion return is achievable with reasonable log price, phase cost and discount rates estimates.

The candidate stand has the following characteristics measured in the field:

- Stand age less than the culmination mean annual increment,
- Current density/basal area (BA) sufficient to meet volume removal criteria approved within an FSP, and
- Site quality and density that allows for residual BA/ha to capture the site's growth potential, identified through the Decision Aids within this guidance or custom stand simulations.

Lodgepole pine

Table 1: Mean annual increment culmination age for lodgepole pine stands of various initial planting density and site index. MAI is based on merchantable volume (DBH=12.5 cm+ and dib=10cm)

Initial density (stems/ha)	Site index (m)					
	16	**18**	**20**	**22**	**24**	**26**
1000	100	85	80	65	60	55
1200	100	85	75	65	60	55
1400	95	85	75	65	55	50
1600	95	80	70	60	55	50
1800	90	75	70	60	55	50
2000	90	75	70	60	50	45
2200	85	75	65	55	50	45
2400	85	75	65	55	50	45
2600	85	75	65	55	45	45

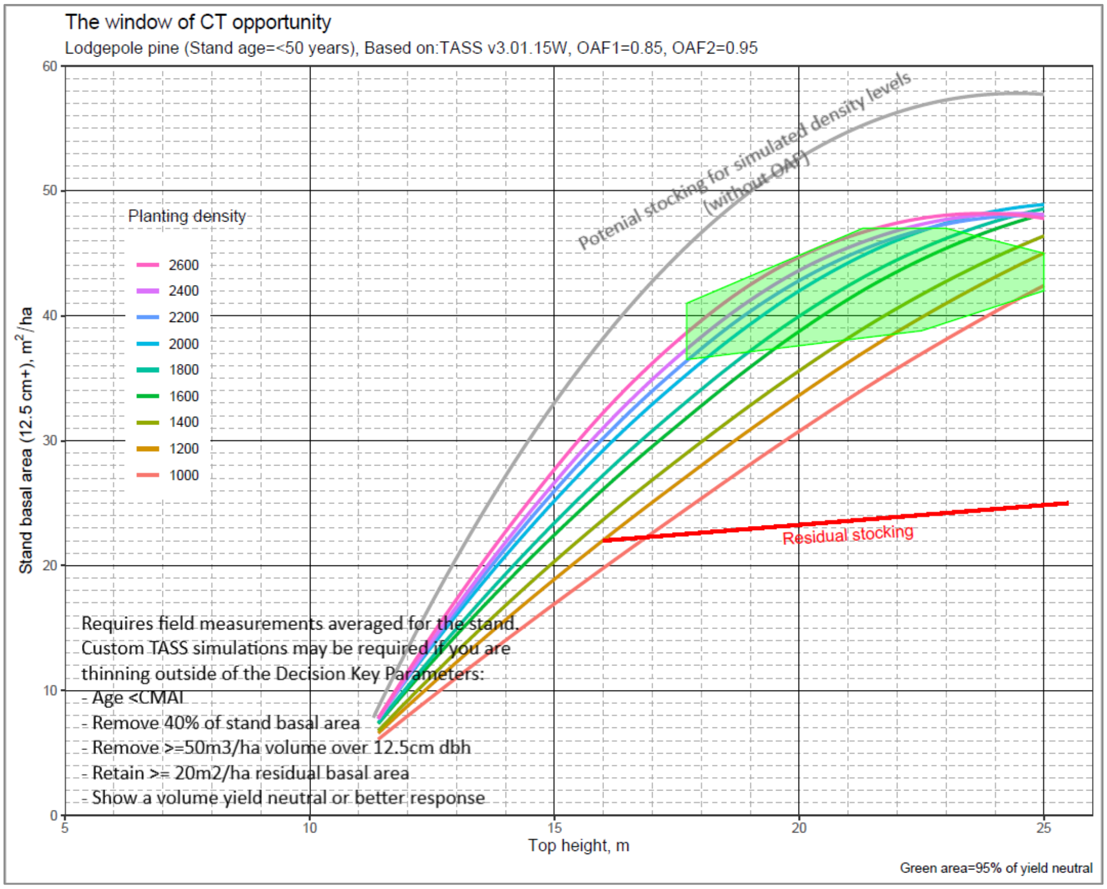


Figure 6: Stand eligibility for commercial thinning for lodgepole pine with a stand age of less than or equal to 50 years

Table 2: Stand eligibility for commercial thinning. Species: lodgepole pine. Numbers provided in the table are the recommended thinning age to extract 50m^3/ha, retain 20m^2/ha basal area and be yield neutral

Initial density (stems/ha)	Site index (m)					
	16	18	20	22	24	26
1000	-	-	-	-	55	50
1200	-	-	65	60	50	45
1400	-	-	65	60	45	40
1600	-	65	60	50	40	35
1800	-	65	60	50	35	35
2000	-	60	50	40	35	35
2200	-	60	50	40	35	35
2400	-	60	50	40	35	35
2600	65	60	50	40	35	35

Note: Lowest possible stand age was used assuming that manager would want to thin the stand as early as possible. Thinning intensity is not presented because the residual basal area will be at least 20 m^2/ha in the residual stand to comply with the minimum stocking standard. Recommended method is “thinning from below”.

White spruce

Table 3: Mean annual increment culmination age for white spruce stands of various initial planting density and site index. MAI is based on merchantable volume (dbh=12.5cm+ and dib=10cm)

Initial density (stems/ha)	Site index (m)					
	16	**18**	**20**	**22**	**24**	**26**
1000	120	105	95	85	80	70
1200	115	105	95	85	75	70
1400	115	105	90	85	75	70
1600	115	100	90	85	75	70
1800	115	105	95	85	75	70
2000	110	100	85	80	75	65
2200	115	100	90	80	75	70
2400	110	100	85	80	70	65
2600	115	100	90	80	70	65

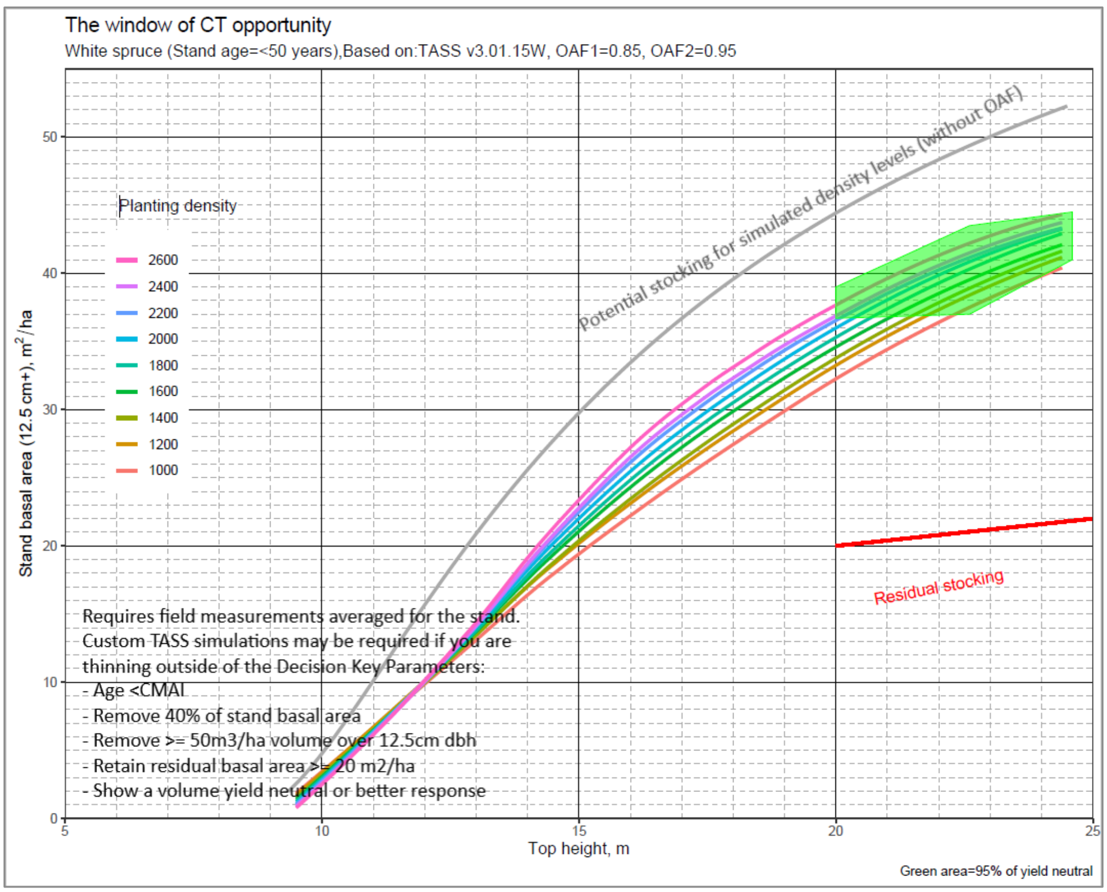


Figure 7: Stand eligibility for commercial thinning for white spruce with a stand age of less than or equal to 50 years

Table 4: Stand eligibility for commercial thinning. Species: white spruce. Numbers provided in the table are the recommended thinning age.

Initial density (stems/ha)	**Site index (m)**					
	16	**18**	**20**	**22**	**24**	**26**
1000	-	-	-	65	65	55
1200	-	-	65	60	55	45
1400	-	-	65	60	50	45
1600	-	-	65	60	50	45
1800	-	-	65	60	50	45
2000	-	65	60	50	45	45
2200	-	65	60	50	45	45
2400	-	65	60	50	45	45
2600	-	65	60	50	45	45

Note: Lowest possible stand age was used assuming that manager would want to thin the stand as early as possible. Thinning intensity is not presented because the residual basal area will be at least 20 m^2/ha in the residual stand to comply with the minimum stocking standard. Recommended thinning will be thinning from below.

Interior Douglas-fir

There was a single TASS simulation that satisfied the Decision Key criteria.

Table 5: Interior Douglas-fir stand parameters that produce a growth neutral response within the TASS II simulations.

Initial Density (stems/ha)	Site Index (m)	Culmination MAI Age (yrs)	Thinning Age (yrs)	Basal Area before thinning (m^2/ha)	Basal Area Removal
2000	26	121	65	42	25%

Appendix 2: Literature Review Executive Summary

A *Commercial Thinning in BC: Literature Review* was prepared to support the development of this guidance document. Key findings from the Executive Summary of that document include:

Species

Four BC commercial thinning (CT) studies reviewed addressed lodgepole pine (Pl), three addressed interior Douglas-fir (Fdi), one addressed white spruce, and one addressed western larch. Ten CT studies addressed coastal Douglas-fir (Fdc) and three addressed western hemlock.

Site Index (SI)

The current TASS CT review is exploring SI 16, 18, 20, 22, 24 and 26. The 1999 *Guidelines for CT* concluded that a better site translates into taller trees, higher volume, or higher net present value; and that analyses for sawlogs and pulpwood markets indicate CT on stands with a SI <18 for Pl and <24 for Fdc are less economically desirable than CT on better growing sites.

Density

The current TASS CT review is exploring initial planting densities of: 1000, 1200, 1400, 1600, 1800, 2000, 2200, 2400 and 2600 sph. The 1999 *Guidelines for CT* cautions that stands with high densities will have many non-merchantable stems that must be handled, potentially decreasing economic viability of a CT operation and increasing risk of stand damage.

Thinning Intensity

The current TASS CT review is exploring thinning intensities (% basal area – BA- removal) of 25, 40, 50 and 60% along with a control where there is no thinning. The 1999 *Guidelines for CT* concluded that the highest growth rates per tree are associated with heavy thinning. A 2018 BC CT study modeled impact of removing 40% of the timber on a timber supply area. A 1996 study included a Pl literature review and concluded that that up to 50% of the BA can be removed from middle-aged and mature stands without loss of stand volume growth. BA removal in other CT studies reviewed ranged from 24 to 50%.

Thinning Age

Current TASS CT review is assessing thinning ages of: 35, 40, 45, 50, 55, 60, 65 years. The 1999 *Guidelines for CT* state that traditional CT is done prior to culmination of mean annual increment (stand age ranging from 30 to 60 years), depending on growth potential. A 1996 study included a Pl literature review and concluded that stands will likely be 50 years of age before a viable CT can be conducted. A 2018 BC study modeled impact of CT occurring 20 years before their 70 to 130 year rotation age. Thinning ages in other studies included: 32 to 48 years; 50 years; 55 years; 60 years; and 110 year old stand.

Final Harvest Age

The current TASS CT review is exploring impact if final harvest is 60, 80, 100, or 120 years of age. A 1996 study included a Pl literature review and concluded that a 25-year response period should be allowed before final harvest. A 2018 BC study modeled impact of CT occurring 20 years before final harvest. A coastal BC study assessed cumulative volume at final harvest of 88 years – 33 years after CT.

A 1996 economic study concluded that the choice of rotation age for final harvest will be critical when assessing the economics of CT lodgepole pine. When comparing the optimum economic rotation age (between 50 and 70 years) of an unthinned stand to that of a thinned stand, the unthinned stand almost always dominates as the better investment. When rotation ages are planned for ages greater than 80 to 90 years (to or past CMAI), the net present value (NPV) of the thinned simulations will dominate.

Thinning Type

In the current TASS CT review, model simulations assume 5 m trails that are cleared, and 15 m leave strips that are thinned from below. Most studies reviewed reported 'thinning from below'; some the reasons include favoring the taller trees by removing competition, improving crop tree volume and diameter growth, reducing mortality losses, and/or removing ladder fuels. Some studies used 'quality thinning' that removed dead, diseased and deformed trees to improve the quality of the stand.

Cumulative Mean Annual Increment (CMAI)

The Decision Key developed to support the current TASS CT review assumes that if a stand exceeds CMAI it is ready for final harvest and is not suitable for CT. The 1999 *Guidelines for CT* note that traditional CT is done prior to CMAI. A 2018 model of CT notes that if the timing and intensity of CT will prolong CMAI.

Merchantable Volume Removal

The Decision Key developed to support the current TASS CT review assumes that the minimum volume removal to be ≥50 m3/ha in order to be economic. A 2018 timber supply model assumed at least 100 m3/ha in order to be eligible for CT. A 1992 Pl CT study noted 115 and 130 m3/ha of sawlogs were removed. An eastern Canada study averaged 63 m3/ha removal and ranged from 17 to 164 m3/ha.

Residual Basal Area

The Decision Key developed to support the current TASS CT review assumes that the minimum basal area (BA) to be retained after CT is ≥20 m2/ha in order to help support final harvest. Three coastal BC studies note the following residual BA: 21 to 35 m2/ha; 34.4 to 51.7 m2/ha; and 32 m2/ha. An eastern Canada study averaged 23.4 m2/ha and ranged from 13.0 to 35.3 m2/ha. Other studies report on sph or volumes pre- and post CT.

Cumulative Merchantable Volume (Thinning + Final Harvest)

The 1999 *Guidelines for CT* notes that stands that have been heavily CT will generally produce less volume than stands that have been lightly thinned. The Ministry CT research website concludes that CT likely only provides marginal increases in the cumulative merchantable volume available from a stand over a rotation. A 1998 TASS Pl simulation study suggests that CT can provide at best only a marginal increase in the cumulative merchantable volume. A 2018 forest level analysis concluded that timber harvest volumes from CT would be within 2% of the base case (with no CT) over the 250 year planning horizon. A 1997 CT forest level analysis of two TSAs showed increases in short-term but little impact on long-term timber supply. A 1995 CT workshop concluded that we should not expect any increase in long-term harvest levels from CT. A 2007 Pl CT study found volumes equal to or higher than unthinned controls for most treatments. Some studies note potential volume gains from CT or that gains will increase with increasing rotation age. Some studies note that the goal is to increase the size and quality of the crop trees (versus increasing volume).

Piece Size

The 1999 *Guidelines for CT* note that species and piece size have a significant impact on revenue. A 1996 Pl CT study reviewed the literature and concluded that all studies in immature stands showed that diameter growth increased following thinning. A 1998 CT Pl economic study using TASS concluded that CT must be justified based on the increase in value of the stand resulting from the concentration of the stand's growth on fewer trees or on the earlier financial return obtained from the CTs. Several studies report higher average diameter and individual tree volume of the thinned stand than unthinned control stands.

Mitigating Mid-Term Timber Supply Impacts

The Ministry CT research website states that CT can provide flexibility by redistributing harvest over time, thereby cushioning the effects of timber supply shortfalls caused by age-class imbalances in the timber supply. The website also notes that CT can also provide harvest volume while meeting visual quality objectives and adjacency constraints. A 1996 Pl CT economic study notes that in management units where there is a dip in timber supply in the mid-term, CT may be able to assist by extending the supply of old growth timber; and by addressing constraints such as 'green up' adjacency. A 2019 timber supply modeling study of one TSA notes that implementing CT at the landscape level scale has the potential to increase mid-term harvest rates and reduce the length of a mid-term timber supply shortage. A 1995 CT report notes that CT can deliver wood earlier and alleviate some timber supply and IRM constraints; and could help keep mills operating, employ local people, and stabilize communities.

Other Topics

The literature review also addresses other CT topics such as utilization level; rotation length; windthrow; road access/distance to mills; terrain; stem damage; root rot; economic considerations; fertilization; and non-timber values including enhancing fire resistance.

Appendix 3: Landscape Level GIS Analysis

Three central interior timber supply areas were included to test the methodology of identifying CT candidate stands in the forest inventory. The table below lists the resultant areas, expressed as a portion of the Timber Harvesting Landbase (THLB), as described in the section "Landscape Level Considerations".

The table below shows the current and near-term candidate stands, assuming no CT occurs between the years 2020 and 2030. The largest increase in candidate stands is in the Prince George Timber Supply Area.

Table 6: Near term Commercial Thinning opportunity

Management Unit	THLB Estimate (ha)	All GIS Target Stands (ha)	Total Yield Neutral (95%) Age 33-67 Area (ha)	Total Yield Neutral (95%) Age 23-57 Area (ha)
Mackenzie TSA	1,360,000	28,746 (2.1%)	1,664 (0.1%)	3,384 (0.2%)
Prince George TSA	3,070,000	142,721 (4.6%)	7,511 (0.2%)	25,222 (0.8%)
Quesnel TSA	1,020,000	37,602 (3.7%)	1,586 (0.2%)	3,913 (0.4%)
Total	***5,450,000***	***209,069 (3.8%)***	***10,761 (0.2%)***	***32,519 (0.6%)***

Appendix 4: Forest Health Considerations

Guidance defining specific damage criteria for assessing residual coniferous trees can be found at the two links below.

STAND DEVELOPMENT MONITORING DAMAGE CRITERIA FOR EVEN-AGED (AGE CLASS 2 & 3) CONIFEROUS TREES

https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/stand_development_monitoring_damage_criteria.pdf

FREE GROWING DAMAGE CRITERIA FOR MULTI-LAYERED STANDS IN BRITISH COLUMBIA

https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/multi-layer_free-growing_damage_criteria.pdf

Also, Forest Health guidance can be found at the link below, in which there are additional links for more detail information for certain pests.

https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-health/forest-pests

Windthrow

Windthrow is a serious concern for CT prescriptions. Reduced stem density combined with increased wind penetration into residual stand affects tree stability and can induce mechanical damage to individual trees and result in uprooting or stem breakage (see below "Stem Damage and Decay") and, ultimately, tree death.

Windthrow hazard and risk can be assessed using the procedure outlined in the BCTS Windthrow Manual[13] and the windthrow field cards. The results of the assessment should be used in designing appropriate residual densities and windfirm boundaries. Soil conditions must not pre-dispose residual trees to wind damage. Areas known to have high winds should be avoided. Knowledge of wind patterns can be used to better assess areas for thinning.

Height/diameter ratio: Height and diameter are measured in the units of m/cm. A high height/diameter ratio means that windthrow, stem breakage and stem bending is likely. While local knowledge and experience is key for assessing stand stability, the rules of thumb regarding stand stability after thinning, or risk values, are:

- Lodgepole pine: Residual tree ratios in excess of 0.9 indicate low residual stand stability following thinning
- Douglas-fir: Sites with either weak expression of dominance, poor sites, or a ratio in excess of 0.8 signifies low stand stability.
- Other species and situations: Thinning where residual trees have a height/diameter ratio greater than 1.0 is considered risky.

Multiple thinning entries: In stands where a 40% basal area removal would destabilize the stand (such as high-hazard sites) multiple, low-intensity thinning entries may be beneficial for fibre utilization and to maintain a stable stand. Because the TASS modelling in this guidance considered a single-entry,

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[13] BCTS Windthrow Manual, April 2010. Was written for the Coast; however, the same principles apply to the interior. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/bc-timber-sales/business-plans-performance-reports/bcts-coastal-windthrow-manual.pdf

additional custom TASS runs may be requested, or the Stand Density Management Diagram publication is a good reference to consult when preparing the professional rationale.

If windthrow occurs after CT operations, re-evaluate the windthrow hazard of the remaining trees within the stand before making the decision whether to 1) clearcut the stand, 2) salvage the windthrow and the remaining vulnerable stems, or 3) leave the windthrow. Removing or leaving windthrown timber could have impacts to the FSP commitments and bark beetle infestation.

Stem Damage and Decay

In CT and partial cut harvest operations, the amount of stem and top damage increases with the size of the equipment used and with the number of passes through the stand. Damage to the residual stand may be reduced by harvest strategies that minimize the movement of equipment within the stand and by gaining cooperation of harvest personnel.

The timing of the operations is important when the residual stand includes high pathogen susceptible species. The amount of wounding and size of injury are greater in spring and early summer when the bark is loose.

The impact of stem damage in a CT stand depends in part on the leave tree species. Tree species may be grouped into categories based on their susceptibility to decay pathogen from greatest to least:

- Broadleaved species
- *Abies* true firs, Hemlock, Sitka spruce and western redcedar <60 years
- Yellow cedar, other spruces, western larch and western redcedar >60 years
- Douglas-fir and western white pine
- Lodgepole pine and Ponderosa pine

Ideally, the residual stand should have minimal mechanical damage after the CT treatment. Proper planning and training of operators will help you achieve this. Stocking standards are expected to identify the acceptable damage criteria of residual trees.

- Top damage is of greatest concern, since this becomes an entry point for stem decay pathogens.
- Stem scarring can cause a certain amount of stem decay resulting from those infections.
- Decay and resin-soaked wood caused by wounds result in loss of volume and quality in the most valuable portion of the tree and therefore losses in value are greater than the decay volume alone would indicate.

Drought

There is published evidence of increased evapotranspiration as a result of higher wind speeds in thinned stands, and this exposure can impair stem conductivity by restricting water supply to the foliage and produce die-back symptoms including loss of foliage and tree vigour. Knowing where high hazard drought areas are forecasted to be in the province can help tailor thinning operations to areas of low drought risk for a minimum of tree damage.

Root Disease

In the publication, Managing Root Disease in British Columbia (Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2018) the Provincial pathologists advise that

> *"Intensive silviculture treatments are not recommended in portions of stands that contain root disease. Attempts to reduce root disease inoculum during stand tending operations are expensive and largely ineffective. Any potential economic gains anticipated from intensive silviculture treatments, such as fertilizing, spacing or pruning, may be reduced by future losses from root disease."*

Because of the statement above, reviewing the site's risk for pathogens, and conducting pre-treatment site survey for root disease presence is recommended. Please follow the recommended procedures in the guidebook cited above and stratify root disease centers out of the CT treatment area.

Armillaria, Phellinus and Tomentosus**:** Surveyors should have knowledge of stand and tree level symptoms for both *Phellinus* and *Armillaria* root diseases, given the large overlap in their distribution. Infection by root disease occurs early. Root disease infection on susceptible hosts peak at approximately 20years. Silviculture treatments, including CT, should not occur on stands less than 20 years of age.

Heterobasidion**:** This is a common root and butt rotting pathogen infecting a wide range of host of both conifers and hardwoods in British Columbia. Species of *Heterobasidion* (*H. occidentale and H. irregulare*) can infect via spores which can germinate on cut stump surfaces and tree wounds when environmental conditions are favorable.

Applying urea to freshly cut stumps promotes colonization of the stump surface by numerous antagonistic fungi (Johansson et al. 2002). Ideally, this treatment should be carried out at the same time as the thinning. Alternatively, it can be done in the days following thinning. Treatment of stumps with urea appears to be effective in Europe, but the product in question has not been tested in Canada. Currently, there are no products registered specifically for treating *Heterobasidion* root and butt rot in Canada.

Hard Pine Stem Rusts

Thinning stands will result in new microclimatic conditions, changes in crown structure of leave trees and changes in inoculum levels of the disease present.

Western gall rust (*Peridermium harknessii* J.P. Moore) is endemic in many of the lodgepole pine stands in the interior of BC. Codominant and dominant crown-position trees are more likely to become infested with the disease than the smaller stems in the stand. However, incidence doesn't always correlate to impact to the timber. Model outputs from TASSIII suggest that a 20% infection rate has a 3.9% reduction in fibre yield, compared to a control scenario.

A mechanical thinning treatment to remove the infested trees may not have the desired volume and value response, because this is likely to become a "thinning from above" treatment, where the largest trees are removed. Practitioners should consider balancing the desired wood-quality improvement and yield target. One way to achieve this is to remove trees infected with more than one rust species and retaining some of the lower-severity infected trees (ie only one rust species present).

TASS modelling has shown that thinning that selectively removes rust infected and other small sized trees manually (no access trail for machines) from the stand produces higher yield than control after 100 years of stand age. The lumber recovery model, SAWSIM, showed that CT increases sawlog production in stands on good-quality sites that were established with higher planting density.

Stalactiform **and** ***Comandra*** **blister rust**: In areas where these pathogens are known to occur, a considerable allowance should be made for further disease losses after CT operations. Diseased trees should be removed during CT.

Dwarf Mistletoe

Opening the stand through thinning may stimulate dwarf mistletoe *(Arceuthobium* spp.) seed production on previously shaded infections. During thinning, mistletoe infected residual trees, groups of trees or infected bordering stands should be cut first. Trees with stem infections should be removed and destroyed. Those with branch infections can also be removed or, if practical, pruned.

Appendix 5: Economics of Commercial Thinning

Introduction

This project employed conventional economic analysis to evaluate the commercial thinning (CT) treatments developed by the CT Working Group (WG) for timber stands within the same site index, initial stocking density and age class, for both lodgepole pine (Pli) and white spruce (Sw). Net present value calculations for the conversion return of each treatment were calculated using a discount rate currently applied to other FLNRORD programs. The decision rule is to adopt the treatment yielding the highest net present value from the set of possible treatments and this issue is discussed in more detail in the Guidelines section below. This analysis focusses on stand level calculations only.

A log-based valuation model was adopted for this project[14]. It is simpler, less data dependent and is thought to provide sufficient accuracy compared to the alternative end-product valuation model. The net present value of a conversion return – the combination of an allowance for profit and risk and stumpage - was calculated by subtracting logging cost estimates for each commercial thinning operation from a set of BC Interior log prices compiled by Timber Pricing Branch. Average monthly log prices for the 12 months to May, 2020 were compiled for pulpwood (all species), and SPF and Hem-Bal sawlog and peeler grades and they are provided in Table 1 below.

Table 1: Average log prices by log grade

Log grade	12-month average price ($\$/m^3$)	
	SPF	Hem-Bal
Pulpwood	53.12	53.12
Sawlog	87.89	84.09
Peeler	113.45	107.67

A logging cost schedule was developed by industry WG members that provided estimates of current harvesting costs. These costs for CT, Final Harvest of CT stands (FHCT) and final harvest for non-CT stands (NT) were estimated to be $\$57.15/m^3$, $\$43.15/m^3$ and $\$46.15/m^3$, respectively. The phase cost breakdown for each of these options is provided in Table 2 below. Significantly higher tree to roadside costs are assumed for CT operations. An average cycle time of 3.5 hours is assumed for all three schedules.

[14] The alternative is to develop an end-product model, which calculates net income by subtracting both logging and manufacturing costs from a volume weighted set of end-product selling prices.

Table 2: CT unit logging costs by treatment and phase.

Phase	Unit Cost ($/m^3)		
Treatment	CT	FHCT	NT
Tree to Roadside (F, B, Y)	34.00	20.00	22.00
Loading	2.50	2.50	2.50
Hauling (Cycle time @ 3.5 hrs.)	11.55	11.55	11.55
Roads	2.00	2.00	3.00
Road Maintenance	2.50	2.50	2.50
Mobilization/demobilization	0.60	0.60	0.60
Overhead	4.00	4.00	4.00
Total:	57.15	43.15	46.15

Conversion return calculations were completed with the aid of the Financial Analysis of Silviculture Investment & Economic Returns (FAN$IER) model. FAN$IER was updated to a 2020 from a 2006 cost base using more current economic information, where possible. This included BC-based default values for log prices (by log grade) and costs (falling, bucking, yarding, hauling, development, administration, and silviculture). FAN$IER also applies user-defined prices and costs in calculations where they are deemed more accurate or relevant. Please refer to Stone (1996) at pp. 4-6 for an explanation of the equations employed by FAN$IER.

A real discount rate of 2% was applied to the conversion return present value calculations. This rate was adopted from FLNRORD Forests for Tomorrow procedures. The inflation rate was assumed to be zero. A discussion of an appropriate stumpage level for commercially thinned stands of timber was beyond the scope of this project; focus centered on positive conversion return calculations only.

In addition to the economic assumptions stated above, the analysis also assumed that stand establishment costs are sunk, since they do not bear on CT treatment decisions. The base year for treatments is typically the year that stands are thinned, so the present value calculations are set to this date. For this analysis the base year was set two years less than the treatment age to provide improved graphics within FAN$IER.

Results

Table 3 below provides selected conversion return estimates from simulations of both Pli and Sw stands of timber. The final rotation age for all treatments is 80 years. Untreated stands for both species provided the highest NPV.

Table 3. Selected conversion return estimates for Pli and Sw @ 80 years, Site index 22m, establishment density 1200 sph, that was commercially thinned at age 45 years to differing % basal area removal.

Pli Basal Area Removal at CT	NPV ($/ha)
Untreated	8191
25%	7684
40%	7439
50%	7156

Sw Basal Area Removal at CT	NPV ($/ha)
Untreated	6135
25%	5866
40%	5883
50%	5944

The NPV for the untreated stand is $8,191/ha at 80 years. As the percentage of basal area removed increases, the NPV of the stand decreases – to $7,684/ha at 25% removal, $7,439/ha at 40% removal, and lastly, $7,156/ha at 50% basal area removed. All CT treatments are conducted at a stand age of 45 years.

Sw stands provide a different set of results for the same set of treatments. Once again, the base case provides the highest NPV, at $6,135/ha. But as the basal area percentage removal increases, NPVs remain more or less constant, at $5,866/ha, $5,883/ha and $5,944/ha for 25, 40 and 50% basal area removal, respectively.

The results provided in Table 3 are also shown graphically in Figures 1 and 2 below. Figure 1 provides both the yields and NPV results for all four Pli treatments. The TASS yields are the lighter-coloured sigmoid curves; the highest curve is the untreated stand and the other three curves follow the treatment order presented in Table 1. The untreated stand provides the highest yield; as more basal area is removed by the CT, yield at final harvest also decreases by the amount of basal area removed

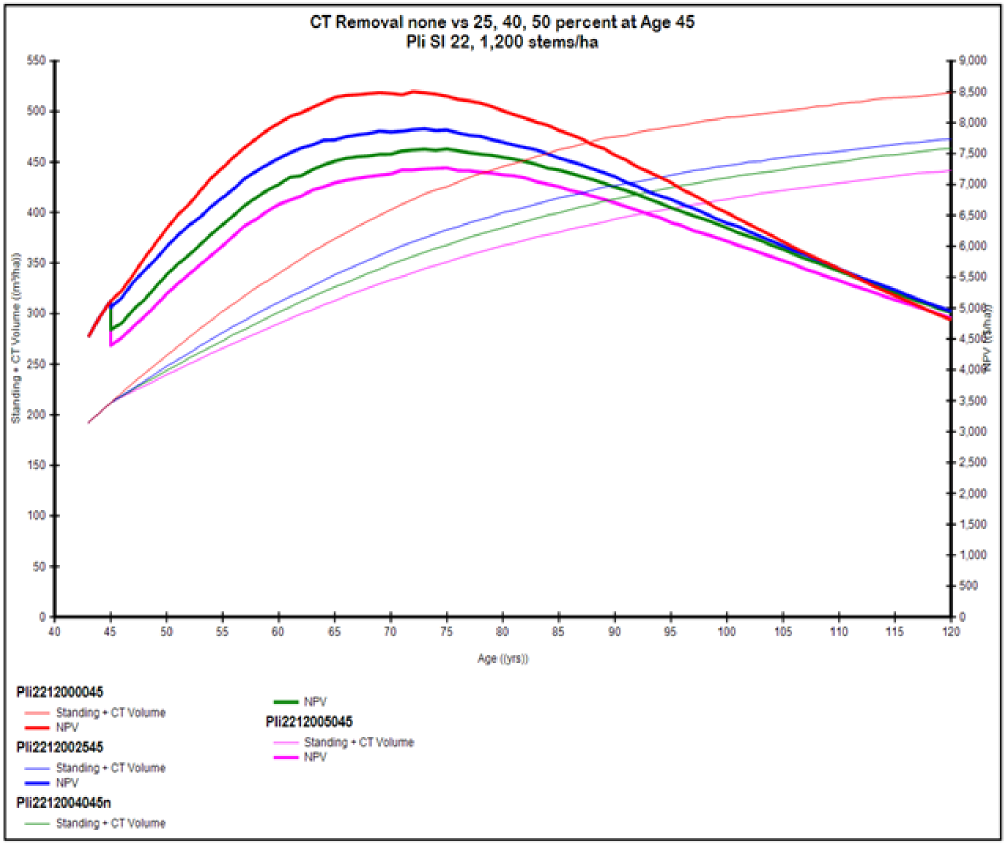

Figure 1. Lodgepole pine Yield and NPV curves at Untreated (0), 25, 40, and 50% Basal Area Removal

The darker-coloured set of curves are the NPV curves for each treatment. They follow the same order as the yield curves – the untreated stand provides the highest NPV, followed by NPV curves for the 25, 40, and 50% basal area treatments. The analogous set of curves for Sw are provided in Figure 2 below.

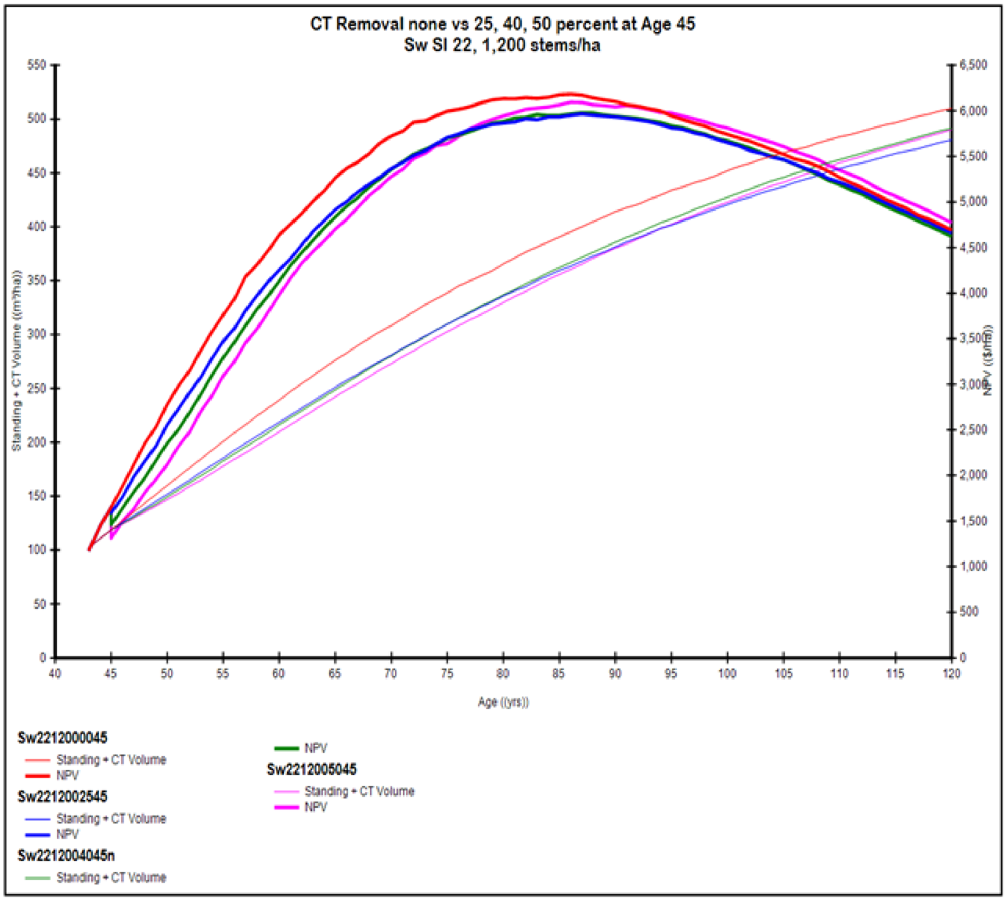

Figure 2. White spruce Yield and NPV curves at Untreated (0), 25, 40 and 50% Basal Area Removal

The choice of the rotation age for the final harvest is an important consideration to the economics of commercial thinning but harvesting timber at economic rotation ages has not been the focus of this project. Rather, a rotation age of 80 years was chosen to compare the impact of varied CT treatments on the NPV. NPVs for untreated stands are greater than the NPVs for treated stands because it is more economic to wait until for the final harvest at 80 years than it is to thin at 45 years and harvest the remaining stems at 80 years of age.

Figures 1 and 2 show that as the rotation age increases beyond 80 years, NPV simulations for treated stands surpass the clearcut control. The figures also show that for all treatment regimes, stand NPVs decrease past the economic rotation age and converge at approximately 110 years. This is attributed to two factors. First, the thinning treatments concentrated growth onto fewer, larger stems which, presumably, produce a higher unit log value, since both wood quality and quantity (i.e., piece size) increase following the treatment. Second, the treatments produced an interim revenue through the harvesting of the thinned stems that, had they been left standing, would not have grown higher than 2%, the discount rate used here.

For treated Pli stands in Figure 1, the commercially thinned simulations also show that, the lighter the thinning, the higher the NPV, at a rotation age of 80 years. For treated Sw stands in Figure 2, NPVs are very similar since yields are very similar at 80 years of age.

Note that the present value of the CT conversion returns shown here are positive. Economic analysis of silviculture in BC has, in the past, shown negative returns, given the long rotation ages required before harvesting mature timber. Revenues eventually obtained at this time are discounted heavily. But for CT treatments, discounting has worked in its favor since revenue is received when the stand is thinned while the cost of the reduced final harvest is incurred at the end of the period. Discounting works in reverse, given the incidence of costs and revenues since CT net revenues are not discounted, while the final harvest cost is discounted along with revenues received at that time. The low discount rate of 2% (real) has contributed to the positive returns along with the fact that regeneration costs are sunk and not included in the NPV calculations.

Even though this analysis has not focused on the “best” time to harvest timber, it is important to note that typical BC forest management objectives include the maximization of sustained yield volumes and preservation of ecological services. These objectives, read together, will extend rotation ages beyond the economic rotation, and even beyond the age of culmination of mean annual increment. At some point, the management rule will be to select the treatment that maximizes NPV, while at the same time meet other forest management goals. CT operations may be able to contribute to these other objectives by providing, for example, more foraging habitat for key animal species.

Figures 3-8 present simulation results for an increase in treatment age, fertilization following thinning treatments and the impact on yield and NPV of an increase in site index both Pli and Sw stands. These figures represent sensitivities to key assumptions made in the initial analysis. Figure 3 below compares Pli thinning treatments at 45 and 55 years of age[15]. There are two sets of NPV curves in Figure 3, for treated/untreated Pli stands at 45 and 55 years, respectively. The results show that the higher NPV is obtained from thinning the 55 over the 45-year-old stand of timber.

[15] Note the X-axis is labelled in years since CT treatment rather than age of the stand. This is a necessary artifact of the graphing procedures for Figures 3 and 4 only.

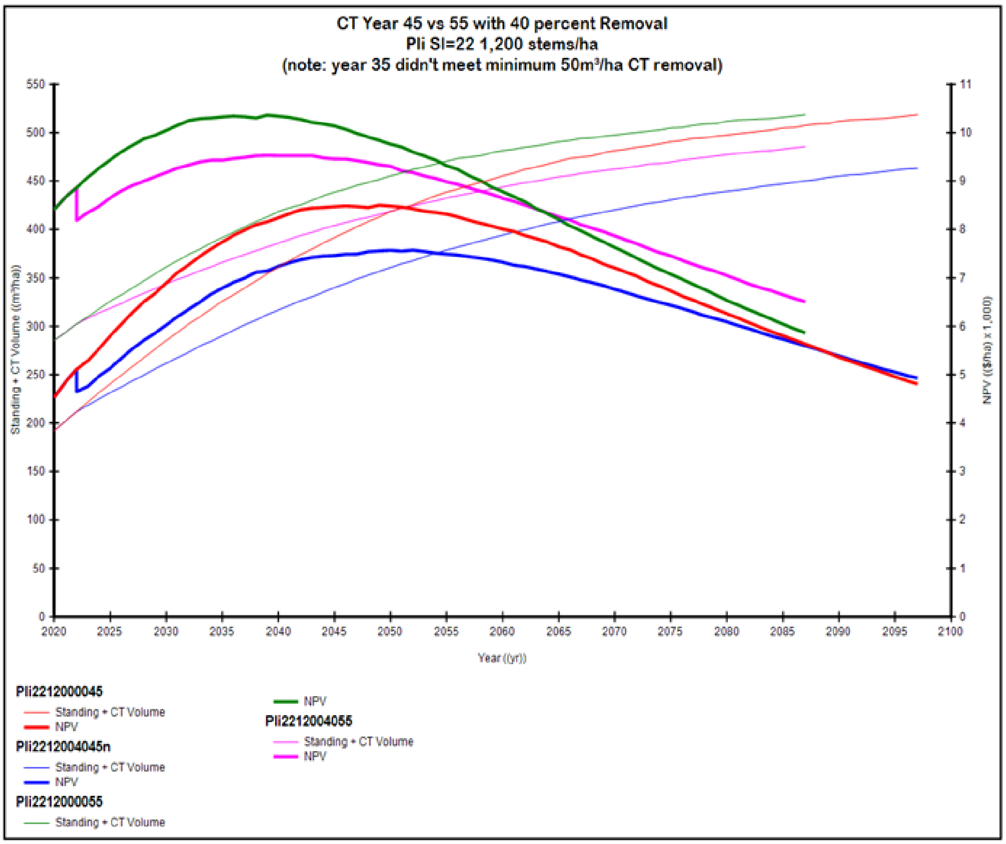

Figure 3. Comparison between Pli thinning ages (CT @ Year 45 v. 55, 40% BA removal)

Similar results were found in the Sw simulations, shown in Figure 4 below. The 55-year-old treated stands also yielded a higher NPV than the 45-year-old stands. A key message when planning CT operations is to prioritize the older stands first, especially if clearcutting the stand is not possible due to other management constraints.

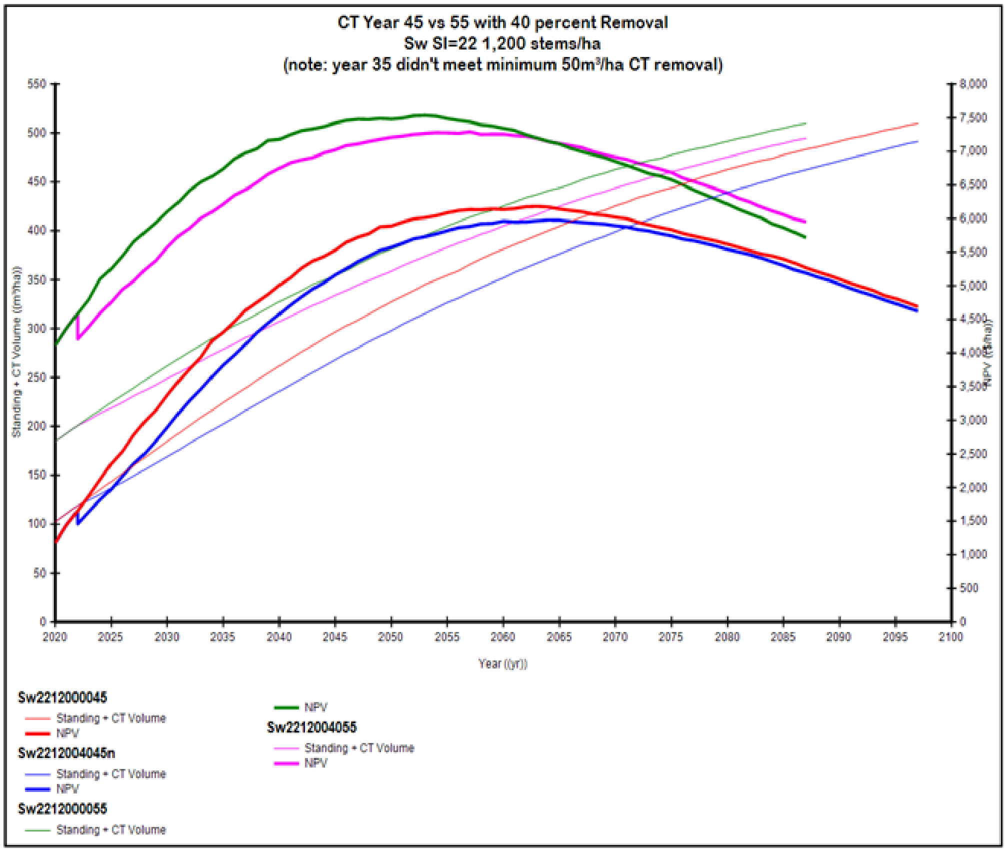

Figure 4. Comparison between Sw thinning ages (CT @ Year 45 v. 55, 40% BA removal)

Figures 5 and 6 provide the results of a fertilization treatment of Pli following CT. Results for three simulations are presented here - for an untreated Pli stand, CT treatment and CT plus fertilization treatment. The untreated stand still yields the highest volume, but fertilization increases the yield. NPVs are roughly equal until 80 years of age, albeit lower that the NPV for the untreated stand. At that time the NPV of the CT-only stand overtakes the NPV for the CT plus fertilization stand.

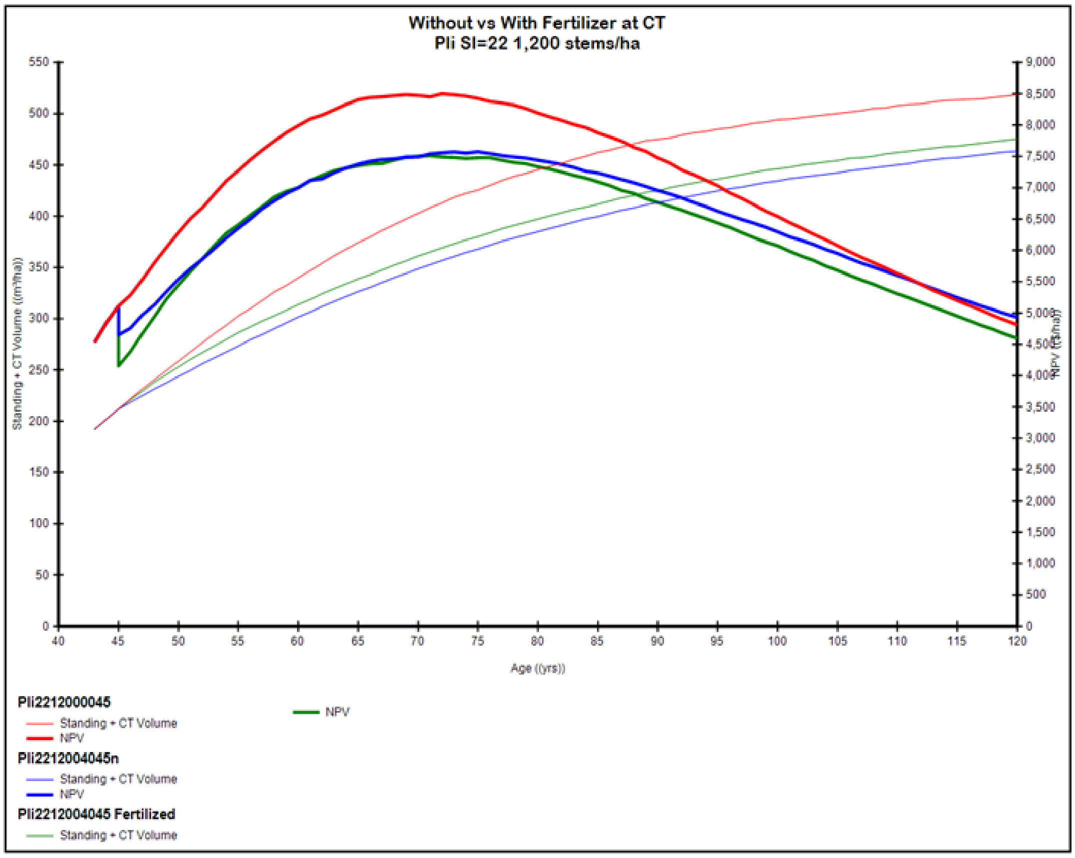

Figure 5. Fertilization after thinning in Pli stands

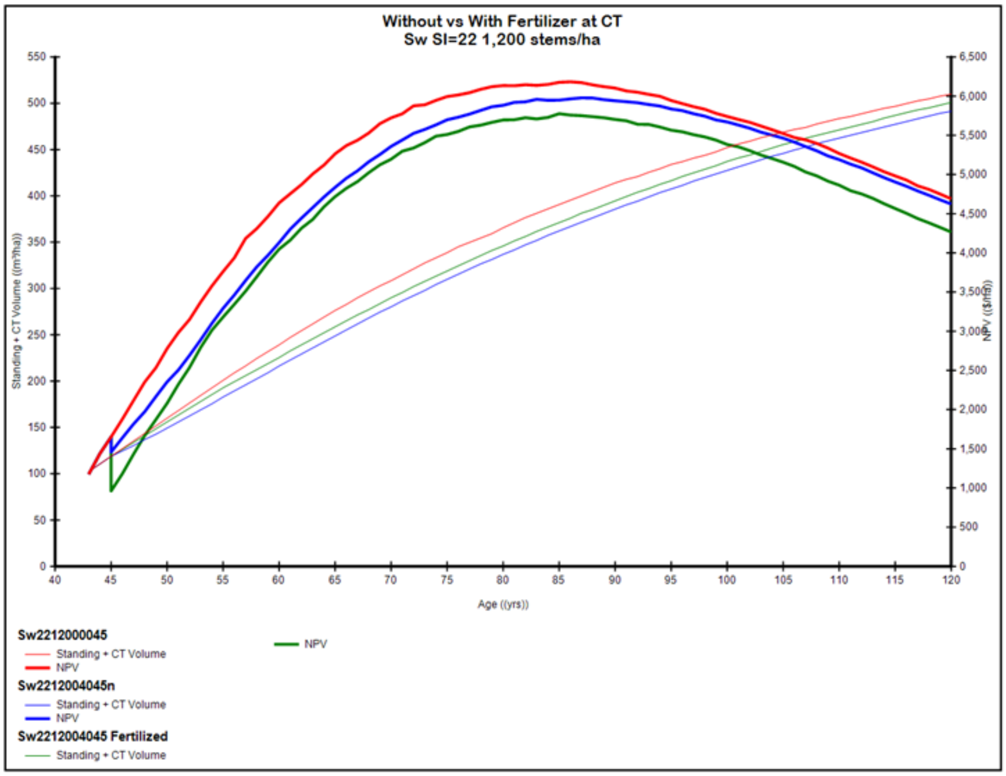

Figure 6. Fertilization after thinning in S_w stands

A similar result for is presented for Sw in Figure 6 above. The NPV is higher for the untreated stand compared to the treated and treated plus fertilized stand. The NPV of the CT-only stand surpasses the NPV of the CT plus fertilization stand at approximately 20 years following treatment and remains higher throughout the simulation. There is a demonstrable yield gain following fertilization, but it is not justified on economic grounds.

Most of this analysis focused on TASS simulations for site index 22 stands, since many of the CT candidate Pli and Sw stands in the Mackenzie, Prince George and Quesnel TSAs fall into this site index class. However, the WG was curious to understand the impact of CT treatments on stands in a higher site index class. Yield simulations and NPV calculations were completed for both Pli and Sw assuming a site index of 26 and the results are presented in Figures 7 and 8 below.

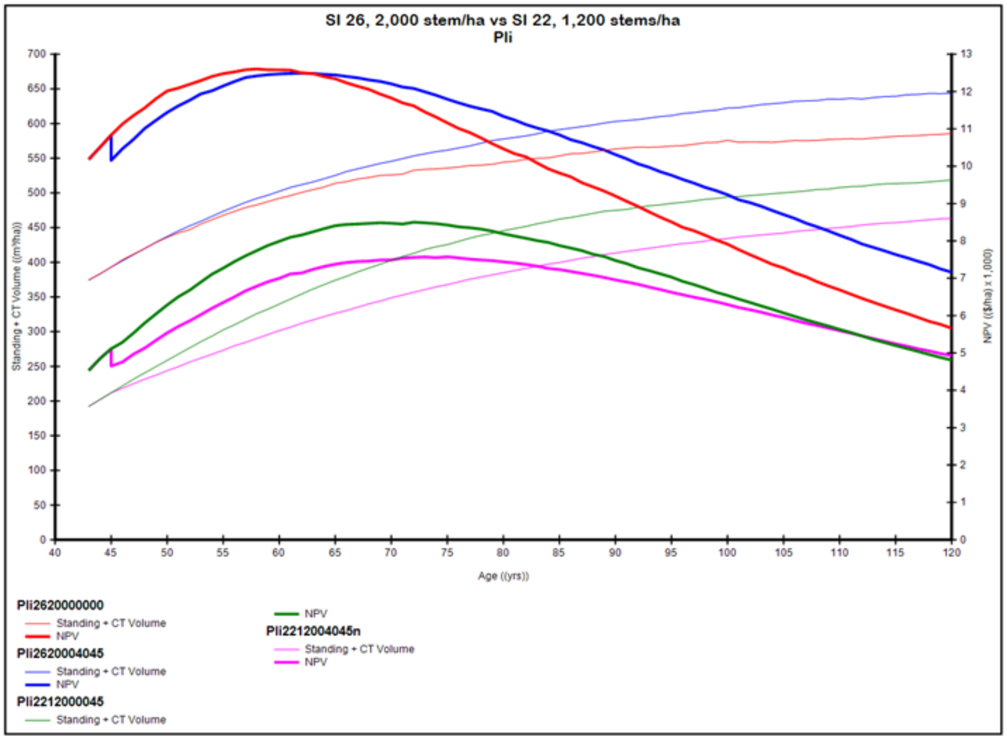

Figure 7. Impact on NPV of SI 26 v. SI 22 for Pli stands

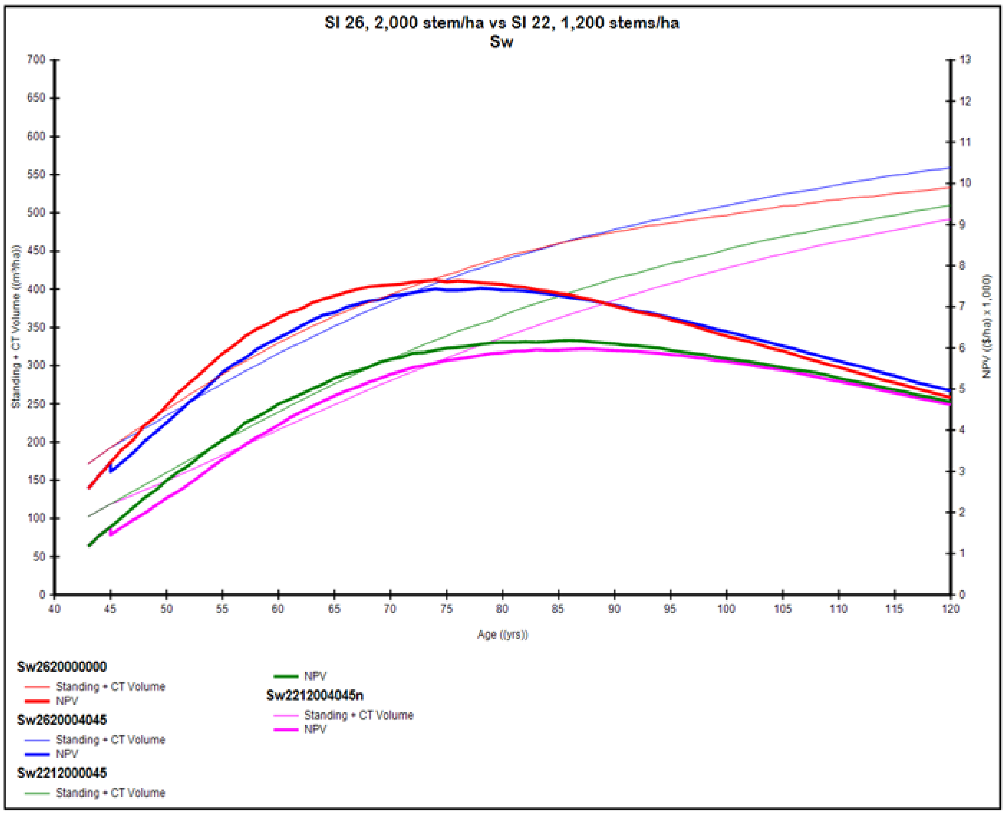

Figure 8. Impact on NPV of SI 26 v. SI 22 for Sw stands

NPV curves for both species are higher in the site index 26 stands and the maximum NPV occurs sooner since the stands are growing faster. Moreover, the NPVs for the treated site index 26 stands surpass the NPVs for the untreated stands. This result is particularly evident in Pli at approximately 64 years of age. CT treatments become more viable economically in stands with higher site index classes.

Guidelines

Results show that thinning responses overwhelm the present value calculations within a relevant range of rotation ages and SI classes. Regardless of the sensitivities considered for log prices, costs or discount rates, the base case (i.e. no thinning treatment) provides a higher NPV than the NPV for treated stands within the Mackenzie, Prince George, and Quesnel TSAs. The NPVs is still positive in some treated stands but not as high as NPV for untreated stands.

It is recognized that CT is still in its infancy in the BC Interior. Further work is required to better understand CT potential. Previous work[16] advised that CT treatments be undertaken with caution since not all of them yield positive NPVs. Within this context, the following economic guidelines are provided

[16] See "Commercial Thinning of Lodgepole Pine: An Economic Analysis. Unpublished Working Paper 6-017, by M. Stone. September, 1996.

to licensees contemplating CT operations on their management units and should be read together with other guidelines and principles presented in this document:

- Undertake CT operations if it can be demonstrated that conversion return estimates are positive, and
- When estimating the conversion return, reasonable log price, logging phase cost and discount rate estimates are used in the calculations.

CT operations on Crown land are discouraged where conversion returns are forecast to be negative, unless other extenuating circumstances prevail. For this version of the guidelines, only timber (net) revenues (i.e. conversion returns) are considered. Guideline revisions may include revenues from other sources or non-market values arising from CT operations.