SECONDARY STAND STRUCTURE AND ITS TIMBER SUPPLY IMPLICATIONS FOR MOUNTAIN PINE BEETLE ATTACKED FORESTS ON THE NECHAKO PLATEAU OF BRITISH COLUMBIA

by

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Abstract

Post-mountain pine beetle epidemic, secondary stand structure measured in 1370 mature leading pine plots in the central interior of British Columbia indicate significant levels of advanced regeneration (AR) in most Biogeoclimatic (BEC) subzones. Future growth of AR was predicted using SORTIE ND and VDYP7 natural stand growth and yield models with inputs such as species composition, diameter distribution, site index (BHA50), basal area and quadratic mean diameter. The SELES (STSM) spatially explicit landscape event simulation model forecasts timber supply incorporating AR focusing on alleviating predicted mid-term (15 to 60 year) fall-down.

SELES forecasts incorporating AR using VDYP7 results in a 6% increase in mean mid-term harvest level for the Prince George Timber Supply Area. If SORTIE ND is used, mid-term forecast is increased by 23%. Additional scenarios show benefits to mid-term timber supply when stands with well developed AR are reserved for harvest until after the initial salvage period.

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GLOSSARY

Abbreviation	Unabbreviated text	Definition/explanation
AAC	allowable annual cut	Amount of timber permitted to be harvested expressed as cubic metres (m^3) per year. In British Columbia AAC for Tree Farm Licences and Timber Supply Areas are determined by the Chief Forester based on considerations outlined in section 8 of the *Forest Act.*
AC	age class	In British Columbia forest inventory is classified into 9 age groups the first 7 of which are 20 year groupings. See Table 2.1
AR	advanced regeneration	Understory trees made up of saplings and seedlings. For the purposes of this case study defined here as commercial tree species between 1.37 metres in height and <12.5 cm in diameter measured at breast height.
BA	basal area	Tree basal area is the cross sectional area of a tree bole measured at breast height and is generally expressed in square metres. $BA_m = \pi \times (dbh_m/2)^2$ where dbh is expressed in metres. Result is in m^2 It is a useful measure of stand density when expressed as m2/ha.
BC	British Columbia	Westernmost Province in Canada
BCMPB	British Columbia Mountain Pine Beetle Model	Provincial-level projection of the current mountain pine beetle outbreak updated annually since 2004 (BCMPB v1). This model predicts mountain pine beetle caused pine mortality into the future and was originally funded by Natural Resources Canada under the Mountain Pine Beetle Initiative. A significant input into this model is the annual *Summary of Forest Health Conditions in BC.*
BEC	Biogeoclimatic ecosystem classification	Land classification system use in British Columbia that considers moisture, temperature and vegetation. Subzones of interest are: SBS (sub boreal spruce) dk: dry cool SBS dw2: dry warm SBS dw3: dry warm SBS mc3: moist cold SBS mk1: moist cool SBS wk1: wet cool SBS vk: very wet cool

COFI	Council of Forest Industries	The Council of Forest Industries in an umbrella organization that represents the BC interior forest industry in matters of policy and lumber grading standards. COFI companies operate 100 production facilities in over 60 forest dependent communities in the interior of British Columbia. COFI and the Ministry of Forests and Range jointly participated in a Mountain Pine Beetle Task Force from 2002 to 2007.
dbh	diameter at breast height	For this study breast height is 1.37 metres up from the germination point of a tree.
DBHg	quadratic mean diameter	The average diameter (measured at breast height and generally expressed in centimetres) of trees in a stand where the average is weighted by basal area.
DJA	Fort St. James forest district	The most northern of the 3 districts in the Prince George Timber Supply Area spreading from Stuart Lake in the south to the headwaters of the Skeena River in the north.
DNA	Nadina forest district	Not in the Prince George Timber Supply Area the Nadina forest district is immediately to the west of the Vanderhoof forest district.
DPG	Prince George forest district	The most eastern of the 3 districts in the Prince George Timber Supply Area spreading from the Robson Valley in the east and Bowron River in the south to Clucus Lake in the west and McLeod Lake in the North
DVA	Vanderhoof forest district	The forest district in the south western portion of the Prince George Timber Supply Area spreading from Tweedsmuir Park in the southwest to the Entiako Protected Area in the West.
Fall-down	Timber supply fall down	The time in the harvest forecast modeling where salvage of MPB is complete and timber supply is reduced.
FIA	Forest Investment Account	Funding delivery model currently used in British Columbia to finance forest research, inventory and knowledge transfer.
FAIB	Forest Analysis and Inventory Branch	Branch of the British Columbia Ministry of Forests and Range that has the responsibility for providing information and analysis to the Chief Forester when determining allowable annual cuts.
GIS	Geographic Information System	Geomatics tool used for mapping. ESRIs Arc-Info is used for all maps in this Thesis.

GPS	Global Positioning System	Satellite based geo-referencing system that indicates location on the earth's surface. Location is given using 'northings' and 'eastings' which are similar to latitude and longitude and are used to describe plot location. Plot locations in this study are generally accurate to 10 metres.
ha	hectare	Measure of land area being 10,000 square metres (100 by 100 metres). Stand attributes such as volume and basal area are expressed as cubic metres per hectare (m^3/ha) or square metres per hectare (m^2/ha).
m^3	cubic metre	International standard measure of timber volume (log [m^3/tree]) or stand [m^3/hectare]).
MFR	Ministry of Forests and Range	British Columbia government administrative body that is granted the authority to manage the forest and range resource.
MTTS	Mid-term timber supply	With reference to projected timber supplies in British Columbia the mid-term begins after the anticipated fall-down 10 to 20 years from the start of the mountain pine beetle epidemic.
MPB	mountain pine beetle	(*Dendroctonus ponderosae* Hopkins)
MPBI	Mountain Pine Beetle Initiative	Federal funding program administered by the Canadian Forest Service to encourage research into the impacts of the current mountain pine beetle epidemic.
PG TSA	Prince George Timber Supply Area	One of 37 forest management units in British Columbia that supports volume based timber tenures such as replaceable forest licences. The PG TSA contains 3 forest districts including Prince George (DPG), Vanderhoof (DVA) and Fort St. James (DJA)
Pl	lodgepole pine	*Pinus contorta* Dougl. ex Loud.var. *latifolia* Engelm.
SBS	Sub-Boreal Spruce BEC zone	A BEC subzone in the central interior of BC dominated by pine and spruce forests of the Nechako Plateau.
SELES	Spatial Explicit Landscape Event Simulator	Computer modeling platform used to build spatially explicit landscape simulation models that explore changes in landscapes resulting from natural and anthropogenic events and processes. SELES STSM (spatial timber supply model) is used in the case study of this thesis.

SORTIE-ND	Software for spatially-explicit simulation of forest dynamics.	Used in this study as a timber growth and yield model that predicts volume for natural (unmanaged) beetle attacked stands. This model has been localized for British Columbia originally in collaboration with Charles Canham of the Cary Institute of Ecosystem Studies, Millbrook, New York, Dave Coates, Phil LePage, Elaine Wright and other scientists from the Research Section of the British Columbia Forest Service. See: http://www.bvcentre.ca/sortie-nd
sph	stems per hectare	Measure of the density of seedlings, saplings or trees.
Spp.	tree species	Tree species commonly found in the study area: <u>abbreviation</u>: <u>common name</u>: <u>*Latin name*</u> **Ac**: cottonwood (*Populus trichocarpa* Torr. & A.Gray) **At**: aspen (*Populus tremuloides* Michx.) **Bl**: Sub-alpine fir (balsam) (*Abies lasiocarpa* (Hook.) Nutt.) **Cw**: western redcedar (*Thuja plicata* (Donn ex D. Don in Lamb)) **Fd**: Douglas-fir (*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco) **Hw**: western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) **Pl**: lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) **Sb**: black spruce (*Picea mariana* (Mill) BSP) **Sx**: interior spruce (*Picea glauca* (Moench) Voss x *Picea engelmannii* Parry ex Engelm.)
SSS	Secondary stand structure	Live remaining trees after mountain pine beetle has infested a stand and moved on. Classified into four categories for this study: **seedlings**: trees between 0.10 and < 1.37 metres (dbh) tall **saplings**: trees greater than 0 cm diameter at dbh and less than 7.5 cm dbh. **poles**: trees between 7.5 cm and < 12.5 cm dbh **residual overstory**: trees with a dbh of 12.5 cm and greater.

TIPSY (TASS)	Table Interpolation Program for Stand Yields (Tree and Stand Simulator)	TIPSY is a growth and yield program that provides electronic access to the managed stand yield tables generated by TASS. TASS is a Growth and yield model developed in British Columbia used to predict forest stand attributes (volume, height, density, basal area etc.) based on variables such as average age, site productivity and species. TIPSY was developed mainly for use in predicting future volumes of managed stands. Accessed at: http://www.for.gov.bc.ca/HRE/gymodels/TIPSY/
THLB	Timber harvesting land base	Forested area judged to support economically viable timber harvest at a specific point in time.
TSA	Timber Supply Area	BC forest management unit that contains volume based tenures such as Forest Licences.
TSP	temporary sample plot	For the purposes of this study 5 or more TSPs were established in each randomly sampled stand. Plots are temporary in that they may have been revisited 3 times but were not expected to be used for any long-term studies.
TSR	timber supply review	The British Columbia government directed process that examines the timber supply for management unit and results in the determination of an allowable annual cut level.
VDYP7	Variable Density Yield Prediction version 7	Empirical timber growth and yield model developed in British Columbia that predicts attributes such as stand density, basal area and volume for natural stands from inputs variables such as species and site index.
VRI	Vegetation Resource Inventory	British Columbia forest land inventory classification system.

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For me, the stress of Thesis deadlines and associated lack of sleep brings on impatience and a lack of seeming to care about anything but what I am focused on at the time. Through all of this my wife Anne has stuck with me, supported me, encouraged me, put up with my daily undone household responsibilities, stick handled the phone calls and fended off the less important and frivolous matters that would keep me from this important study. Thank-you! For this I am forever grateful! I know that without you I would not have completed this.

In July of 2002, on a helicopter reconnaissance of the southern part of the Vanderhoof forest district I was shocked and awed by the advancing front of mountain pine beetle attack. I came home that day and told Anne that based on what I had observed I believed that it was 'all over' for the forest industry in the central interior of British Columbia. The following year found me as a sessional instructor at the University of Northern British Columbia where I taught forest Policy, Planning and Integrated Resource Management. There I met several colleagues who were doing research in mountain pine beetle related topics, one of whom, Dr Chris Hawkins, was prepared to take me on as a master's student. Thank-you Chris! In 2007 the timber supply review (TSR) process for the Prince George TSA was initiated which presented a unique opportunity to use the 'official' modeling information generated from the TSR process combined with the advanced regeneration metrics generated from data collected by Chris's UNBC Mixedwood group. I was away to the races! Thanks for your encouragement, advice, graciousness and patience through it all Chris!

My other committee members, Dr Bryan Bogdanski (Canadian Forest Service) and Jim Snetsinger (MFR) also had a keen interest in my chosen topic. Keen enough to meet monthly over the last two years! I am thankful for the guidance and encouragement you provided including Bryan's extensive help with editing and Jim's commitment to see this to fruition when things were going slowly. When Dr. John Nelson (UBC) graciously agreed to be my external examiner the team of experts was truly complete! Thank you all.

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When modeling timber supply and forecasting what the results of mans current actions might be, one must always keep the following perspective:

"The mind of man plans his way but the Lord determines his steps" Proverbs 16:9

CHAPTER 1.

INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

The pine forests of western North America are experiencing an unprecedented mountain pine beetle (*Dendroctonus ponderosae* Hopkins) epidemic. British Columbia (BC) has focused significant resources on this problem including designated staffing, annual provincial bark beetle strategies and increases in permissible timber harvest levels for salvage of dead timber. As much as 65% of mature lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) trees may be killed by the end of the epidemic (Walton 2010). This leaves stands with residual, live non-pine mature trees, saplings and seedlings that could eventually grow to become the future forest if these stands are not logged (Coates *et al.* 2006). The primary questions arising are how much of the remaining live trees, seedlings and saplings or secondary stand structure is there, and how will it contribute to future timber supply and future forest conditions?

Thesis Statement: In the Nechako Plateau of the central interior of British Columbia, advanced regeneration and residual overstory existing in mature lodgepole pine stands killed by mountain pine beetle can contribute significantly to future timber harvests.

This thesis will examine the effects of the current mountain pine beetle (MPB) epidemic on the lodgepole pine forests of the Prince George Timber Supply Area (PG TSA) in the central BC interior. Significant negative publicity over the last several years has influenced the general public to believe that these pine forests are dead. Few realize the

MPB is an integral part of the ecology of these pine dominated forests (Klutsch *et al.* 2009). Many believe that the government must rehabilitate these forests through harvest of dead timber and massive re-planting programs. In BC, the Chief Forester has raised allowable annual cuts (AAC) significantly in order to permit salvage of some of this dead timber before it falls down, decays or burns (British Columbia Ministry of Forests 2003, Pousette and Hawkins 2006).

Despite large increases in AAC, not all of the MPB killed timber will be salvaged (Pedersen 2003). The Ministry of Forests and Range (MFR) estimates there is over 1.35 billion cubic metres (m^3) of susceptible mature pine timber on the provincial timber harvesting land base (British Columbia Ministry of Forests and Range 2007). It is also estimated that just over one billion m^3 will be killed by the end of the current epidemic (Westfall and Ebata 2008). Shelf life of dead timber will play a significant role in the viability and economics of harvesting it (Lewis and Hartley 2006; Ministry of Forests and Range 2010). Shelf life is defined as the period of time that MPB killed timber is usable to manufacture into a specific product (Lewis and Hartley 2006). In the PG TSA, much of this timber is currently being utilized as sawlog. Government is also encouraging the development of a bio-energy industry that could use the timber not desirable for either sawlog or pulp (Wright 2007; Ministry of Forests and Range 2010).

Field observations indicate that the majority of these MPB killed stands have a component of live saplings, seedlings and smaller diameter mature trees (poles), referred to as secondary stand structure (Coates *et al.* 2006). It may provide adequate stocking densities to ensure a healthy future forest (Coates *et al.* 2006; Runzer *et al.* 2008; Coates *et al.* 2009). The BC Vegetation Resource Inventory (VRI) does not collect information regarding seedlings or saplings. Recognizing this deficiency, between 2004 and 2007 Rakochy (2005); Hawkins and Rakochy (2007) and Runzer *et al.* (2008) collected lodgepole pine mortality and secondary stand structure data from MPB attacked lodgepole pine stands in the southern portion of the Nadina forest district and the central and southern portion of the Prince George Timber Supply Area (TSA). These data were used in this thesis.

Timber supply projections undertaken by government and industry show significant reductions in timber availability post MPB salvage (British Columbia Ministry of Forests 2003; COFI 2006; British Columbia Ministry of Forests and Range 2006; Morice and Lakes IFPA 2007). To date, the majority of these analyses have not considered incorporating estimates of secondary stand structure and its growth into modeling assumptions. This may be because; i) accurate estimates have not been available, ii) estimates are highly variable, and iii) no reasonable methodology for incorporating the estimates into timber supply models has been developed.

1.2 STUDY OBJECTIVES

This thesis proposes a timber supply modeling methodology to incorporate the advanced regeneration (AR) information. This method is applied in a case study of the Prince George Timber Supply Area. Results of different assumptions and timber planning strategies are compared for future harvest levels achievable in the mid-term period. The mid-term is defined as the period after MPB related salvage is complete and before harvest begins in second growth stands. One of the major foundations of timber supply modeling is estimates of stand growth and yield. Specifically this study will:

1. Estimate the amount of live secondary stand structure including AR and residual overstory that exists in attacked mature leading pine stands.

2. Propose a methodology for incorporation of advanced regeneration into the growth and yield models for use in timber supply models. Predictions will be made as to how well secondary stand structure may grow and how much volume these stands will yield in the future.
3. Propose and test a methodology to incorporate growth and yield predictions for secondary stand structure into timber supply models.
4. Examine in a case study how existing secondary stand structure might affect mid-term timber supply in the Prince George TSA.

Several growth and yield models exist and may be appropriate to estimate forest growth after MPB attack. This thesis will quantify values for input variables required in two growth and yield models, SORTIE ND (Canham 2001) and Variable Density Yield Prediction version 7 (VDYP7) (British Columbia Ministry of Forests and Range 2009b). Further, growth and yield modeling will support a timber supply case study of the Prince George TSA (Figure 1.1).

Post MPB stand structure will be classified for:

saplings: trees > 0 cm diameter measured at 1.37 metres height (breast height (dbh)) and < 7.5 cm dbh.

poles: trees between 7.5 cm and < 12.5 cm dbh

overstory: trees with a dbh of 12.5 cm and greater.

Theme areas examined include:

Ecological – Forests and how they evolve.

Modeling – Estimating and projecting stand yields and growth.

Timber supply – Developing modeling methodologies for incorporating the contribution expected from forests that are not salvaged.

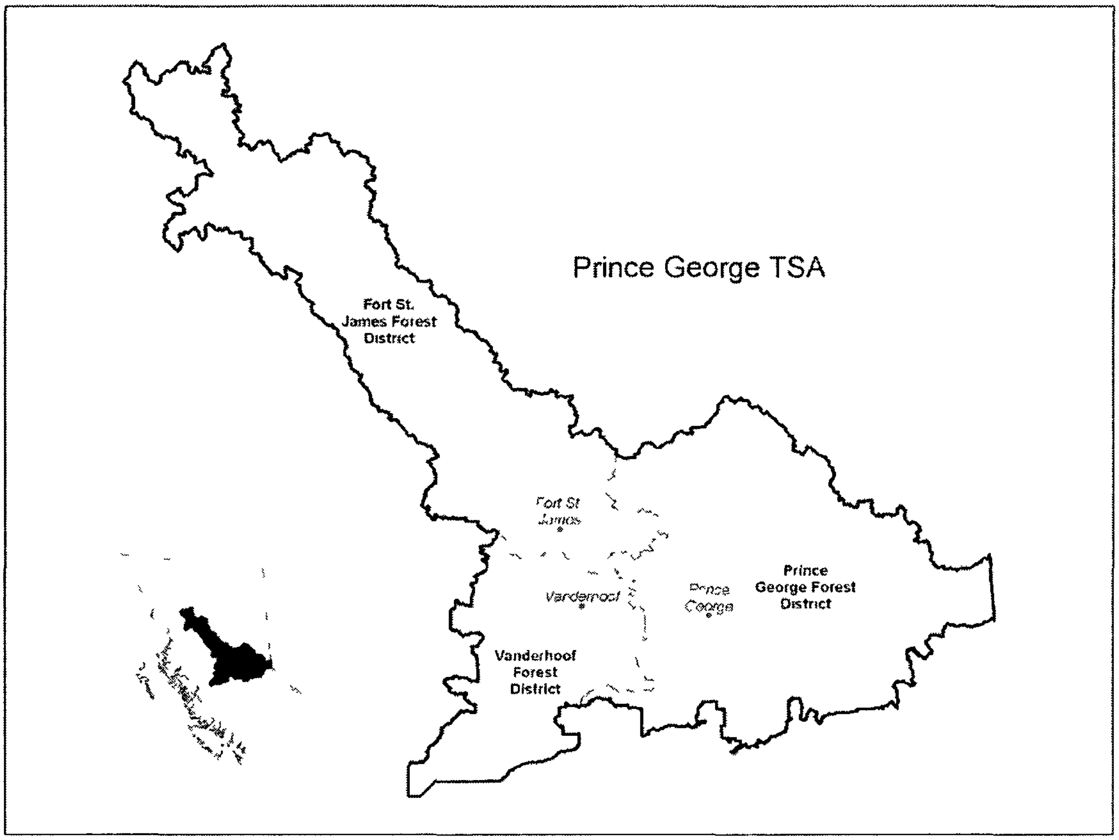

Figure 1.1: Overview map of the three forest districts in the Prince George Timber Supply Area in central BC.

The contribution of secondary stand structure to future timber supply after a large scale MPB disturbance is important in light of predictions of a severely reduced mid-term timber supply and considerations being given to spending public funds on forest rehabilitation programs.

It is acknowledged that there are other significant benefits to overall forest health from protection of secondary stand structure (Snetsinger 2005; Coates *et al.* 2006; Griesbauer and Green 2006; Burton 2008). These include improved hydrologic recovery rate and water quality (Snetsinger 2005, Rex and Dube 2006), preservation of visual values (Hodges 2008), maintenance of biodiversity and wildlife values (Burton 2008) and potential mitigation of climate change through more rapid and immediate uptake of CO_2 through carbon sequestration (Hebda 2006, Hodges 2008). These other benefits are recognized as vitally important but are not addressed here.

1.3 LITERATURE REVIEW

The literature review covers a wide range of topics integral to modeling assumptions made in the case study. Subjects reviewed include:

- Mountain pine beetle biology and host silvics.
- Root cause of the current MPB epidemic.
- Mortality experienced in documented MPB epidemics in British Columbia.
- Abundance of live secondary stand structure following MPB.
- Growth and yield of secondary stand structure.
- Timber supply modeling and allowable annual cut in response to MPB.

1.2.1 Mountain Pine Beetle Biology

The mountain pine beetle is a bark beetle of the Scolytide family (Safranyik and Vithayasai 1971). In BC, the MPB is known to attack lodgepole (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.), ponderosa (Pinus *ponderosa* Dougl. ex Laws.), western white (*Pinus monticola* Dougl. ex D. Don in Lamb.), limber pine (*Pinus flexilis* James) and whitebark pine (*Pinus albicaulis* Engelm.). Occasionally, when reaching epidemic levels, other species such as white spruce (*Picea glauca* (Moench) Voss) and interior spruce (*Picea glauca* (Moench) Voss x *Picea engelmannii* Parry ex Engelm.) are attacked (Doane *et al.* 1936; Amman 1976; Amman *et al.* 1990; Huber *et al.* 2009).

Mountain pine beetles live out most of their life cycle under the bark. After chewing through the bark female beetles move upward constructing vertical egg galleries which can be more than a metre long (Reid 1963). These galleries are bored mostly in the phloem and partially into the sapwood. During the summer and early fall eggs are laid along both sides of the galleries and generally larva hatch in 10 to 14 days (Reid 1963; Amman *et al.*1989). Larva immediately bore individual horizontal galleries increasing in size as they feed on the phloem. These galleries have been observed to be as long as 10 centimetres and terminate in a round shaped pupal cavity where the fully grown larva transforms into a pupa (Reid 1963; Amman *et al.* 1989). Generally the stage between egg hatch and pupa formation lasts from August to the following June or July at which time the mature adult emerges from exit holes in the bark and fly to attack a new host and the life cycle is repeated (Doane *et al.* 1936; Amman *et al.* 1989).

Many factors affect the success and continuation of the MPB life cycle. Weather (temperature and moisture) can affect the timing of individual phases (adult, egg, larva and pupa) and may result in extending the cycle over two years or in ideal conditions may result in two full life cycles in one year (Amman *et al.* 1989). The number of eggs that the female beetle lays and in turn successfully develop into pupa can also be dependent on food source in terms of phloem thickness (Amman 1976; Björklund *et al.*2009) and crowding by adjacent beetles (Cole 1973). Generally as tree diameter and age increases, phloem thickness also increases (Amman 1976). When beetles attack very small diameter (7.5 to 10 cm) immature trees, few if any mature beetles have been observed to emerge (Hodges 2008). Extreme cold during the fall, winter and spring can result in mortality of the MPB (Amman *et al.* 1989).

Many lay people believe that MPB alone kill lodgepole pine trees and in instances where individual tree attack rates are high this may be the case as beetles can completely destroy the phloem layer essentially girdling the tree. Mountain pine beetle carry several species of blue stain fungi including *Ophiostoma clavigerum* (Robinson-Jeffrey and Davids) and *Ophiostoma montium* (Rumbold) von Arx. (Solheim and Krokene 1998). These fungi are carried into the tree by the mountain pine beetle and invade the sapwood colonizing the rays and tracheids and breaking down cell walls which interrupts water transport (Reid *et al.* 1967). Reid *et al.* (1967) also reported that blue stain fungi can completely invade the cells of the sapwood within a month of MPB attack which is long before larvae have hatched and begin boring horizontally to create pupal chambers. This suggests that blue stain fungi are the primary cause for tree mortality and that the MPB is an accomplice or primary vector.

1.3.2 Silvics of Lodgepole Pine

Lodgepole pine forests are common to the central interior of BC. Stands are generally even aged and originate from fire caused landscape level disturbances (Lotan 1975; DeLong 1998). Seed production is generally very prolific and serotinous and non-serotinous cones are produced (Hellum 1983). Because of the method of natural regeneration, stands tend to exist in pure form with few other tree species present in the dominant and co-dominant crown layers (Schmidt and Alexander 1985) (Figure 1.2).

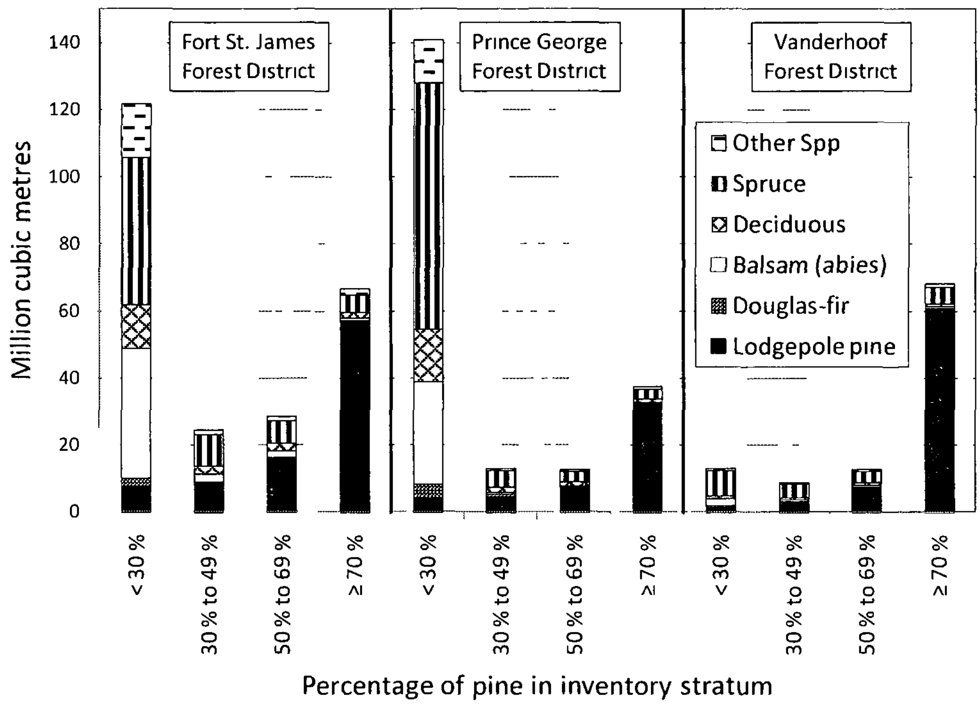

Figure 1.2: Standing mature volume by species in the Prince George TSA timber harvesting land base: stratified by the percentage that pine represents of the forest inventory polygon label.[1]

In the Vanderhoof forest district (DVA), 61 million of the 73 million m^3 of mature pine is found in stands where pine makes up 70% or more of the volume. In the Prince George forest district (DPG), 33 million of the 48 million m^3 is found in these purer pine stands. Note that some lodgepole pine also exists in stands where the pine makes up less than 30% of the volume. Pine represents less than 2% of this stratum in DVA and less than 9% in DPG. Sixty-seven million cubic metres (m^3) of standing mature volume currently

[1] Extracted from the Ministry of Forests and Range Vegetation Resource Inventory file used for the 2010 PG TSA timber supply review This represents forest growth and harvesting to March 2009 and includes all stands greater than or equal to 60 years old. Volumes are compiled to 12 5+ cm dbh for all species. Used with permission.

exists in the Fort St James forest district (DJA) in the purer (≥ 70%) pine stands In all three districts, the sum of pine found in all mixed stands (<30%, 30% to 49% and 50% to 69%) is 60 million m^3, which is significantly less than the 151 million m^3 of pine in stands where pine is pure (≥ 70%) (Figure 1 2)

The total pine mature pine growing stock, 211 million m^3, represents 38 % of the total growing stock of the TSA which is 549 million m^3 The Provincial Chief Forester and the Regional Executive Director of the Northern Interior Forest Region (NIFR) have encouraged forest licensees to focus harvest on purer pine stands first and curtail harvest in the more mixed species stands until the salvage of beetle killed pine is nearing completion [2] The mixed stands make up a component of what is referred to as potential mid-term timber supply (MTTS)

Immature lodgepole pine begins its seasonal growth earlier than most other tree species which allows it to take advantage of moisture from snowmelt (Satterland 1995) This factor, as well as an affinity to grow in full sunlight (Lotan 1975), gives pine a distinct advantage over other conifer species and allows it to invade and occupy a large variety of climatic and soil conditions In the interior of BC, natural fire origin stands have been observed where initial stand densities are so high (30,000+ stems per hectare (sph)) that height growth has stagnated (Farnden and Herring 2002) These stands are the exception as today young pine stands exist mostly in plantations where density is controlled (Runzer *et al* 2008) Growth and yield models indicate that planted pine stands at 30 years of age with an establishment density of 1600 sph can achieve diameters of 15 cm and heights of 13 metres

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[2] Letter from the Ministry of Forests and Range, Northern Interior Forest Region Executive Director (Bill Warner) to All Major Licensees and BC Timber Sales Managers regarding Mid-Term Timber Supply Report Card dated July 16th, 2007

depending on site productivity.[3] Typically smaller diameter trees have thinner outer bark and phloem (Amman 1972) and observations from the current epidemic support the notion that success of MPB brood production is directly proportional to stem diameter (Björklund *et al.* 2009).

In the SBS BEC zone (Meidinger *et al.* 1991) lodgepole pine can grow to be over 200 years old, but an examination of the field data found few trees older than 160 to 180 years. Data collected and used in this thesis indicate that dbh of these older trees can reach 45 cm but this is rare and more commonly dbh ranges between 30 and 40 cm. Data also shows heights ranging from 20 metres on poorer sites to 30 metres, and taller, on good sites in the SBS mk1 and SBS wk1 northwest and east of Prince George. Lodgepole pine boles are cylindrical with little taper resulting in suitable bark and phloem thickness for successful brood development in a significantly large portion of the tree (Björklund *et al.* 2009). In the current epidemic, extensive beetle attack is observed along the full length of most merchantable logs in virtually all salvage logging operations around the PG TSA[4].

As mature even aged lodgepole pine stands age in the SBS BEC zone, they can be replaced by species such as interior spruce, subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), Engelmann spruce and Douglas-fir (*Pseudotsuga menzeiesii* (Mirb. Franco) var glauca) (Meidinger *et al.* 1991).

1.3.3 FACTORS INFLUENCING THE CURRENT MPB EPIDEMIC

Under normal conditions, MPB are endemic in the central interior of BC. Amman

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[3] TIPSY v 4 1d (British Columbia Ministry of Forests and Range 2007) model run for stands in the Prince George forest district with site index (BHA_{50}) of 20, OAF1=0 85, OAF2=0.95, regeneration delay of 0 years and 100% lodgepole pine planted at initial density of 1600 stems/ha.

[4] Hodges, K Personal Communication June 2009 Ken Hodges is a retired Ministry of Forests Stewardship Forester Phone 250-964-9675

(1978) reports that epidemic situations can erupt under the following conditions:

- Landscape level expanse of mature pine trees
- Average tree diameters greater than 20 cm
- Substantial proportion of trees with phloem thicknesses in excess of 0.25 cm
- Favourable climatic conditions
- Sufficient MPB populations

1.3.3.1 Abundance of Susceptible Host

Many sources cite the major factor contributing to the current infestation as being the aging of British Columbia's pine forests well past what is considered normal based on natural disturbance regimes of the SBS BEC zone (DeLong 2009). Approximately 65 years ago Sloan (1945) reported that only 22.74% (5.98 million ha) of the productive forest land in the interior districts (Figure 1.3) of British Columbia was considered to be mature timber (greater than 80 years old). The remaining 77% or 20.31 million ha, was logged, logged and burned, burned or immature timber. The area of young forests was considerably more than today. Sloan reported that the productive (land capable of growing trees) land base for the interior was 26.29 million ha out of the total interior land base in the interior of 78.20 million ha. The interior districts unproductive land (for forestry), 51.90 million ha included scrub forest (non-commercial), barren (alpine and subalpine), swamp, water and agriculture.

Taylor and Carroll (2004) reported that only 18% of the area with pine leading stands in British Columbia was susceptible (>80 years old) to MPB attack in 1910. By 1990, 53% of BC's lodgepole pine forests were considered susceptible to attack (Taylor and Carroll 2004). Wilson (2004) reported that when the current outbreak began to accelerate in 2000, approximately 70% (1 billion m^3) of all of British Columbia's pine had become vulnerable to MPB attack.

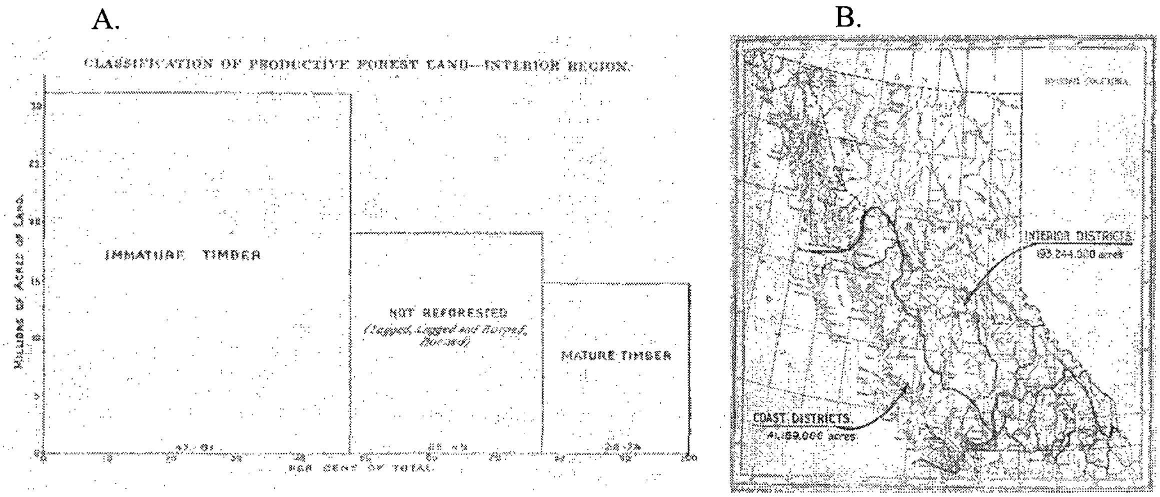

Figure 1.3: Area distribution of productive land by maturity class for the Interior Districts portion of British Columbia as reported by Sloan in 1945. (A. Adapted from Sloan page 25, B. Adapted from Sloan page 17.)

Amman (1972) suggests that pine stands over 80 years old are susceptible to MPB attack. Of the crown forest in the Prince George Timber Supply Area, 1,094,135 ha. (56%) of the leading pine area of 1,937,612 ha. is greater than 80 years old (Figure 1.4). Stands between 60 and 80 years old are considered to be transitional from immature to mature. If these stands are also susceptible to attack, then 1,345,650 hectares (69%) of the THLB would be at risk in the study area.

DeLong (2009) suggests a return interval for fire (stand replacement disturbance cycle) in the SBS BEC zone of 100 years. The expectation is that, in any given year, the probability of being burned is one one-hundredth. For the PG TSA, the current distribution of crown forested area for pine leading stands is markedly different than the theoretical distribution DeLong (2009) suggested (Figure 1.5).

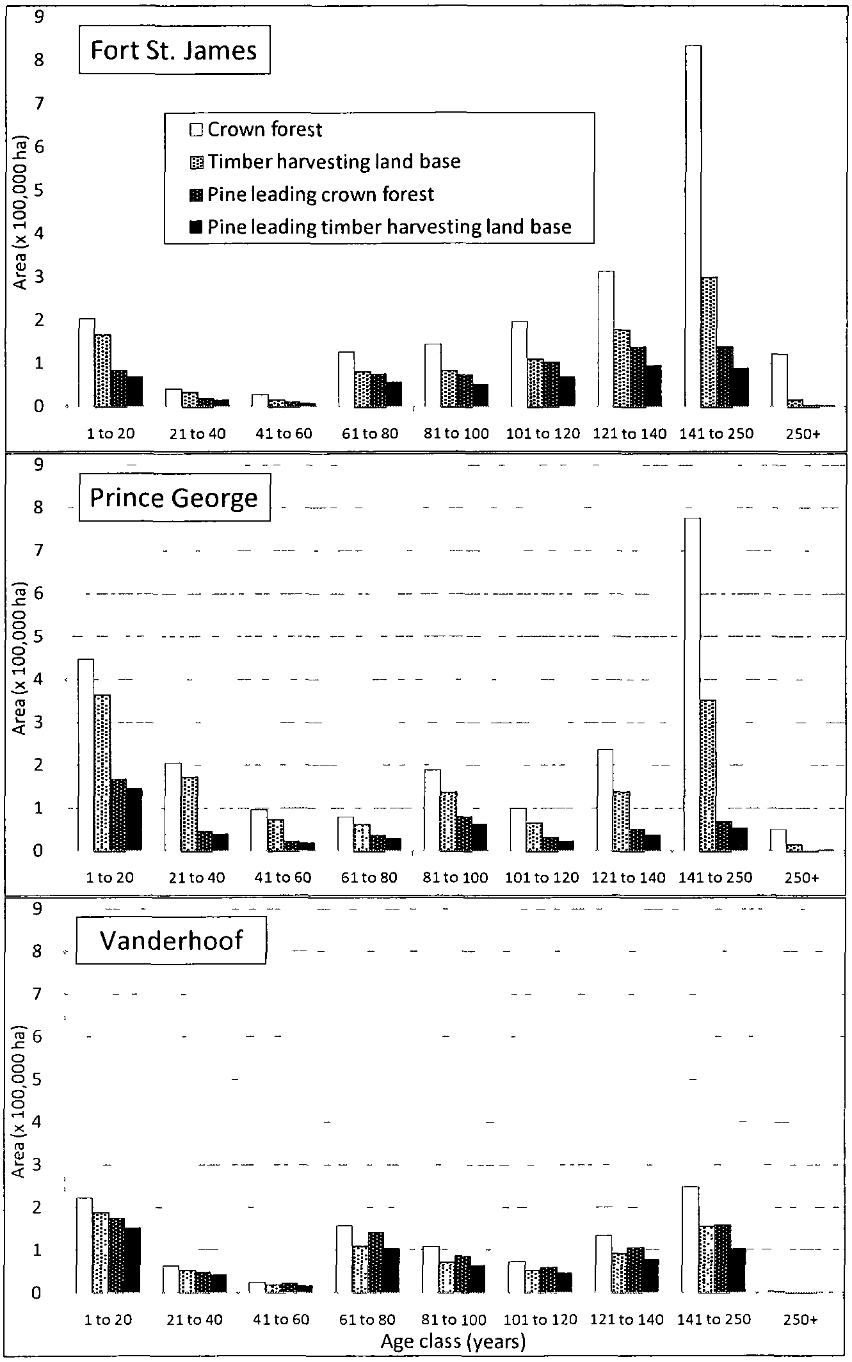

Figure 1.4: Age distribution for lodgepole pine and all species leading stands in the Prince George Timber Supply Area forest districts (current for logging to spring 2009).[5]

[5] Extracted from the Ministry of Forests and Range Vegetation Resource Inventory file used for the 2010 Prince George TSA timber supply review. This represents forest growth and harvesting to March 2009 and reports ages of dead pine forests based on pre-MPB attack . Used with permission.

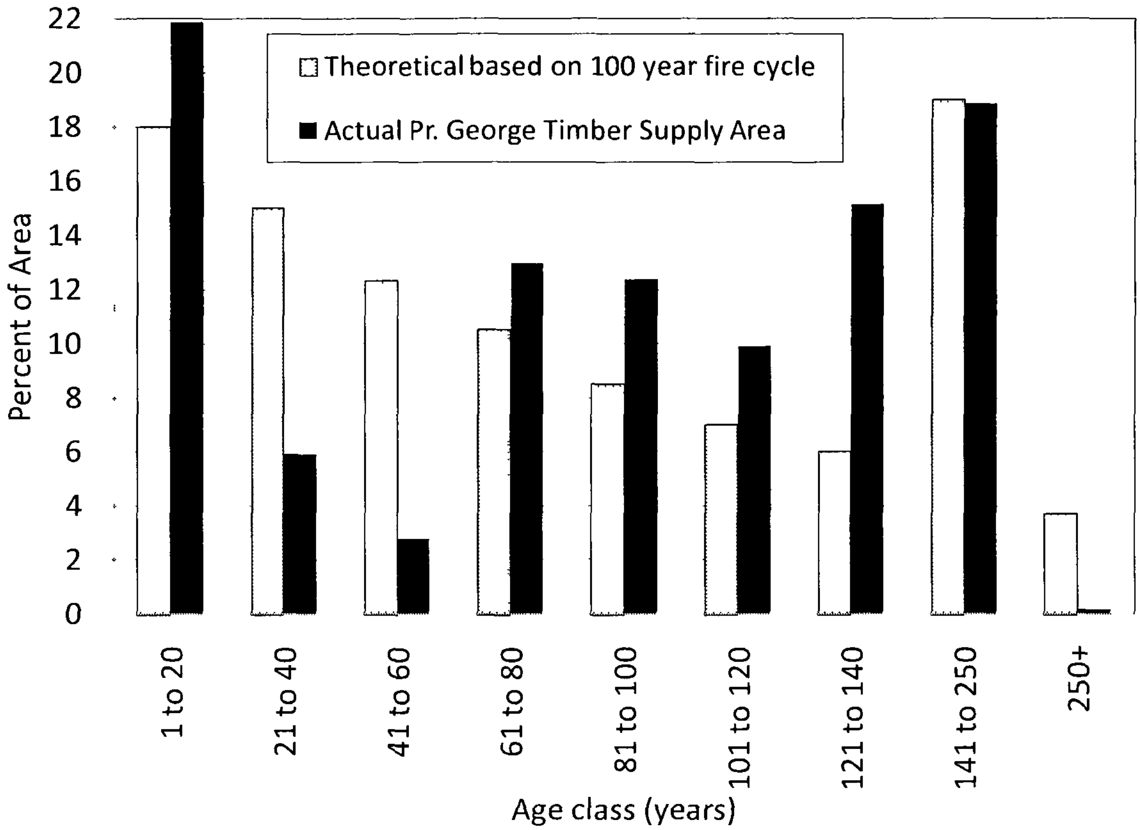

Figure 1.5: Current age class distribution of leading pine stands (crown forest) in the Prince George Timber Supply Area and the theoretical distribution (100 year fire cycle) based on DeLong (2009) and Andison (1996).

The 22% in age class 1 to 20 in the PG TSA is not a result of wildfire but rather the large amount of industrial logging and planting of pine that has occured over the last 30 years.[6] Lodgepole pine has been a prefered species for planting harvested areas as it allows achievement of reforestation obligations, associated with free to grow requirements, sooner than other species. Less than 9% of the area exists in stands aged 21 to 60 years old compared to the 27% that DeLong (2009) predicts. Taylor and Carroll (2004) suggested that the small amount of area in stands with ages 21 to 60 are the result of very successful fire

[6] Based on information from the Vegetation Resource Inventory file used in this study

supression over the previous 60 to 80 years. This is contrary to Meyn *et al.* (2009) who reports that the level of fire supression has no effect on area burned when comparing BEC zones. This latter study found that, for most of BCs BEC zones, area burned annually is most correlated to drought conditions in summer (June, July and August) (Meyn *et al.* 2009).

Currently, over 14.7% (285,000 hectares) more area occurs in leading pine with ages greater than 61 years old than is predicted by DeLong (2009). In the PG TSA, over 250,000 ha. of older leading pine stands have been salvaged since the epidemic began in 2002.[7] At the start of the epidemic it was estimated there was approximately 535,000 hectares more area susceptable to MPB (> 60 years old) than what would have been present under a natural disturbance regeime.

1.3.3.2 Favourable Climate

Climate is reported to regulate MPB population dynamics in several ways. Safranyik (1978) suggests four main climate influences:

Winter minimum temperates

Summer heat accumultions (for larval developement)

Summer rainfall timing (inhibit flight)

Spring/Summer moisture accumulations

In the past, extreme winter minimum temperatures have served to keep MPB populations in check. As fall and winter progresses, MPB cold tolerance increases through the production of an antifreeze like substance called glycerol which circulates in the blood (Somme 1964). Maximum cold tolerance is acheved in December/January when temperatures less than -38°C must be reached to kill most larvae (Safranyik and Linton

[7] See footnote 6.

1991). Logan *et al.* (1995) found that mountain pine beetle larva have the greatest cold tolerance with lethal temperatures for third and fourth instars between -29°C and -40°C.

Safranyik (1978) found that early winter (late October and early November) and late winter temperatures of -26°C were lethal to MPB adults and larva. In past outbreaks, populations have been kept at endemic levels and also knocked back by cold temperatures occuring prior to the beetle developing winter tolerance. This occured with the 1980s outbreak in the Cariboo/Chilcotin area of BC when the minimum temperature recorded by Envirnment Canada at Alexis Creek dropped to - 31°C on October 31 1984 (Safranyik and Linton 1991). Similarly in 1985, between November 10 and December 2, the Alexis Creek weather station recorded 13 days (11 consecutively) with daily minimum temperatures less than -26 C (Safranyik and Linton 1991). Even if MPB had survived the cold October of 1984, temperatures on the last three days of December dropped and daily minimums were not above -38 C with a low of -43 C on December 30 (Safranyik and Linton 1991). Safranyik and Linton (1991) also noted that in the time period between 1975 and 1983 the Alexis Creek weather station records show no period of time when temperatures dropped below lethal minimus for MPB for more than two consecutive days.

In summary, the cause of the current MPB epidemic is multifactorial. However, it was likely the result of the vast amount of suitable host and favourable climatic conditions. Larry Pederson, Chief Forester of BC, in the 2004 PG TSA Rationale for Allowable Annual Cut, summed up the situation as follows:

"I do not believe that anyone can profess to know exactly what caused the expansive nature of the infestation. I am informed about the increased amount of mature lodgepole forests due in part to forest fire suppression in the province over the last century, and that warmer weather has increased the historic range of the pine beetle in BC. However, these events are only available for our recent recorded history, about the last one hundred years. It is unknown if these events have combined in such a manner in previous centuries.... While it is difficult to determine the exact causes, forest researchers and practitioners are trying to understand the nature of the epidemic and develop adaptive forest management practices in response to it." (Pedersen 2004 p.21)

1.3.4 Mortality Resulting from Mountain Pine Beetle Infestations

Safranyik and Carroll (2006) report that mature stand level mortality from MPB at epidemic levels can be nearly complete (100%) but indicate that at the landscape level mortality is normally in the range of 30% to 45% of trees. Shore and Safranyik (1992) suggest stand level mortality is generally correlated with the susceptibility of the potential host trees to infestation.

The relationship between MPB attack rates and stand species composition was examined by Amman and Baker (1972) in the Teton National Forest in Wyoming. Stands with up to 36% of species other than pine were found to be attacked at the same rate as stands with as little as 10% mixed species. Shore and Safranyik (1992) recognized Amman and Bakers (1972) findings but believe that as the frequency of non-host species increases in a stand, the probability of MPB finding (and attacking) pine trees should decrease. Klutsch *et al.* (2009) studied stand characteristics over seven years (2000 to 2007) for an MPB outbreak in north central Colorado. They found that probability of attack in a stand increased in proportion to lodgepole pine BA (m^2/ha). They also found that attack was more likely in stands with lower BA of non-host species. Klutsch *et al.* (2009) acknowledge that the outbreak had not completely collapsed at the time of their sampling and results may change.

1.3.4.1 Relationship between Tree Diameter at Breast Height and Mortality

The probability of individual tree mortality from MPB, based on its dbh (1.37 m height from germination point), has been reported by several researchers for past epidemics. Safranyik and Carroll (2006) suggested that during epidemics mortality is proportional to dbh and that the minimum dbh attacked is generally about 10 cm (Figure 1.6A.). Björklund *et al.* (2009) used data from a previous study by Shore (2000) and found that the relationship was characterized by a sigmoid curve (Figure 1.6B). The latter study suggests that expected tree mortality is approximately 10% for a tree that is 10 cm dbh, 40% for a tree that is 20 cm dbh, approximately 70% for a tree that is 30 cm in dbh and reaches a maximum mortality of approximately 80% for trees greater than 35 cm dbh . Forty years earlier Cole and Amman (1969) studied mortality in two stands in north western Wyoming and found a direct relationship between dbh and mortality (Figure 1.6C.). They found one percent mortality for 10 cm dbh trees, 20% for 20 cm trees, 55% for 30 cm trees and 87% mortality in trees that were 41 cm in dbh (Figure 1.6A.). Björklund *et al.* (2009) report mortality rates similar to the upper bounds described by Safranyik and Carroll (2006) but differ in suggesting the probability of mortality peaks at approximately 80% for trees that have achieved 40 cm dbh whereas Safranyik and Carroll report 100% mortality can be expected for large trees. Cole and Amman (1969) projections of mortality (Figure 1.6C.) fit within the lower bounds of Safranyik and Carroll (2006) mortality range (Figure 1.6A).

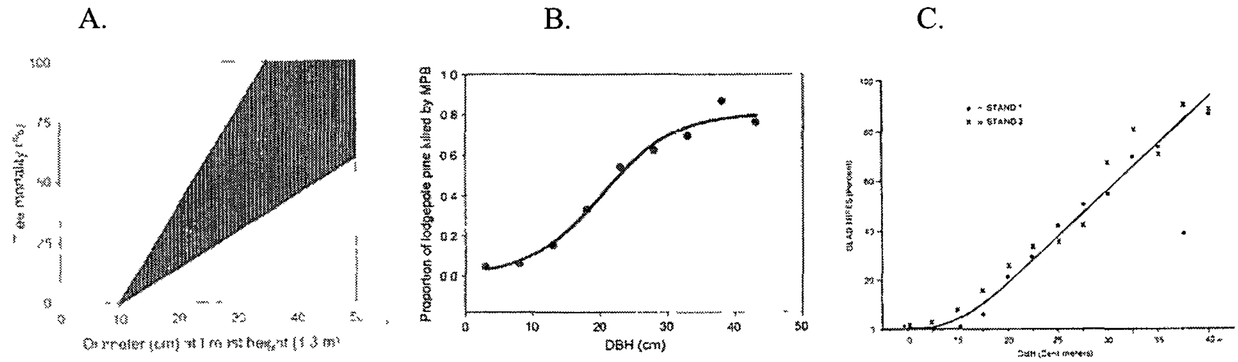

Figure 1.6: Expected rate of lodgepole pine tree mortality based on dbh during past MPB epidemics. (A. Adapted from Figure 22 in Safrinyik and Carroll (2006), B. Adapted from Figure 1 in Björklund *et al.* (2009) and C. Adapted from Figure 1 in Cole and Amman (1969))

Shore and Safrinyik (1992) also examined the relationship between dbh and tree basal area (BA) mortality using unpublished data from 38 stands in the Cariboo Forest Region. Basal area mortality increased from approximately 40% for trees in the 35 to 40 cm dbh diameter class to approximately 60% for trees in the 40 to 45 cm dbh diameter class (Figure 1.7). Klutsch *et al.* (2009) found that probability of infestation was directly correlated with lodgepole pine BA and that stands with as little as 2 m^2/ha of pine had a 0.64 probability of infestation. They found, for infested stands, 62% of lodgepole pine over 12.7 cm dbh was killed and that this reduced the lodgepole pine BA by 71%. When considering all trees over 2.5 cm dbh, MPB induced mortality represents a 42% reduction in density (from 1028 to 593 sph), a 69% reduction in BA (from 27.8 to 8.5 m^2/ha) and a 34% reduction in quadratic mean diameter (from 21.2 to 13.9 cm) (Klutsch *et al.* 2009).

1.3.4.2 Provincial Level Estimates of Current MPB caused Mortality

Two survey systems have been used to estimate the mortality of mature lodgepole pine for the Province of British Columbia.

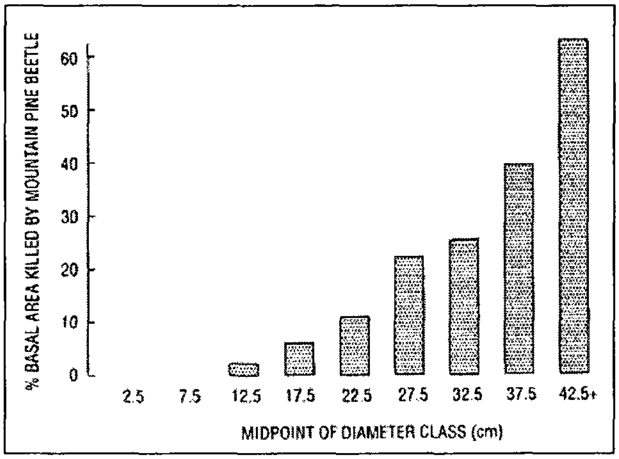

Figure 1.7: Mountain pine beetle caused lodgepole pine basal area mortality by diameter class for stands attacked during the Cariboo/Chilcotin epidemic of the mid 1980s. Adapted from Figure 3 in Shore and Safranyik (1992).

The Canadian Forest Service tracked MPB infestations through aerial surveys of red needled pine forests from 1979 to 1995: Forest Insect and Disease (FID) surveys. In 1999 this tracking responsibility was transferred to the province of BC (Westfall 2001 to 2006) and published in Pest Management Reports entitled *Summary of forest health conditions in British Columbia* (Westfall and Ebata 2008). For larger polygons with similar mortality, intensity is delineated based on the following categories (British Columbia Ministry of Forests 2000): "trace": < 1% of the trees in the polygon were recently killed, "light": 1 to 10% recently killed, (red attack), "moderate": 11 to 29% recently killed, "severe": 30 to 49% recently killed and "very severe": 50% + recently killed (Westfall and Ebata 2008). For mapping purposes, very small infestations of less than 50 individual killed trees are delineated as an area of less that 0.5 hectares and clasified as "severe" (Westfall and Ebata 2008). Figure 1.8 shows the area affected by MPB in BC since 1979. The outbreak on the Cariboo/Chilcotin plateau in the mid-1980s is evident but is dwarfed by the current outbreak.

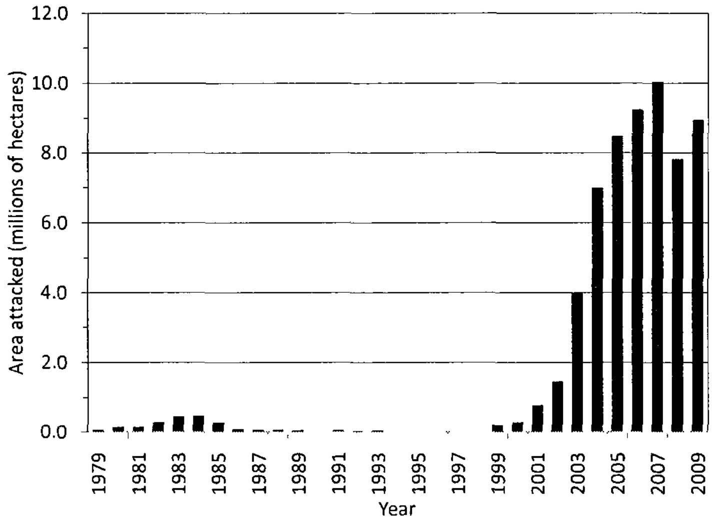

Figure 1.8: Area affected by mountain pine beetle in British Columbia.[8]

Difficulties were encountered with the 2008 aerial surveys used in the *Summary of Forest Health Conditions in BC.* Walton (2009) reports that problems with weather condition and the availability of contractors resulted in the aerial surveys being completed much later than was optimal. The units affected are the Lakes, Mackenzie and Dawson Creek TSAs and the Vanderhoof, Fort St. James and Prince George forest districts which all showed a drop in overall infestation levels in 2008 according to the aerial overview surveys (Walton 2009). According to the survey, area affected by MPB peaked in 2007 and is on the decline. The volume of pine killed has been derived from this survey (Table 1.1 and 1.2, Appendix I) despite warnings from Westfall and Ebata (2008 p.5) that state:

> *"The use of aerial overview survey data is limited for certain applications. Hectares of damage from past years by the same forest health agent cannot be added cumulatively, as new mortality or defoliation can appear in all or a portion of the same stands that were damaged previously. Also, fairly broad intensity classes and now errors*

[8] Data sources: 1979 to 1995: Forest Inventory and Disease (FIDS) surveys (Natural Resources Canada, Canadian Forest Service), 1999 to 2009: Summary of Forest Health Conditions in British Columbia - 2001 to 2008 (Westfall, Westfall and Ebata), No data is available for years 1990, 1996, 1997 and 1998. 2009 data accessed March 2010 at http://www.for.gov.bc.ca/hfp/health/overview/2009table.htm

of omission (i.e. missed trees) must be considered. For example, calculating accurate mortality volume estimations are not possible since the actual number of trees killed (and consequently, volume) is not precise."

In order for Eng *et al.*(2004) and currently Walton (2010), to develope estimates and projections of future MPB related mortality using the BCMPB model, the volume of successive years of actual measured mortality was determined (Table 1.1). This was achieved by using the mortality data gathered in the aerial surveys done for the annual *Summary of Forest Health Conditions in BC.* This is discussed in section 1.3.4.3. Appendix I contains detailed reports of cumulative mortality for individual forest management units made by the BCMPB v5 model which is derived from the provincial aerial overview surveys.

Table 1.1: Cumulative attacked mature pine volume for the Province of British Columbia as reported by the *BCMPB model.*

year	Attacked mature pine volume reported by the ***BCMPB v6*** model (millions of cubic metres)
2001	**23**
2002	**50**
2003	**101**
2004	**173**
2005	**303**
2006	**412**
2007	**506**
2008	**539**
2009	**630**

The second provincial level estimate of mortality was made by the joint Mountain Pine Beetle Task Force (Council of Forest Industries (COFI) and Ministry of Forests and Range) from 2000 through to 2007. It is based on a province wide annual survey conducted by Industrial Forestry Service Ltd. that gathered estimated mortality from local knowledge of industrial and government forestry workers.[9] This estimate includes mortality related to green attack (based on on-the-ground beetle probing), red attack (generally one year after attack) and gray attack (post needle drop). See Appendix II for details of cumulative volume attack reported by the Mountain Pine Beetle Task Force for forest management units and Appendix III for maps of the progression of attack.

Table 1.2: Mature pine volume[10] (cubic metres in stands older than 60 years) attacked in the three forest districts of the Prince George Timber Supply Area as reported by the BCMPB v5 model.

Forest District[1]	2007 actual annual attack	actual cumulative attack to and including 2007	2008 projected annual attack	projected cumulative attack to and including 2008	projected cumulative attack to 2024	Susceptible mature pine	2024 projected mortality as a % of susceptible pine
DVA	3,899,664	70,714,288	1,997,744	72,712,032	75,010,352	97,572,032	76 9
DPG	7,715,568	45,981,280	3,260,272	49,241,552	54,775,024	77,959,552	70 3
DJA	14,684,752	45,001,488	10,770,672	55,772,160	91,103,760	109,423,680	83 3

The Mountain Pine Beetle Task Force reported that by 2008, cumulative attack was 710 million m^3 (Appendix II), approximately nine times the provincial AAC.[11] After 2008 the Mountain Pine Beetle Task Force ceased reporting on MPB mortality BCMPB v7 released in May of 2010 indicated that 630 million m^3 of pine had been killed by MPB by 2009.[12] This compares to a total estimated susceptible pine of 135 million m^3. Accurate estimates at a provincial level are difficult and may never be known with confidence. Based

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[9] Bailey, C Personal commmunication July 2009 Chris Bailey is a forestry consultant with Industrial Forestry Service Ltd cbailey@indforserv bc ca

[10] Volumes reported are compiled to a sawlog utilization standard of 12 5 cm at dbh

[11] Provincial AAC for Timber Supply Areas and Tree Farm Licences as of July 1st 2010 is 84,927,628 m^3 as reported by the MFR on-line at http //www for gov bc ca/hts/aac htm

[12] Provincial-Level Projection of the current Mountain Pine Beetle Outbreak Year 7 (Current Results) 2010 Accessed on June 25 2010 at http //www for gov bc ca/HRE/BCMPB/Year7 htm

on the two sources documented above, pine mortality is likely between 47% and 54 % of susceptible pine. For purposes of the case study following, BCMPB v5 is used as a basis for mortality but was modified for DPG to reflect localized findings.

Hawkes *et al.* (2003) state that salvage of the large amount of timber killed by MPB is not possible because of limited extraction and processing capacity of the forest industry. Pedersen (2003) stated in his presentation to the MPB Symposium in Kelowna that there would be at least 200,000,000 m^3 not salvaged. Burton (2008) reported that as much as one third of the mature MPB killed timber may never be salvaged. Clearly there will be a significant amount of standing dead timber.

1.3.4.3 Provincial Level Estimates of Future MPB Caused Mortality

Mortality results derived from data gathered by the MFR for the *Summary of Forest Health Conditions in BC* were used as one of the inputs into the BCMPB model to project mortality into the future (Eng *et al.* 2004). The BCMPB v5 model is used to project future MPB mortality in provincial timber supply reviews (TSR) (Fall *et al.* 2007). The BCMPB model reports mortality for mature pine in all stands including leading spruce, subalpine fir, Douglas-fir and broadleaf stands. The BCMPB model has been revised annually since 2004 and with each new revision current estimates of mortality from the provincial aerial overview surveys are incorporated. Over the last 5 years (BCMPB v2 to v6) predictions of future MPB mortality have decreased for the three forest districts in the Prince George TSA (Figure 1.9). The BCMPB model is highly dependent on the mortality observed in the annual *Summary of Forest Health Conditions in BC* and if there are errors in cumulative attack, these will be passed on.

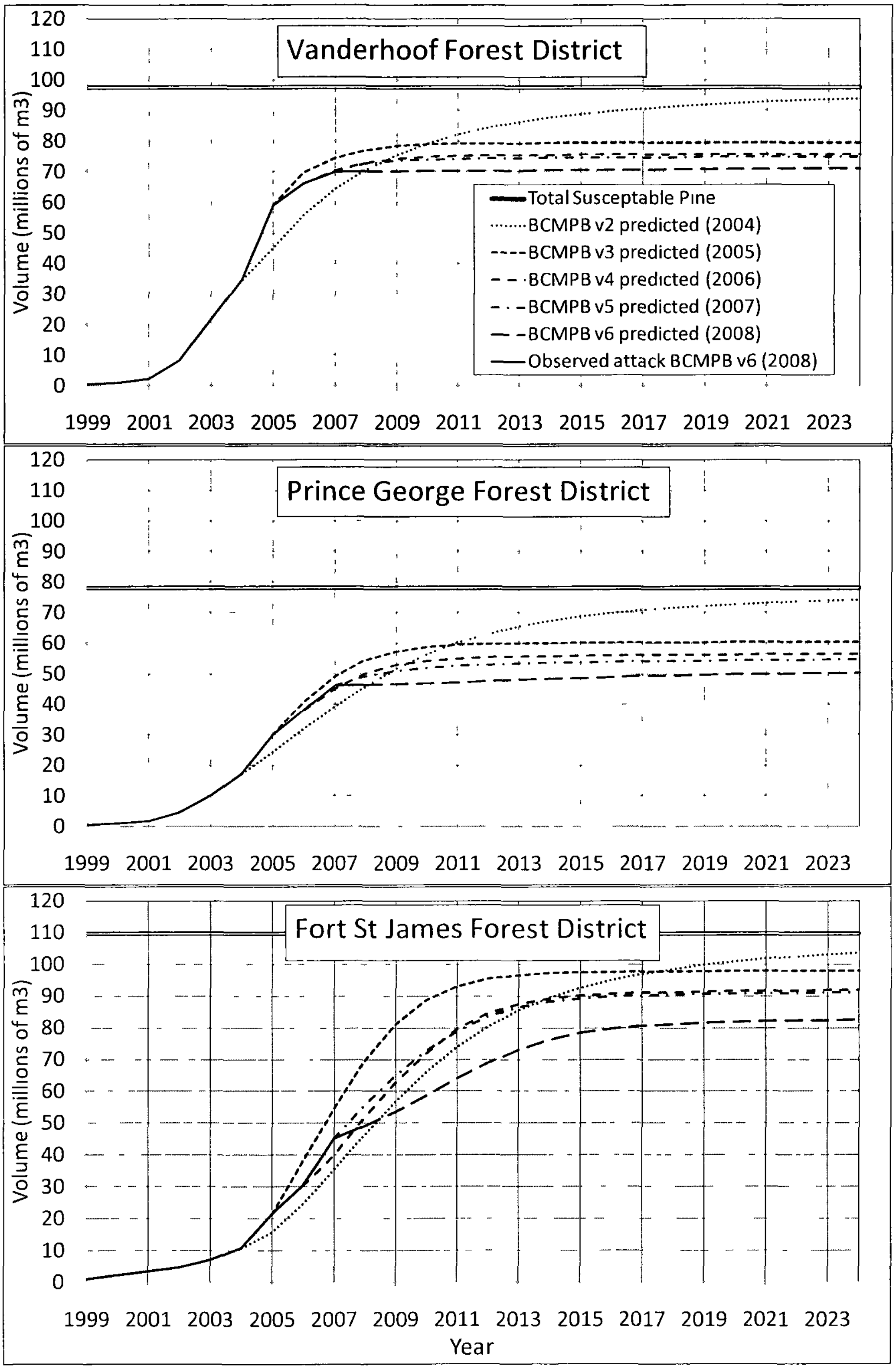

Figure 1.9: Observed and BCMPB (v2, v3, v4, v5 and v6) predicted MPB caused mature (age 60+) pine mortality for the three districts in the Prince George TSA.

For the study area, BCMPB v5 predicts that by 2024, 77% of the pine in the Vanderhoof forest district, 70% in the Prince George and 83 % in the Fort St James forest district will be killed by MPB (Table 1 2) BCMPB v5 reports that both the Vanderhoof forest district at 73% mortality and the Prince George forest district at 59% mortality had experienced the majority of their MPB attack by 2007 whereas the Fort St James forest district had only experienced 41% mortality (Table 1 2) Predictions of mortality have steadily declined since the BCMPB modeling initiative began due to incorporation of actual aerial survey mortality estimates in successive years (Figure 1 9)

1.3.4.4 Mortality Observed from an Aerial Reconnaissance Based Inventory of Prince George Forest District

Staff in the Prince George forest district hypothesized that the provincial aerial overview survey which supports the annual *Summary of Forest Health Conditions in BC* and is reported in the BCMPB reports has underestimated mortality [13] In the summer of 2008, the DPG stewardship staff surveyed mortality in mature pine leading stands in the western and northern portions of the district (Appendix IV)

A general flight plan was established and 38 forest vegetation resource inventory (VRI) polygons were randomly selected along the flight line for helicopter based air calls of pine mortality Methodology consisted of first entering northings and eastings of all of the plots into the helicopter mounted GPS receiver and flying along the flight line to the prescribed polygon Once the polygon was located and confirmed, the helicopter circled the entire stand and 3 classifiers estimated the percentage of stems (over 12 5 cm dbh) they

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[13] Burrows, J Personal communication March 2008 Jeff Burrows is the Stewardship Officer in the Prince George forest district jeff burrows@gov bc ca

believed to be dead based on red and gray attack. Photographs were taken of all stands. Mortality was estimated to the nearest 5% based on the consensus of the classifiers[14]. Appendix IV is a map of the plot locations and a list of the forest inventory polygon map labels. The majority of the samples fall in the SBS mk1 and SBS dw3 subzones (Meidinger *et al.* 1991). While this survey cannot be considered completely unbiased because of the sample location methodology it is still a good indication of the extent of the attack.

Average mortality increased with age: 76% for 61 to 80 year old stands, to 93% for stands in the 141 to 250 year range (Table 1.3). This was much greater than estimates from the BCMPB model (Walton 2009).

Table 1.3: Estimated mature merchantable pine mortality by age class for the 2008 Prince George forest district helicopter MPB survey.

age class[14] (years)	Number of sample stands	Estimated Mortality range[15] (%)	Sample mean percentage of merchantable pine trees killed by MPB	Standard deviation of sample mean
61 to 80	6	40 to 95	76	22
81 to 100	8	40 to 95	77	19
101 to 120	2	80 to 95	88	11
121 to 140	6	75 to 95	88	9
141 to 250	15	75 to 100	93	7

1.3.4.5 Mortality Observed in Forest Licensee Cutting Permits Submitted to the Prince George Forest District

Unpublished data obtained from the DPG MFR also indicates the level of lodgepole pine mortality experienced in recent forest licensee cutting permits is greater than that

[14] Age class is obtained from Vegetation Resource Inventory map labels.
[15] See Appendix IV for data.

projected by BCMPB (Figure 1.10 and Table 1.4).[16] For purposes of stumpage appraisal, all cutting permits must be accompanied by an acceptable timber cruise and compilation summary. The appraisal report indicates the volume expected to be harvested by species, volume per hectare, tree mortality, stand and stock tables, and other attributes. This database contains records for approximately 18.5 million m^3 of harvest volume from January 1, 2006 to November 30, 2009. Of this total volume, 18.3 million m^3 was in cutting permits that have some pine component. Twelve point seven million m^3 was pine of which 10.6 million m^3 was MPB killed pine (Table 1.4). Since January of 2008 pine mortality has exceeded 65% of the pine volume (Figure 1.10).

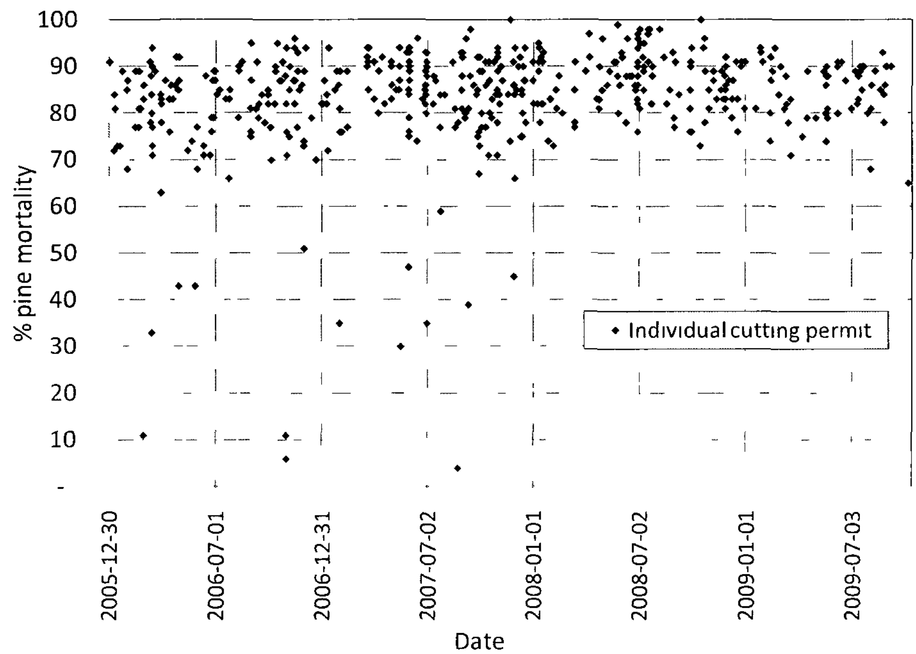

Figure 1.10: Percent pine mortality by merchantable volume and effective appraisal date for cutting permits received in the Prince George forest district between January 1, 2006 and November 30, 2009.[17]

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[16] Data obtained from DPG Forest Tenures January 2010. Used with permission. Contact Rose O'Connor Appraisal Co-ordinator, Ministry of Forests and Range, Prince George forest district, 2000 S Ospika Blvd, Prince George BC. rose.o'connor@gov.bc.ca

[17] Permits with no merchantable pine volume have been excluded. See also Table 1.4

There are several reasons Licensees may be targeting pine stands with high mortality

1 The stumpage appraisal system encourages salvage through reduced rates of $0 25 per m^3 for significantly degraded lodgepole pine timber (Grade 4) [18]

2 Stewardship direction from the Chief Forester and Northern Interior Regional Executive Director has encouraged the focus of harvest in MPB killed pine stands (Pedersen 2003b)

3 Interest in maintaining as high a mid-term harvest level as possible

On average, over the past two years, 86% (2008) and 85% (2009), of all pine volume in cutting permit submissions was killed by mountain pine beetle (Table 1 4, Figure 1 10) The standard deviation of the average is considerably reduced from the 2006 and 2007 data indicating the cutting permits were more uniform

Table 1.4 Volume statistics (timber cruise compilation) including percent pine mortality averaged by calendar year for cutting permits (with a pine component) received in the Prince George forest district between January 1, 2006 and November 30, 2009

Calendar year	Number of cutting permits	Total net merchantable volume of all species (m^3)	Total net merchantable volume of pine (m^3)	Total net merchantable volume of MPB killed pine (m^3)	Average % MPB killed pine volume	Std dev % MPB killed pine volume
2006	127	5,218,220	3,661,660	2,911,910	79 5	14 8
2007	165	6,544,656	4,329,049	3,578,780	82 7	12 7
2008	131	3,751,870	2,683,226	2,318,380	86 4	6 3
2009 (to Nov 30)	69	5,247,317	2,073,899	1,758,112	84 8	6 4
All years	492	18,335,395	12,747,834	10,567,182	82 9	11 5

[18] The BC Inteiior Appraisal Manual can be accessed at http //www for gov bc ca/hva/manuals/interior htm

1.3.5 Abundance of Live Secondary Stand Structure Following MPB

Leading pine forests that have been attacked by MPB have varying amounts of remaining live trees, saplings and seedlings (Figure 1.11 and 1.12) that have been referred to as "secondary stand structure" (SSS) or "secondary structure" (Coates *et al.* 2006). Research into the abundance of SSS in mature pine leading stands after MPB infestation has recently been completed for the SBS BEC subzones in the Nadina (Lakes TSA), Vanderhoof and Prince George forest districts including the SBS dk, SBS dw2, SBS dw3, SBS mc2 and SBS mc3.

Coates *et al.* (2006) used data collected from seven sources to explore the question of whether there is there sufficient SSS that can reach harvestable volumes by the time timber supply forecasts predict a mid-term fall-down. They reported that 40 to 50% of all pine leading stands in the study area had understory densities greater than 1000 sph which they deemed sufficient to be considered adequately stocked. Approximately 20 to 25% of stands had inadequate SSS. Coates *et al.* (2006) noted that their study does not make allowances for moribund or secondary stand structure with poor form or live crown ratios. It also does not make estimates of well-spaced acceptable species. Coates *et al.* (2006) reported that 20 to 35% of stands in the study area had 5 to 10 m^2/ha of BA and they have the potential to contribute to mid-term timber supply if not logged.

Coates *et al.* (2006) found that there was significant variability between BEC subzones: the SBS dk having the least and the SBS mc2 the most SSS. The species composition of the understory (seedlings and saplings) component of SSS was variable with spruce (hybrid and black) dominating in the SBS dk and dw3. Spruce also dominated saplings in the SBS dw2 and mc3. Sub-alpine fir (*Abies*) dominated seedlings and saplings in the SBS mc2 and saplings in the SBS mc3. Douglas-fir dominated for seedlings in the SBS dw3. Although not dominant in any of the BEC subzones, pine made up over 25% of the species composition of saplings in the SBS dw3 and seedlings and saplings in the SBS dk and SBS dw2. For the canopy and sub-canopy SSS, where BA was used to define the contribution by species, interior spruce dominated in all but the SBS mc2 where sub-alpine fir made up just over half of the BA. Other species present in the canopy and sub-canopy in minor amounts were Douglas-fir and aspen (Coates *et al.* 2006).

A similar study of pine stands over 60 years old in the 100 Mile, Quesnel and Williams Lake TSAs (Cariboo/Chilcotin region of BC) found that seedling and sapling median densities ranged from a high of 4700 sph in the Engelman Spruce-Subalpine Fir (ESSF) BEC zone to a low of 1019 sph in the SBS BEC zone (Coates *et al.* 2009). The Interior Douglas Fir (IDF), Sub-Boreal Pine Spruce (SBPS) and the Montane Spruce (MS), showed median densities of 2917, 1651 and 1400 sph respectively. Coates *et al.* (2009) found that 70% of all plots surveyed (n=1109) had over 1000 sph of seedlings and saplings.

The Coates *et al.* (2009) study used data from plots surveyed before, during and after MPB attack. To account for inevitable MPB caused mortality, all pine stems over 7.5 cm dbh were assumed to die and were not considered as contributing to live BA post-MPB attack. Coates *et al.* (2009) recognized that some of these trees would survive but this assumption meant their estimates of live post-MPB BA were conservative. Thirty four percent of all plots had over 5 m^2/ha of BA when all conifer stems over 1.37 m tall were included. For the SBS, 47% of plots had a BA over 6 m^2/ha which is suggested to be equivalent to the same BA present in a 20-year old pine plantation (Coates *et al.* 2009). This study also confirmed findings from Coates's (2006) earlier work in the central interior that levels of secondary stand structure are highly variable.

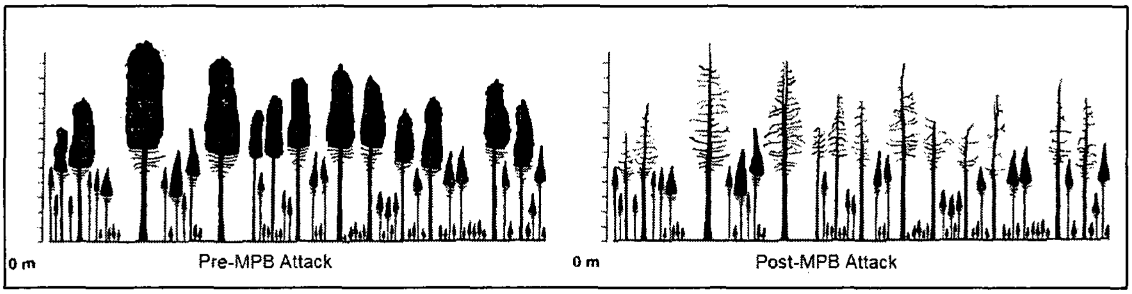

Figure 1.11: Schematic cross sectional diagram of a mature lodgepole pine forest pre and post mountain pine beetle attack showing typical remaining live secondary stand structure in the SBS BEC zone (adapted from Moss, 2005).

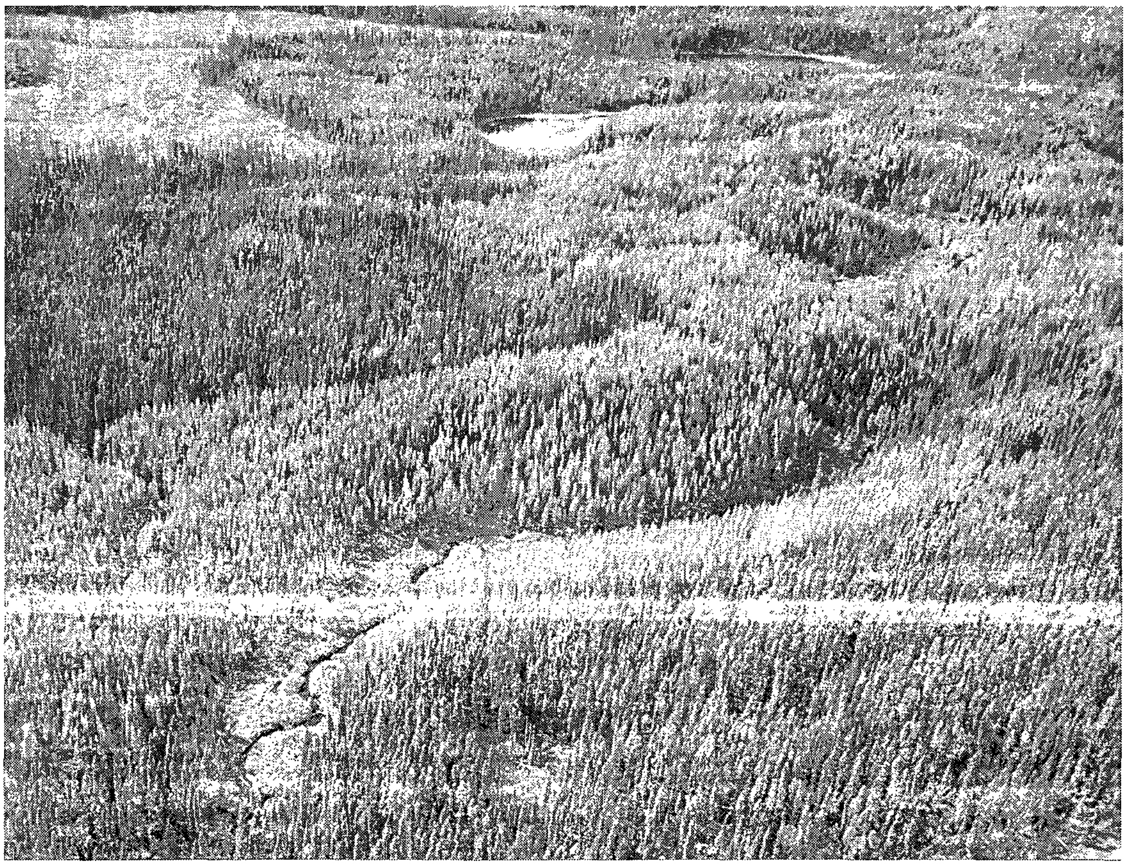

Figure 1.12: Oblique aerial photo of mature pine forests in the Summit Lake area north of Prince George showing MPB mortality and live secondary stand structure[19].

[19] Photo: Ken Hodges, BC Ministry of Forests and Range, August 2007.

1.3.6 Growth and Yield of Secondary Stand Structure and Stand Succession

Modeling the growth and yield of stands following MPB infestation is difficult (Kimmons *et al.* 2005; Griesbauer and Green 2006: LeMay *et al.* 2007; Sattler 2009). Post-MPB attacked stands are often complex in terms of tree species composition, size (diameter and height), age, vigour, spacing, layers, abundance and health (Griesbauer and Green 2006, LeMay *et al.* 2007, Sattler 2009). LeMay *et al.* (2006, 2007) examined ways to estimate regeneration in forests following MPB attack and found SORTIE-ND to be a model with potential because of its use of attributes such as predicted light levels, recruitment, growth and mortality. Sattler (2009) combined regeneration outputs from SORTIE-ND with Prognosis^{BC} to predict natural regeneration in unsalvaged MPB attacked stands in the central and southern BC interior. His study found that the combined models made reasonable predictions of BA over a 25-year horizon for advanced regeneration sized trees but poor predictions for densities of regenerating trees (saplings) (Sattler 2009). This is consistent with Griesbauer and Green (2006) who suggest competitive exclusion does not favour recruitment of new seedlings following stand releasing events. Rakochy (2005) found no seedling recruitment in sampled stands. Instead, Griesbauer and Green (2006) state that forest regeneration following disturbance by MPB is dependent upon the reorganization of existing SSS.

Several studies have demonstrated that live SSS remaining after a MPB infestation respond (release) to increased available light, moisture and nutrients with increased growth. One of the best studies to demonstrate this is by Heath and Alfaro (1990). They examined a mixed lodgepole pine - Douglas-fir stand that had experienced 76% pine mortality as part of the 1971 Cariboo-Chilcotin MPB epidemic. They reported that in the period following infestation, remaining live lodgepole pine trees generally doubled their diameter growth while remaining Douglas-fir trees also experienced increased growth inversely proportional to initial diameter. For Douglas-fir, increases in annual diameter growth rates began in years one to four post attack and peaked between years five and seven. For lodgepole pine, increases in diameter growth were observed between years two and six post MPB attack and peaked in years five to nine. Increased diameter growth persisted in both species until the year of the study in 1985 which was 14 years after initial attack (Heath and Alfaro 1990). Similarly Amman (1977) observed an unquantified diameter growth response for subalpine fir in mixed stands following MPB related lodgepole pine mortality in a site in north western Wyoming. Coates *et al.* (2006) also observed that understory trees (seedlings, saplings and poles) released two to three years after overstory mature pine trees were killed by MPB.

Forest succession occurs in stands following MPB attack if wildfire is absent and shade tolerant species exist (Amman 1977). In a study of three sites in the forests of the foothills of the US Rocky Mountains, Amman (1977) found that, at higher elevations, lodgepole pine stands repeatedly depleted by MPB attack eventually succeed to Englemann spruce and subalpine fir forests. At lower elevations succession was to Douglas-fir.

Shrimpton (1994) examined forest succession 50 years after the MPB outbreak of the 1930s in Kootenay National Park. This epidemic killed approximately 80% of the merchantable pine trees (85% of the volume) in three even aged leading pine stands (130, 110 and 60 years old) on 10,400 hectares. Annual reports generated by the Vernon Forest Insect Laboratory indicate that pre-MPB attacked stands had minor amounts of mature spruce in the dominant and co-dominate layers and components of spruce understory which increased up the sides of the valleys (Shrimpton 1994). Pre-MPB average volume for the two mature stands was 350 m^3/ha, average BA of 28 m^2/ha and average dbh of 25 cm. Immediately post-MPB outbreak, the average volume per hectare of live trees was 50 m^3/ha, average BA of 6 m^2/ha and average dbh of 21 cm (Shrimpton 1994). Fifty years later, average volume had recovered to 200 m^3/ha, average BA was 25 m^2/ha and average dbh was 31 cm.

At that time, Shrimpton (1994) observed that the "mature" stand layer was predominantly spruce (80%): 50% originating from dominant and co-dominants present at the time of the epidemic and the rest originating from the residual understory. The remaining portion of the mature layer (20%) consisted of residual pine that had survived MPB attack and small proportions of Douglas fir, subalpine fir, aspen and paper birch. Shrimpton (1994) also noted that the overstory stocking was variable and regeneration "sparce" and "uneven" 50 years after attack. Regeneration under these stands was 88% spruce with minor components of subalpine fir and Douglas fir. Shrimpton (1994) further noted that his findings were consistent with the 1942 Forest Insect and Disease Report that predicted the results of the attack would be a "spruce type" stand.

1.3.7 Timber Supply Modeling and Mountain Pine Beetle

1.3.7.1 British Columbia Response to Mountain Pine Beetle through Allowable Annual Cut Increases

Provincial AAC has been increased for TSAs, Tree Farm Licences (TFL), Community Forests and Woodlots in order to salvage dead timber resulting from the MPB (Table 1.5).

Table 1.5: British Columbia allowable annual cut as of July 2009 with details for forest management units with uplifts for salvage of mountain pine beetle killed timber.

Forest management unit	Allowable annual cut uplift to address MPB (m^3 per year)	Total allowable annual cut inclusive of MPB uplift[20] (m^3 per year)
Forest management units with MPB AAC Uplifts		
Timber Supply Areas (TSA)		
Kamloops	1,000,000	4,353,000
Lakes	1,662,000	3,162,000
Merritt	1,000,000	2,814,000
Okanagan	700,000	3,375,000
100 Mile House	666,000	2,000,000
Prince George	5,580,000	14,944,000
Quesnel	2,940,000	5,280,000
Williams Lake	2,852,000	5,770,000
Total TSA	16,400,000	41,698,000
Tree Farm Licences (TFL)		
14 (Tembec Industries)	20,000	180,000
18 (Canadian Forest Products)	112,000	290,000
35 (Weyerhauser Canada)	200,000	326,000
42 (Tanzul Timber)	40,000	160,000
48 (Canadian Forest Products)	56,000	900,000
49 (Tolko Industries)	200,000	580,000
52 (West Fraser)	307,000	1,000,000
53 (Dunkley Lumber)[21]	640,000	880,000
Total TFL	1,575,000	4,316,000
Sub-total TSAs and TFLs with MPB AAC Uplifts	**17,975,000**	**46,014,000**
Forest management units that do not have MPB AAC Uplifts		
Timber Supply Areas (TSA)	0	26,531,000
Tree Farm Licences (TFL)[22]	0	12,618,000
Sub-total forest management units with no MPB uplifts	0	39,149,000
Total Provincial TSA and TFL	17,975,000	85,163,000

[20] Only the forest management units with AAC uplifts for salvage of MPB damaged stands are detailed by individual forest management unit in this table (British Columbia Ministry of Forests and Range 2009)

[21] TFL 53 has recently completed salvage of MPB damaged timber and the AAC was reduced to 219,000 m^3/year as of October 31, 2008 The figures shown here represents the AAC during the last 3 years that the AAC was uplifted

[22]There are 2 coastal TFLs where the allowable annual cut is set as an area allowed to be harvested annually These units (TFLs 54 and 57) have a combined AAC of 701 hectares per year and do not have MPB associated uplifts

Currently the provincial AAC is approximately 88,300,000 m^3/year made up of 68,400,000 m^3/year from TSAs and 16,900,000 m^3/year from TFLs with an additional combined AAC of approximately 3,000,000 m^3/year from Woodlots and Community Forests (British Columbia Ministry of Forests and Range 2009a). Prior to the MPB epidemic, the combined provincial TSA and TFL allowable annual cut was set at 70,500,000 m^3/year. MPB related AAC uplifts represent a 21% increase (Table 1.5) over pre-MPB levels. MPB associated uplifts represent 39% of the current AAC for those units with AAC uplifts.

The largest proportional uplift was TFL 53 with a 267% increase followed by the Quesnel TSA with 126%. In absolute terms, the PG TSA leads with an increase in AAC of 5.58 million m^3 per year. In the Chief Foresters AAC rationale document for the PG TSA, it was suggested that approximately four million of the increased cut be directed to DVA (British Columbia Ministry of Forests 2004). Prior to the uplift, the sustainable annual level of harvest in Vanderhoof was estimated to be 2 million m^3. The uplift represents an increase of 200%

1.3.7.2 Provincial Level timber supply forecasts: potential impact of Mountain Pine Beetle

Both Government and the forest industry have predicted the impact that MPB may have on long-term provincial timber supplies in BC. After the AAC uplifts discussed previously are reduced, there will be a period of time termed "mid-term timber supply fall-down" where the pre-MPB AAC will need to be reduced to maintain long term sustainability. For the Prince George TSA, the mid-term fall-down in timber supply is predicted to begin about 2021 and last until such time as the second growth stands associated with the current salvage activity reach maturity in 2040 to 2050 (British Columbia Ministry of Forests and

Range 2010). Other forest management units may experience timber supply fall-down as soon as 2015 or as late as 2025 (Figure 1.13) depending on when the MPB infestation reached epidemic levels.

In 2003, the BC Ministry of Forests performed timber supply analysis to examine the potential impact of MPB on 12 of the most severely infested forest management units (Pedersen 2003). Key assumptions for the analysis were; 15-year shelf life for MPB killed pine, one half of all mature pine older than 80 years were killed by 2002 and harvesting consisted of 60% pine and 40% other species (Pedersen 2003b). The analysis reported that timber supplies would decline by 2017 to a level that was 19% lower than pre-MPB AAC and that 200,000,000 m^3 of pine volume would not be salvaged (Pedersen 2003b).

In 2006, COFI released a timber supply analysis report that examined 19 timber supply areas where it was believed that MPB infestation would impact future timber supplies. This analysis concluded that harvesting must continue to focus on infested pine for as long as possible in order to decrease the mid-term timber supply fall-down. (Council of Forest Industries 2006). All scenarios presented in this analysis assumed that if mature MPB affected leading pine stands were not salvaged, they would experience a 15-year delay before regenerating to natural stand yield (VDYP) where volumes were reduced by 20% (Council of Forest Industries 2006). No consideration for SSS was made.

In 2007, a roll-up of the current timber supply forecasts for TSA and TFL forest management units was done by Forest Analysis and Inventory Branch (FAIB) of the MFR (solid line labelled "Total Province" Figure 1.13) (British Columbia Ministry of Forests and Range 2007a). In this roll-up, the projected mid-term timber supply level of 56.7 million m^3/year is 20% lower than the provincial pre-uplift AAC of 70.5 million m^3. Individual forecasts predict that the hardest hit forest management units such as the Quesnel and Vanderhoof forest districts may have mid-term timber supply fall-down greater than 50% while units with less mature pine will have proportionately less fall-down (British Columbia Ministry of Forests and Range 2007a).

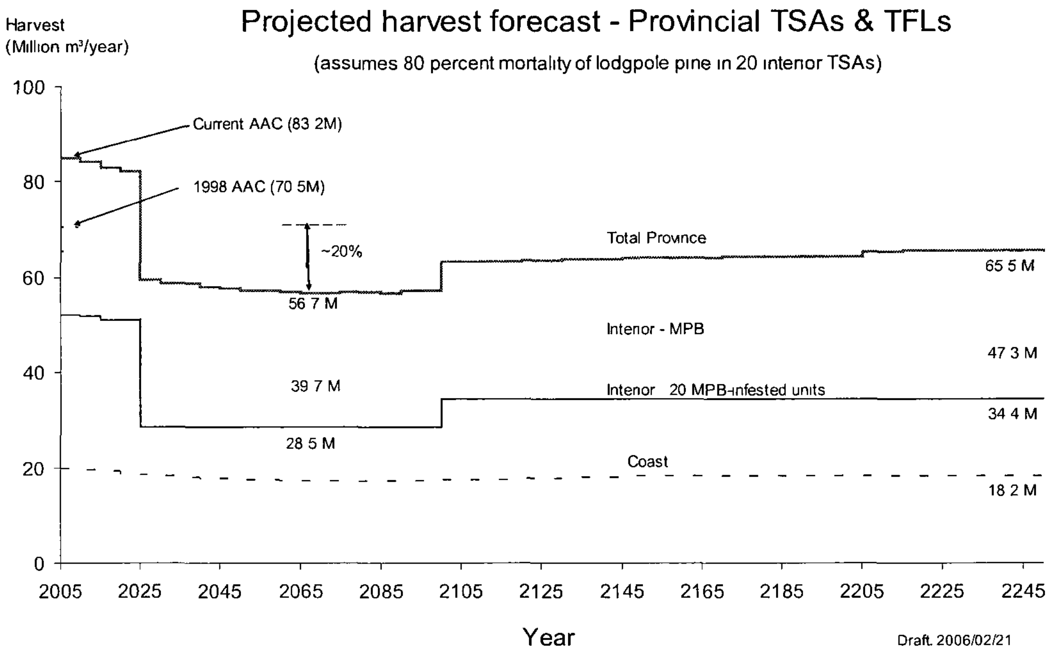

Figure 1.13: British Columbia provincial harvest forecast projections as of 2006 showing the short and long-term impact of the current mountain pine beetle infestation [23]

[23] Notes provided with figure by Forest Analysis and Inventory Staff (BC Ministry of Forests and Range)

- The harvest forecast represented by "Total Province", "Interior –MPB" and "Coast" are a summary of management unit projections for 37 TSAs and 34 TFLs, based on TSR3 and TSR2 analyses The volume contributions of woodlots and community forest agreements were not included
- The harvest forecast labelled "Interior – 20 MPB-infested units" is a very simplified analysis of the 20 interior MPB-impacted TSAs The projections should be interpreted with some caution Further analysis is underway through formal timber supply reviews to validate these initial projections
- Long-term projected harvest levels do not include expected increases to site productivity estimates for regenerating stands on TSAs
- When modeling the timber supply for the "Interior 20 MPB-infested units" simplified assumptions included a shelf life of 15 years for attacked pine

Concurrent to this roll-up, a timber supply re-analysis of the 20 hardest hit interior TSAs was done. This also appears in Figure 1.13 as a solid line labelled "Interior – 20 MPB infested units". Eighty seven percent of the mature pine in BC is contained in these 20 units (Figure 1.14) (British Columbia Ministry of Forests and Range 2007). In 2007 the combined AAC for the 20 interior units were 54.6 million m^3 with timber supply projections suggesting mid-term levels of approximately half that.

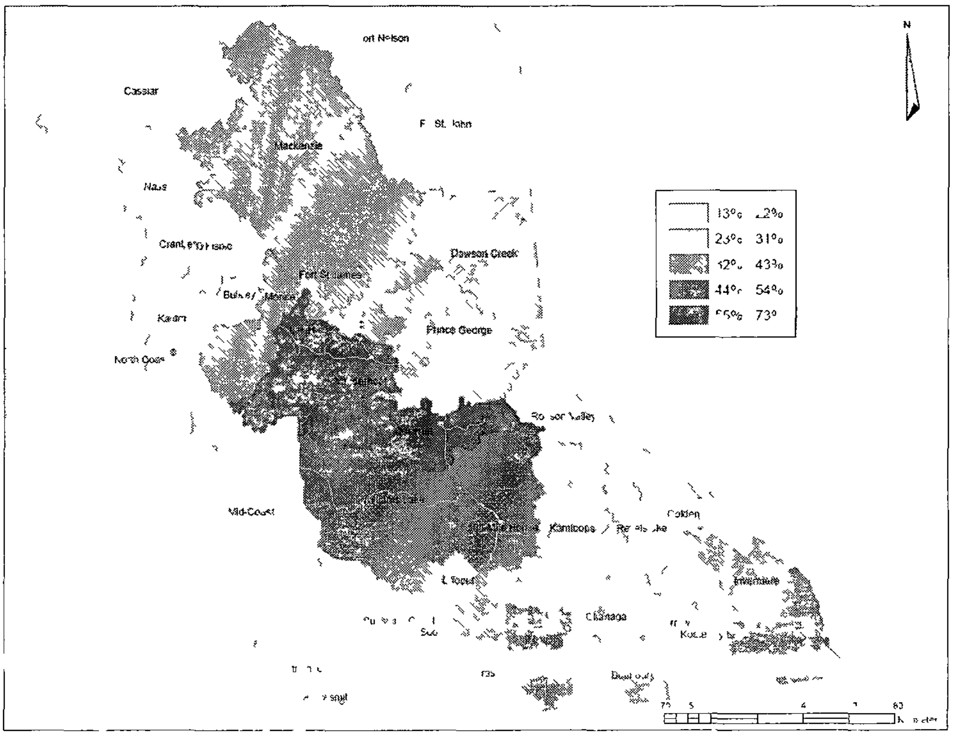

Figure 1.14 Pine volume as a percentage of total mature volume within the timber harvesting land base. Adapted from Figure 2 in *Timber supply and mountain pine beetle infestation in British Columbia 2007 update* (British Columbia Ministry of Forests and Range 2007)

1.3.7.3 Modeling Secondary stand structure in Timber Supply Analysis

Three initiatives have provided insight into how incorporation of the remaining SSS into modeling and analysis procedures might affect future timber supplies. In 2006, the BC

Ministry of Forests and Range contracted Andrew Fall of Gowlland Technologies Ltd. to perform timber supply analysis incorporating Coates *et al.* (2006) findings regarding secondary stand structure.[24] Modeling was done using SELES STSM (Spatial Explicit Landscape Event Simulator: Spatial Timber Supply Model) for the Morice TSA and Vanderhoof forest district. The unpublished report focused on an examination of the mid-term timber supply as defined by the time period between when the currently dead pine stands are no longer viable or feasible for salvage and when the harvest can begin to increase based on harvest of second growth stands (Fall *et al.* 2006). Two levels of SSS were modeled:

- no secondary stand structure (NoSS) where, after a shelf life period, there is a 15-year regeneration delay for MPB killed stands followed by regeneration to a yield curve with 80% of natural volume (VDYP). Fall reported that this assumption was adopted from the 2006 COFI 19 unit MPB analysis;
- Incorporate SSS where, after a shelf life period, stands are placed with specified ages on natural stand yield curves. Placement is based the age at which a stand starting from a clear cut would achieve the observed basal area.

Fall *et al* (2006) reported that incorporation of consideration for SSS could potentially increase the mid-term harvest level by 28% to 40% for the Vanderhoof forest district and 4 to 8% for the Morice TSA. Fall *et al.* (2006) suggest the reason for the large difference in the impact was attributable to the varying dependence of each of the units on pine. Fall *et al.* (2006) suggest that since the Vanderhoof forest district is comprised of 85%

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[24]Unpublished Ministry of Forests and Range report DRAFT Potential timber supply effects of mountain pine beetle and secondary structure in Morice Timber Supply Area and Vanderhoof Forest District, Andrew Fall, Dave Coates, Craig Delong and D Sachs 2006

mature pine stands, assuming an abundance of understory in these stands will enhance potential mid-term timber supply. The Morice TSA has a significant amount of other mature species that can be used to support the mid-term harvest and it is not nearly as dependent on SSS. Fall *et al.*(2006) state that in neither case is the short-term timber supply, during the initial salvage period, detrimentally affected by assumptions made to protect stands with understory.

The Morice and Lakes Innovative Forestry Practices Agreement (IFPA) timber supply analysis also utilized SSS data from Coates *et al.* (2006) (Morice and Lakes IFPA 2007). Coates *et al.* (2006) suggested that 5 m^2 of live basal area per hectare be used as the threshold to determine if sufficient live SSS structure existed in MPB attacked stand and that they could reasonably be expected to contribute to mid-term timber supply.

The Morice IFPA timber supply analysis was done by Tesera Systems Inc. in 2007. A SSS scenario was based on splitting the SSS into two components: an overstory (mature) live layer and an understory (sapling) layer. Fifteen percent (99,620 ha.) of the total THLB in the Morice IFPA area (Morice TSA) was determined to have sufficient understory (Crouse 2007) to warrant protection as potential mid-term timber supply. The IFPA procedure randomly assigned pine leading forest cover polygons as sufficiently stocked with understory (see Table 1.6). These stands were assumed to have understory equivalent to 30-year old stands and were deferred from harvesting for 60 years while they grew on TIPSY generated natural stand yield curves (Crouse 2007). A further 36% (241,252 ha) of the THLB of leading pine stands was determined to have more than 150 m^3/ha of mature live pine, spruce and balsam remaining after the MPB caused pine mortality (Crouse 2007). These stands were also protected from harvest in the timber supply model until after the uplift period

(2017) was over to allow them to be available in the mid-term.

Because of the deferral of mature stands in the 2013 to 2017 time period the timber supply model was only able to achieve 500,000 m^3/year and not the target uplift volume of 3,000,000 m^3 per year whereas scenarios tested without these deferrals achieved the target uplift. However, the secondary stand structure scenario resulted in an increase in the projected mid-term (years 2018 to 2102) harvest from 1.76 to 1.81 million m^3 per year, an increase of 50,000 m^3. The IFPA analysis suggests that the cost of this mid-term increase is a lost opportunity for short-term pine salvage created by the deferral of mature pine stands. The IFPA modeling assumptions result in a volume availability shortfall for the secondary stand structure scenario of 8.3 million m^3 over the 85 years. Unfortunately, the only SSS scenario presented reserved such a significant portion of the dead pine stands for such a long period that the short-term timber supply was drastically reduced and the mid-term was only minimally increased.

Table 1.6: Percent of leading pine stands in the Morice IFPA area that have adequate understory (sapling) stocking to contribute to mid-term timber supply based on Coates *et al.*2006 report to the Chief Forester.

BEC unit	Percentage of area within each BEC Unit that is projected to have an adequate understory component
SBS dk	15
SBS mc2	60
SBS mc3	25
SBS dw2	60
SBS dw3	45

Subsequent to the IFPA analysis the MFR FAIB, performed timber supply analysis of the Morice TSA incorporating secondary stand structure consideration into the SELES model architecture developed by Fall *et al.* (2006); (British Columbia Ministry of Forests and Range

2008a). Modification to the SELES model are detailed in the methodology section of the case study (Chapter 2). Analysis was done in support of the AAC determination. The Public Discussion Paper and the AAC Rationale released by the Ministry of Forests and Range did not make reference to the results of incorporating secondary stand structure into modeling.[25]

1.3.8 SUMMARY

In the past, pine did not make up such a large proportion of the mature forest as it does today (Taylor and Carroll 2004, DeLong 2009). This is of particular concern to the Prince George TSA where over 56% of the pine is in stands older than 80 years which Amman (1972) suggests is susceptible to MPB attack. In the PG TSA, 71% of all mature pine is found in forests where it makes up 70% or more of the standing volume (Figure 1.2). Several sources have observed unprecedented pine mortality in the wake of the current MPB infestation in the central interior (Pedersen 2003, Eng *et al.* 2004, Council of Forest Industries 2006). Provincial estimates range from 630 to 710 million cubic metres already attacked (Table 1.1) of the 1.35 billion m^3 of susceptible pine (Walton 2009). Local estimates for DPG indicate that for logging since January 2008, over 85% of pine volume is dead (Table 1.4). Attack is observed to increases with stand age (Table 1.3) and stem diameter (Figure 1.6 and 1.7).

Observations in unlogged pine stands from previous MPB infestations have shown that where live secondary stand structure remains it can release and contribute to future stand volume (Amman 1977, Heath and Alfaro 1990, Shrimpton 1994). Modeling release, and growth and yield of secondary stand structure has been difficult because of the complex

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[25] Nussbaum, A. Personal communication with Albert Nussbaum, Director, Forest Analysis and Inventory Branch, BC Ministry of Forests and Range June 2009. Albert.Nussbaum@gov.bc.ca.

nature of these stands and incorporating remnant live overstory and advanced regeneration (Kimmons *et al.* 2005; Griesbauer and Green 2006: LeMay *et al.* 2007; Sattler 2009).

Allowable annual cuts in BC have been increased by approximately 18 million m^3 in an effort to capture the dead timber before it decays, falls down or burns (Table 1.5). However, not all dead pine can be salvaged before it is considered unusable (Pedersen 2003). BC's mid-term timber supply is predicted to fall by as much as 20% (Figure 1.13) as a result of the MPB epidemic (British Columbia Ministry of Forests and Range 2007). Individual forest management units will experience more or less of a mid-term fall-down depending on the extent of pine mortality (Figure 1.14) (British Columbia Ministry of Forests and Range 2007a). Timber supply projects have attempted to incorporate secondary stand structure in order to mitigate mid-term fall-down with varying success (Fall *et al.* 2006; Morice and Lakes IFPA, 2007).

To date no study has attempted to model, at a stand level or forest level, growth and yield of advanced regeneration. This is the focus of this thesis. A description of the study area, field sampling methods, advanced regeneration, and techniques employed to incorporate advanced regeneration into growth and yield are discussed in Chapter 2. Chapter 2 also focuses on the methodology used to incorporate advanced regeneration growth and yield into timber supply modeling. Chapter 3 presents the results of a case study where various timber supply modeling scenarios incorporating advanced regeneration are explored. This is followed with a discussion in chapter 4 and conclusions and recommendations for further research in Chapter 5.

CHAPTER 2.

METHODS

2.1 PREAMBLE

Secondary stand structure is defined by Coates *et al.* (2006) as mature trees, saplings and seedlings that have remained alive in pine stands after the current mountain pine beetle infestation has run its course. Currently in British Columbia, a regulation protects stands with significant amounts of secondary stand structure (Government of British Columbia 2004). It is thought that protection of these stands will help to fill the mid-term timber supply fall-down sooner than would be the case under a scenario where stands are clear-cut salvaged and planted. A significant body of research discussed in chapter one suggests that as components of the overstory die and free up nutrients, moisture and light, existing understory seedlings and saplings will respond and take over growing space. This case study proposes a methodology for incorporating considerations of secondary stand structure into timber supply forecasting.

A timber supply analysis has not been published that examines the potential contribution of advanced regeneration because methodologies to incorporate it have not been fully developed. In order to consider secondary stand structure, modifications to SELES spatial timber supply model (SELES STSM) were done by Andrew Fall in 2006.[26] These modifications were intended to facilitate incorporation of Coates *et al.* (2006) estimates of secondary stand structure for the Morice TSA timber supply review process.[27] At that time

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[26] Coates, D. Personal Communication. June 2009. Research Branch, BC MFR. david.coates@gov.bc.ca
[27]See footnote 26

preliminary test modeling was done but no results were published.[28]

In 2007, a timber supply review to determine allowable annual cut for up to the next 10 years in the Prince George Timber Supply Area (PG TSA) was initiated. This presented a unique opportunity to incorporate advanced regeneration information to explore the potential contribution of secondary stand structure to future timber supply. It is anticipated this study will demonstrate the value of new timber supply analysis methodologies which include advanced regeneration and secondary stand structure.

2.1.1 OBJECTIVES

This study is concerned with developing a methodology for incorporating secondary stand structure in the form of advanced regeneration into timber supply modeling.

Specifically, study objectives include:

1. Quantifying advanced regeneration (AR) and modeling it in growth and yield models that can be used in timber supply models.
2. Developing two different approaches to modeling growth and yield information from AR using VDYP7 and SORTIE ND models.
3. Modifying secondary stand structure definitions in the SELES timber supply model to allow incorporation of advanced regeneration.
4. Quantifying timber supply impacts of incorporating various approaches to protection of AR for the PG TSA.

The last objective focuses specifically on the potential contribution of AR to the mid-term timber supply of the PG TSA. Objectives will be accomplished by:

- Isolating and examining the future timber supply contribution from the residual overstory

[28] Fall, A. Personal communication. December 2009. andrew@gowlland.ca

(canopy trees $\geq$ 12.5 cm dbh) and understory (sub-canopy regeneration $\geq$ 1.37 m tall and dbh < 12.5 cm) components of unsalvaged pine stands to the harvest forecasts for the PG TSA.

- Incorporating levels of advanced regeneration reported in section 2.4.3.3 in this thesis into timber supply modeling for the PG TSA using different initial salvage harvest rates.
- Measuring impacts on mid-term timber supply of harvest strategies where pine stands with no or low levels of AR are prioritized for salvage harvest first and stands with higher levels are protected and reserved for harvest until after the salvage period.

2.2 CASE STUDY AREA

The study area is in the heart of the current MPB epidemic in the central interior of British Columbia and covers about 54,000 km^2. This area is dominated by stands where lodgepole pine makes up the majority of trees. Using BC forest inventory data collection standards, stand species' proportion is based on the amount of basal area contributed by individual species.[29] Stands where pine trees represent the most basal area are referred to as leading pine stands.

During 2005, 2006 and 2007 field data was collected in the Prince George (DPG), Vanderhoof (DVA) and small portions of the Fort St James (DJA) and Nadina (DNA) forest districts recording the mortality of mature and immature pine and the secondary stand structure that has remained alive after the current MPB epidemic. Secondary stand structure includes seedlings (0.1 to <1.37 m tall), saplings ($\geq$1.37 m tall to 7 5 cm at dbh) and mature stems (> 7 5 cm dbh). Data were collected by field crews supervised by Chris Hawkins of

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[29] Nakatsu, D. Personal Communication May 2008, Dick Nakatsu retired from the Inventory Officer position at the Northern Interior Forest Region in May of 2010 phone 250-596-1612

the Northern Mixedwood Group at UNBC Field measurements of 2600 plots in over 550 stands were collected through funding from the Forest Investment Account (FIA) Forest Science Program (FSP) and the Federal Mountain Pine Beetle Initiative (MPBI) Appendix V contains a detailed description of the data collected for each plot Generally five plots were placed in each of the sampled stands (polygon) Figure 2 1 shows the location of the mature, greater than 61 years old, samples by year of initial sampling

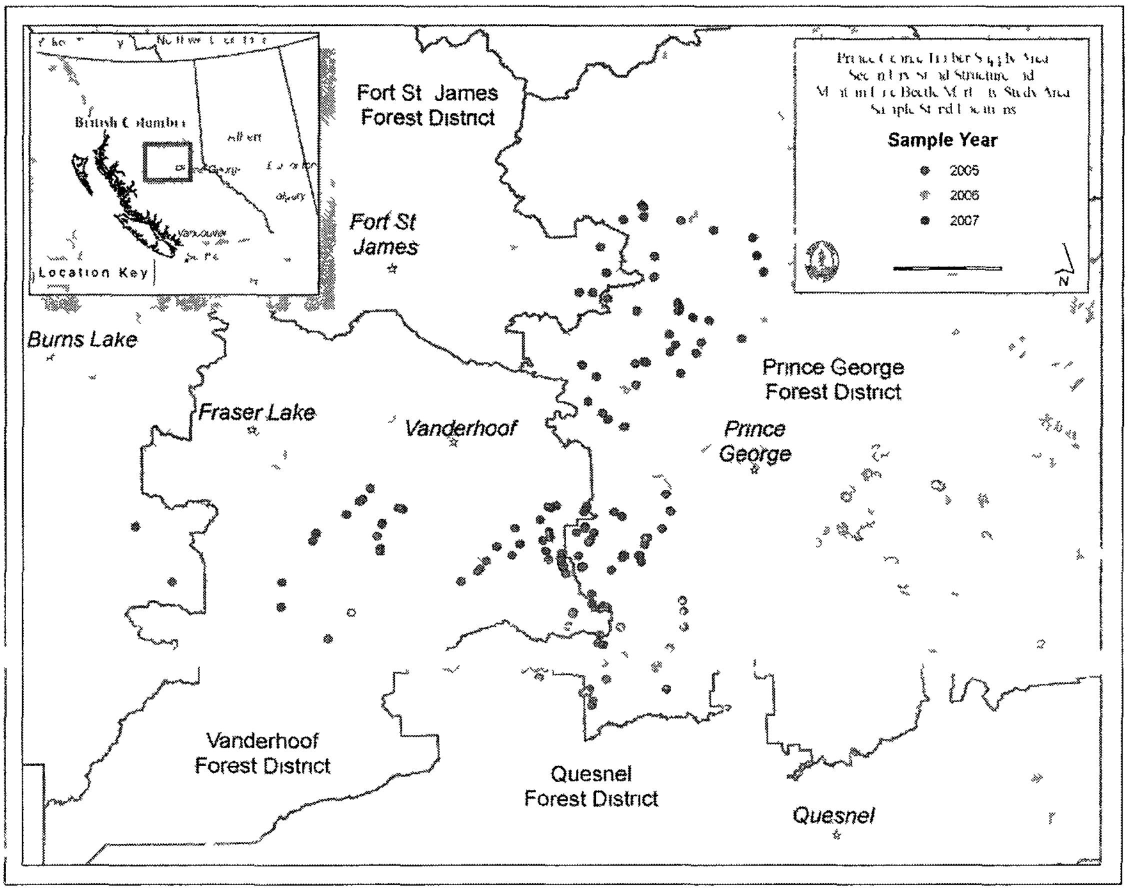

Figure 2.1 Study area showing terrain, major water features, major roads, forest district boundaries and mature sample stand locations by year of initial installation

Data were collected across all age classes and include variables describing the mature (tree layer) and the regeneration layer Species, diameters, heights, site index, vigour and beetle damage were among the attributes measured in all plots. Plots established in 2005 were re-measured in 2006 and again in 2007, if they had not been logged, and mature pine trees remained alive in previous measures. Similarly plots established in 2006 were re-measured in 2007 under the same conditions.

Of the 2600 plots sampled, approximately 1078 were in mature stands. Only data from mature stands aged 61 to 250 years old is used in this study. Plots were classified into age class based on ages of the dominant and co-dominate tree layer (Figure 2.2).

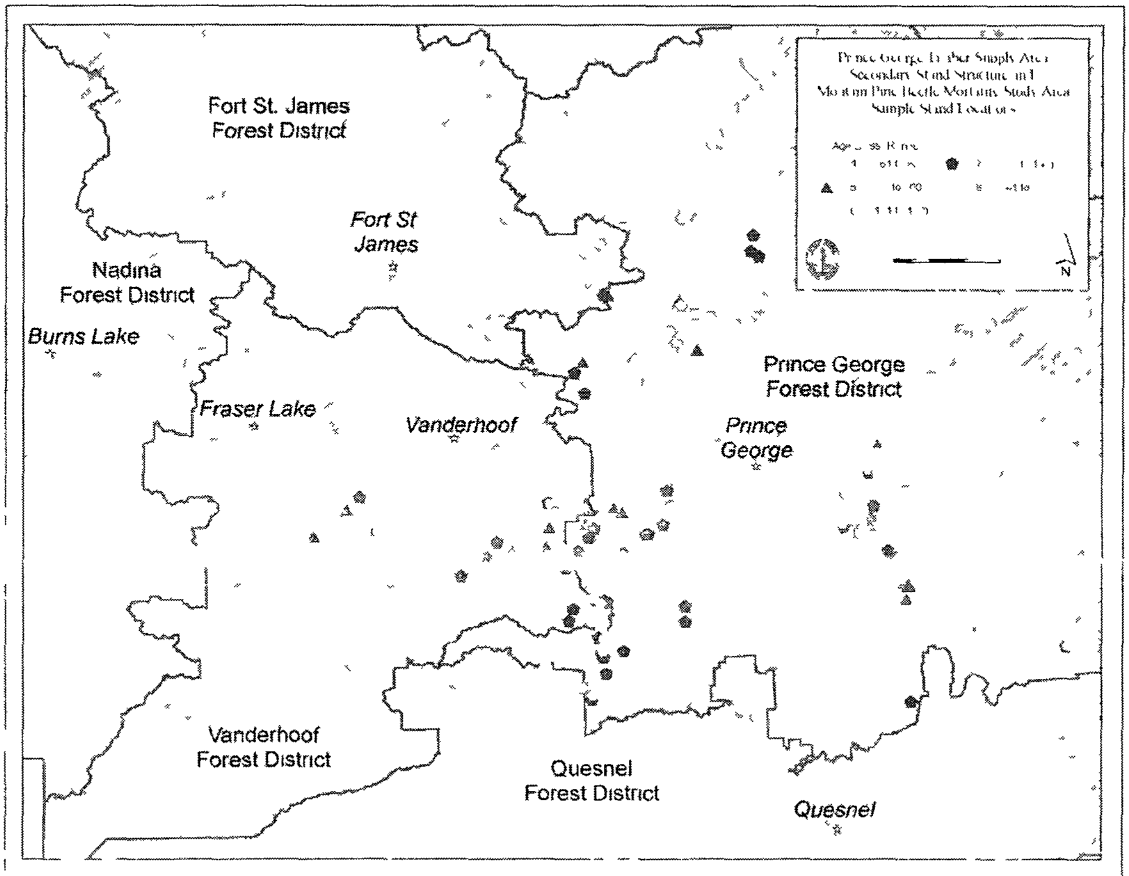

Figure 2.2· Study area showing sampled stands by the age class determined at the time of sampling

Table 2.1: Definition of age classes use in forest inventory classification in British Columbia.

Age Class	Age Range (years)
1	1 to 20
2	21 to 40
3	41 to 60
4	61 to 80
5	81 to 100
6	101 to 120
7	121 to 140
8	141 to 250

The study area is dominated by pine, much of which exists in stands where pine represents 70 percent or more of the stand basal area (Table 1.2 and Figure 2 3).

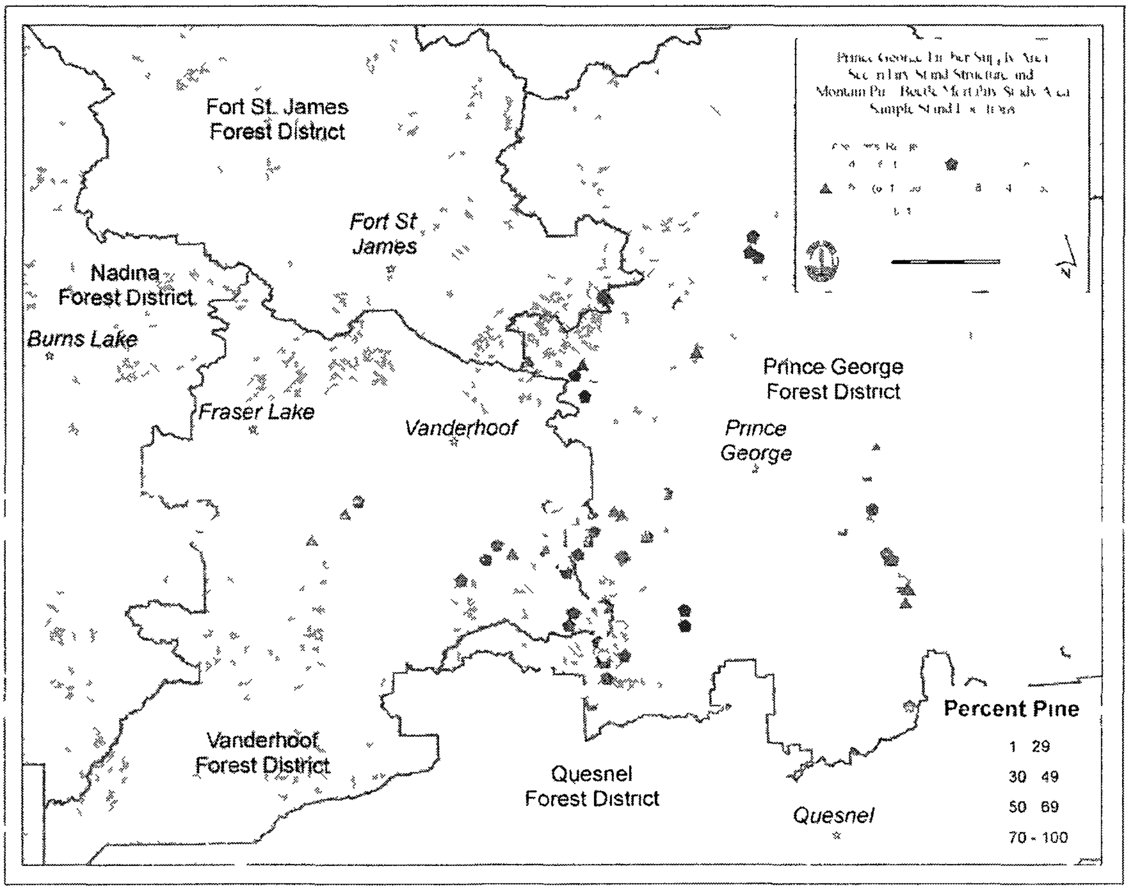

Figure 2.3· Study area themed by the percent that pine makes up of the forest inventory Water features, district boundaries and sampled stands by the age class determined at the time of sampling are also shown

Of the eleven BEC subzones represented ın the study area, seven were sampled ın thıs study (Fıgure 2 4) Two of the eleven BEC subzones are too small to be themed out ın Fıgure 2 4

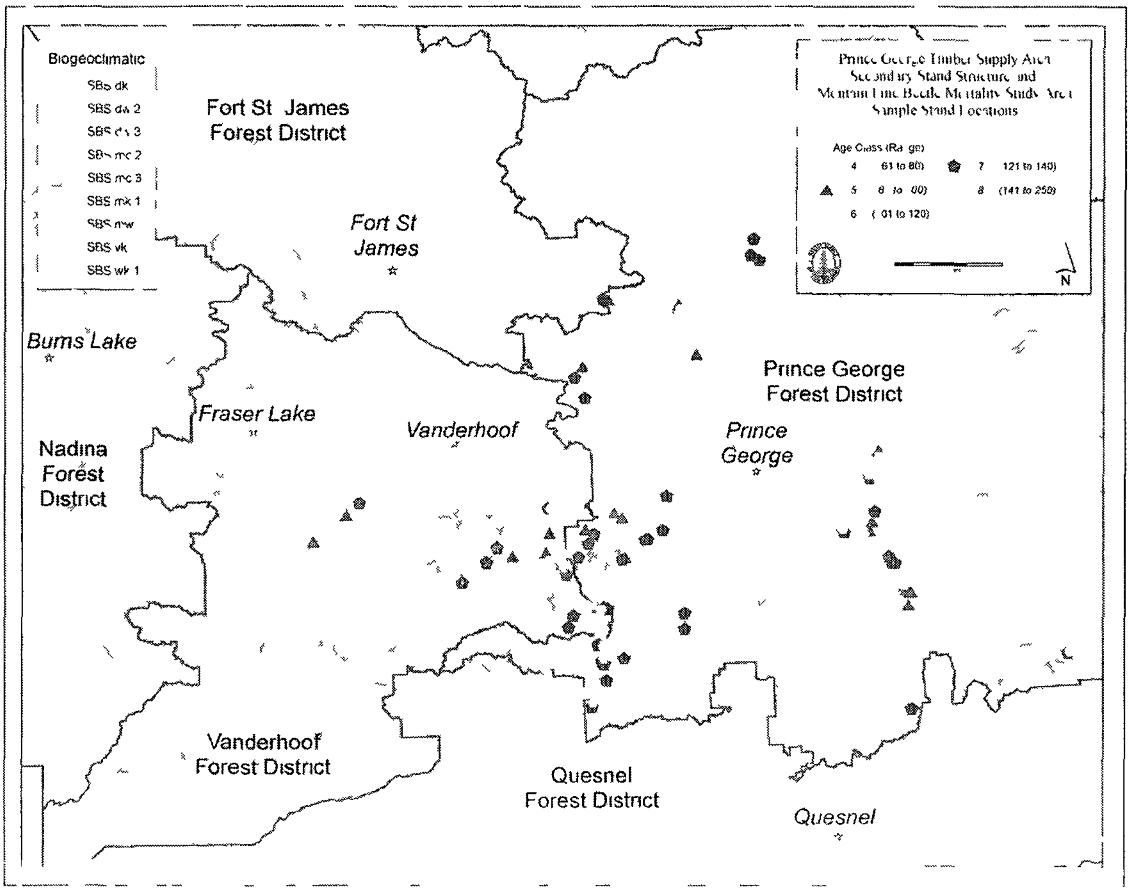

Figure 2.4 Study area showıng domınant SBS BEC subzones and sampled stands by the age class determıned at the tıme of samplıng

2.3 EXPERIMENTAL DESIGN AND PROCEDURES: FIELD COMPONENT

2.3.1 SAMPLE SELECTION

A three step pıocess was used to ıdentıfy and locate suıtable temporary sample plots (TSP) for thıs study

1. Candidate stands were identified on forest cover maps based on meeting the following criteria:
   - Sub boreal spruce (SBS) biogeoclimatic zone (Meidinger *et al.* 1991).
   - Lodgepole pine leading (most abundant species).
2. Field reconnaissance eliminated stands not meeting the criteria for selection and an annual subset of several hundred eligible stands was made.
3. Random selection from eligible stands was made for 70 % of sampling. The remaining 30 % was selected from the pool of eligible stands to ensure representative coverage of the study area age classes.

2.3.2 Field Data Collection

Detailed field sampling procedures are presented in Appendix V. Information collected in each plot includes forest cover label, GPS location, site series, site index (from map label and site tree), macro aspect, tree species, diameter at breast height (dbh, 1.37 m), and stage of MPB attack (Table 2.2). For trees in the mature layer (≥ 7.5 cm dbh) relative crown position (dominant, co-dominant or pole) as well as Worksafe BC danger tree classification was assessed. For trees considered to be advanced regeneration, the sapling layer (heights ≥1.37 metres and dbh <7.5 cm) and the seedling layer (<1.37 metres in height), species, dbh (sapling layer only), height and vigour were collected.

2.3.3 Mountain Pine Beetle Damage Assessment for Mature Trees

For ease of field data collection, mature trees assessed for MPB damage were categorized into several categories depending on the condition of damage (Table 2.2). This coding system was developed by Rakochy (2005). These categories were recorded for the initial year and re-assessed in subsequent years as the damage progressed. In this way the progression of attack from green attack to red and then gray could be tracked. Trees were also tallied if they were dead but had not died due to MPB attack.

Table 2.2: Classification of tree health for mature trees used in this study.

Tree Health	Description	Code
Live Healthy	Healthy tree with no MPB attack	4
Live Moribund	Moribund tree or live tree with very small crown, no MPB attack, and not likely to survive to next assessment	11
MPB attacked	MPB green attack (current year)	5
	MPB fading attack (yellowing)	1
	MPB red attack, ~ 50-100% needles remaining on tree	2
	MPB red attack, ~ 10-49% needles remaining on tree	3
	MPB grey attack, <10% needles remaining - no checking	6
	MPB grey attack, <10% needles remaining - bole checked	7
Dead but not from MPB	Standing, dead from other causes. No MPB galleries or frass observed	8
	Tree lying on the ground, cause of death unknown due to significant deterioration but no MPB galleries or frass observed	9
	Standing but broken at stump and leaning on another tree. No MPB galleries or frass observed	10

2.3.4 Distribution of Samples and Sample Area Information

A criterion for sampling was that a stand had to be leading pine in the inventory label on the forest cover map. Not all mature plots were necessarily leading pine. Of the 1081 mature samples, three were discarded because of irreconcilable inconsistencies found in the data. Further, four samples had no live trees in the tree layer pre-MPB attack. Of the 1074 samples with pre-MPB attack live trees, 604 were installed in 2005, 256 in 2006 and 214 in 2007.

Two hundred and six samples (24%) have less than 50% of their pre-MPB live basal area (for stems $\geq$ 7.5 cm dbh) made up of pine trees (Figure 2.5). Plots installed in 2007, north of Prince George, have 193 (90%) of 214 that have 50% or more of their BA made up of pine. Plots installed in 2006 (Figure 2.1) have the lowest proportion with 172 (67%). Of the 607 samples established in 2005, 332 were re-measured in 2006 and 215 were re-measured in 2007. Samples were not re-measured if all of the pine was attacked and found to be dead or if the sample was logged or burned. Of the 256 plots established in 2006, 98 of these were re-measured in 2007 while 215 plots were established in 2007 and were not re-measured. No re-measurements were taken of the regeneration layer. Of all of the trees sampled in all three years, 65% were lodgepole pine (Table 2.3).

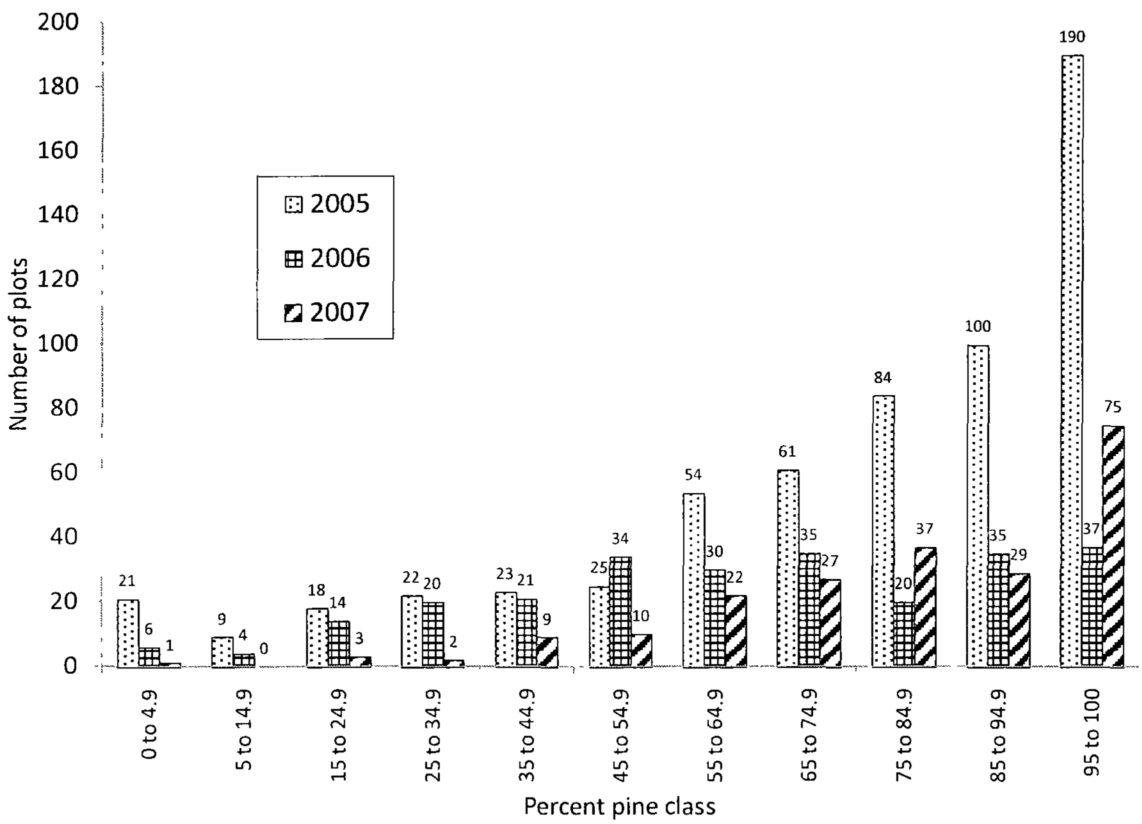

Figure 2.5: Number of plots by year of initial sample installation date by the proportion that pine makes up of the stand basal area (all stems greater than 7.5 cm dbh).

Table 2.3: Number of trees (stems ≥ 7.5 cm dbh) sampled in this study by year of initial sample establishment.

Tree species	2005	2006	2007	All years
Pl	6,322	2,005	1,932	10,259
Others (Ac, At, Bl, Cw, Ep, Hw, Fd, Sb, Sx)	2,757	1,925	844	5,526
All species	9,079	3,930	2,776	15,785
% pine	69.6%	51.0%	69.6%	65.0%

Of all the pine trees sampled that were alive prior to MPB attack, 23.4% were not attacked by MPB in the initial year of sampling (Table 2.4).

Table 2.4: Number of lodgepole pine trees (stems ≥ 7.5 cm dbh) sampled by tree health (MPB attack level) by year initially sampled.

Tree Health	Description	Code(s)	Number of trees sampled			
			2005	2006	2007	all
Live healthy	Healthy tree	4	1,234	379	317	1,930
MPB attacked	MPB green attack	5	478	158	99	735
	MPB fading attack (yellowing)	1	70	24	22	116
	MPB red attack, ~ 50-100% needles on tree	2	687	247	596	1,530
	MPB red attack, ~ 10-49% needles on tree	3	592	156	261	1,009
	MPB grey attack, no checking	6	1,359	512	173	2,044
	MPB grey attack, bole checked	7	545	201	144	890
Live Moribund	Moribund tree or live tree with very small crown with no MPB attack	11	49	19	16	84
Dead	Dead but not from MPB	8, 9, & 10	1,308	309	304	1,921
All trees	All	All	6,322	2,005	1,932	10,259

Sample representativeness was examined for age class and BEC subzone (Table 2.5) and compared to the crown forest in the sample area (Table 2.6).

Table 2.5: Number of samples by BEC Subzone and age class.

BEC Subzone	Number of samples by Age Class (age range: years)						
	4 (61 to 80)	5 (81 to 100)	6 (101 to 120)	7 (121 to 140)	8 (141 to 250)	9 (250+)	all (61 to 250+)
SBS dk	40	0	0	0	0	0	40
SBS dw1	0	0	0	0	0	0	0
SBS dw2	25	1	5	54	34	0	119
SBS dw3	128	61	40	94	82	0	405
SBS mc2	0	0	0	0	0	0	0
SBS mc3	35	3	5	5	10	0	58
SBS mh	0	0	0	0	0	0	0
SBS mk1	97	20	38	29	90	0	274
SBS mw	0	0	0	0	0	0	0
SBS vk	0	0	0	5	5	0	10
SBS wk1	30	35	13	30	64	0	172
All Units	355	120	101	217	285	0	1078

Table 2.6: Area of mature leading pine stands in the sub-boreal spruce BEC subzone in the sample area (Prince George and Vanderhoof forest districts).

BEC Subzone	Area[30] (ha) by age class (age range: years)						
	4 (61 to 80)	5 (81 to 100)	6 (101 to 120)	7 (121 to 140)	8 (141 to 250)	9 (250+)	all (61 to 250+)
SBS dk	24,442	10,918	6,063	12,156	18,713	10	72,302
SBS dw1	80	800	456	55	0	0	1,391
SBS dw2	8,195	8,656	5,519	15,346	14,022	0	51,738
SBS dw3	34,775	42,309	26,593	41,019	23,981	8	168,685
SBS mc2	33,532	14,490	14,468	24,713	39,873	12	127,088
SBS mc3	35,012	22,498	8,966	19,553	35,732	258	122,019
SBS mh	0	137	99	3	0	0	239
SBS mk1	13,676	41,986	15,161	18,299	34,791	0	123,913
SBS mw	1,250	7,230	1,849	1,896	889	0	13,114
SBS vk	129	430	390	1,700	5,289	28	7,966
SBS wk1	3,830	12,529	2,248	4,706	10,900	7	34,220
All Units	154,921	161,983	81,812	139,446	184,190	323	722,675

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[30] The crown forested area incorporates harvesting and disturbance (wildfire) updates to March of 2008

When the percentage distribution of samples were compared with crown forest area, the SBS dk was found to be fairly under represented especially by age class (Table 2.7). Samples were done only in age class 4 (61 to 80). At this point, additional samples from the SBS dk were added from a previous study completed by Rakochy (2005). These samples were located in the southern portion of the Vanderhoof and neighbouring Nadina forest districts (Rakochy 2005). Additional samples were only used in determining the advanced regeneration component of secondary structure for the case study in chapter 2 and 3.

Table 2.7: Percentage of area (crown forest leading pine) represented in the sample area and sample plots by BEC subzone and age class.

BEC subzone	Study Area or **Sample Plots**	4 (61 to 80)	5 (81 to 100)	6 (101 to 120)	7 (121 to 140)	8 (141 to 250)	all (61 to 250+)
SBS dk	Study Area:	3.4	1.5	0.8	1.7	2.6	10.0
	Sample Plots:	**3.7**	**0.0**	**0.0**	**0.0**	**0.0**	**3.7**
SBS dw1	Study Area:	0.0	0.1	0.1	0.0	0.0	0.2
	Sample Plots:	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
SBS dw2	Study Area:	1.1	1.2	0.8	2.1	1.9	7.2
	Sample Plots:	**2.3**	**0.1**	**0.5**	**5.0**	**3.2**	**11.0**
SBS dw3	Study Area:	4.8	5.9	3.7	5.7	3.3	23.3
	Sample Plots:	**11.9**	**5.7**	**3.7**	**8.7**	**7.6**	**37.6**
SBS mc2	Study Area:	4.6	2.0	2.0	3.4	5.5	17.6
	Sample Plots:	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
SBS mc3	Study Area:	4.8	3.1	1.2	2.7	4.9	16.9
	Sample Plots:	**3.3**	**0.3**	**0.5**	**0.5**	**0.9**	**5.4**
SBS mh	Study Area:	0.0	0.0	0.0	0.0	0.0	0.0
	Sample Plots:	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
SBS mk1	Study Area:	1.9	5.8	2.1	2.5	4.8	17.1
	Sample Plots:	**9.0**	**1.9**	**3.5**	**2.7**	**8.3**	**25.4**
SBS mw	Study Area:	0.2	1.0	0.3	0.3	0.1	1.8
	Sample Plots:	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
SBS vk	Study Area:	0.0	0.1	0.1	0.2	0.7	1.1
	Sample Plots:	**0.0**	**0.0**	**0.0**	**0.5**	**0.5**	**0.9**
SBS wk1	Study Area:	0.5	1.7	0.3	0.7	1.5	4.7
	Sample Plots:	**2.8**	**3.2**	**1.2**	**2.8**	**5.9**	**16.0**
All Subzones	Study Area:	21.4	22.4	11.3	19.3	25.5	100.0
	Sample Plots:	**32.9**	**11.1**	**9.4**	**20.1**	**26.4**	**100.0**

Also of note is the apparent lack of samples in the SBS mc2 when 17.6% of the crown forest is found in this subzone (Table 2.7). The SBS mc2 and SBS mc3 subzones in the Prince George TSA have a larger proportion of stands where pine is not the dominant (leading) species. These subzones are characterized by higher elevation subalpine-fir and spruce stands in the Vanderhoof and Fort St. James forest districts. For this reason it was expected that fewer samples would be required in this subzone. It was also determined after this analysis, that because field crews had difficulty differentiating between the SBS mc2 from the SBS mc3, these two subzones were lumped together and labelled SBS mc3.

2.4 CASE STUDY: METHODOLOGY FOR INCORPORATING DATA INTO TIMBER SUPPLY MODELING

2.4.1 DEFINING THE CASE STUDY "BASE CASE"

The ability to evaluate and compare techniques for incorporating AR into timber supply is facilitated by keeping all other modeling inputs constant. To facilitate this study, a base case is chosen that capitalizes on analysis done by the Ministry of Forests and Range in the forest management unit where the advanced regeneration data were collected. All data and modeling files including GIS spatial layers and SELES STSM input files for the 2009/2010 Prince George Timber Supply Area Timber Supply Analysis were graciously provided for use in this study by the British Columbia MFR Forest Analysis and Inventory Branch (FAIB).[31] Test scenarios, using the files provided, ensure that study results reproduced what was achieved in the MFR analysis.

Two potential options were evaluated as the base case which is the two alternative

[31] Data provided by Albert Nussbaum, Director, MFR FAIB, July 2009. albert.nussbaum@gov.bc.ca

harvest forecasts presented from the PG TSA Public Discussion Paper (Figure 2.6); (British Columbia Ministry of Forests and Range 2010). Alternative Scenario 1 maintains the current AAC of 14.944 million m^3 for 12 years, then drops to a mid-term level of approximately 4.2 million until year 40 then jumps up in two steps to a long-term level of 9.2 million m^3 per year. The initial harvest level achieved for Alternative Scenario 2 (move to Ft. St James to salvage) is 12.5 million m^3 per year followed by projected reduction in harvest in year 14 to a mid-term level of just over 6 million which lasts until year 40 increasing to the long-term level of 9.5 million m^3 achieved in year 80 (Figure 2.6). The higher mid-term level (years 12 to 40) achieved in Alternative Scenario 2 is a result of increased harvest beyond a level that is sustainable for non-pine profile. The sustainable flat-line harvest for non-pine is 4.2 million m^3/year. It is the basis for the mid-term harvest level achieved in Alternative Scenario 1. A detailed discussion of these results are presented in the PG TSA Public Discussion Paper (PDP).[32]

Alternative Scenario 2 – "move to Ft. St James to salvage" is chosen as the base case for this study because it maximizes the mid-term harvest portion of the forecast (Figure 2.6). This helps to ensure that impacts associated with methodology used to incorporate AR will be reflected in harvest forecasts. This scenario uses the initial annual target harvest level of 12.5 million which best reflects the actual average annual TSA harvest of 11.3 million m^3 experienced over the past 5 years (2004 to 2008). It is anticipated that due to the current downturn in the world economy, demand for fibre may continue to remain low for several years (Bogdanski *et al.* 2010). Certain modeled scenarios were also tested using initial target harvests of 14.944 million m^3 (current AAC) to explore whether a higher salvage rate would

[32] See pages 10 and 11 of the 2010 PG TSA Public Discussion Paper accessed on June 1st 2010 at http://www.for.gov.bc.ca/hts/tsa/tsa24/tsr4/24ts10pdp.pdf

affect the mid-term harvest level achieved in the modeling. In this case study, all of the assumptions associated with modeling other resource values such as wildlife, visually sensitive areas, and riparian were identical to what was used to establish the Alternative Scenario 2 (base case). These assumptions are documented in the Prince George TSA Data Package (British Columbia Ministry of Forests and Range 2008b).[33]

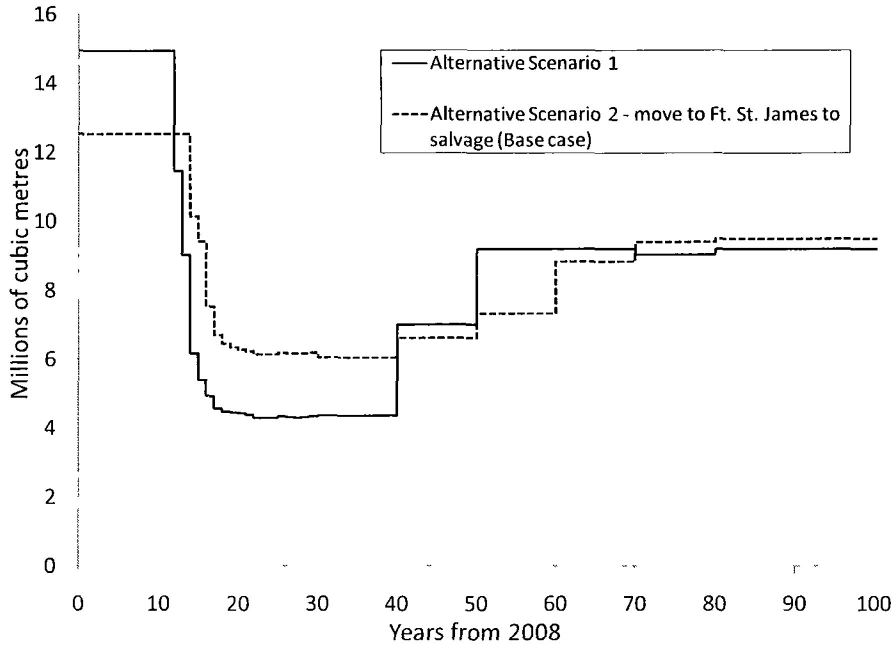

Figure 2.6: Harvest forecasts from the SELES model showing two feasible alternative solutions for the Prince George Timber Supply Area [Adapted from Figure 2 in Prince George TSA Timber Supply Analysis Public Discussion Paper: (British Columbia Ministry of Forests and Range 2010) used with permission].

Shelf life

The shelf life assumption used in the base case warrants discussion. Shelf life is defined in the PG TSA Timber Supply Review Public Discussion Paper as the length of time

[33]See: http://www.for.gov.bc.ca/hts/tsa/tsa24/tsr4/24ts08dp.pdf

a tree that has been killed by MPB is expected to remain standing.[34] This definition assumes that standing dead pine trees may be usable for products such as lumber, bioenergy fibre or pulp for 15 years. This assumption is based on anticipated fall down rates.[35] Once trees fall over they are no longer considered easily usable or desirable. A Canfor spokesperson claims that they are routinely processing logs in their Vanderhoof Plateau Sawmill that are nine-year post MPB attack Although grade and recovery are down significantly they anticipate being able to use up to 15-year post attack logs.[36] Other major forest licensees claim that shelf life is as short as 3 years for use as lumber.[37] Traditionally British Columbia's AAC has been set for sawlogs but the 2008 PG TSA Data Package states the desire to use a shelf life that allows the Chief Forester to set an allowable cut that considers all standing dead pine.[38] The base case remains true to this with the understanding that variations in shelf life could have significant affects on short-and long-term timber supply projections as is indicated by the 2010 PG TSA Public Discussion Paper.[39] This study remains focused on deriving a reasonable methodology for incorporating AR into timber supply analysis and does not explore the many other assumptions that drive timber supply projections.

The forest inventory used for the timber supply modeling scenarios is current for logging and disturbance to 2008. The timber harvesting land base contains 659,509 hectares of leading pine stands which are older than 60 years and represent potential opportunity for

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[34] Page 14 of the 2010 PG TSA Timber Supply Review Public Discussion Paper Accessed on June 1st 2010 at http //www for gov bc ca/hts/tsa/tsa24/tsr4/24ts10pdp pdf

[35] Page 39 and 39 of the 2008 PG TSA Timber Supply Review Data Package Accessed June 20 2010 at http //www for gov bc ca/hts/tsa/tsa24/tsr4/24ts08dp pdf

[36] Lazaruk, T Personal Communication May 2010 Terry Lazaruk is the Strategic Planning Coordinator Canfor Northern Operations, phone 260 567-8260, email Lazaruk@canfor com

[37] See footnote number 35

[38] See footnote number 35

[39] See footnote number 35

supporting advanced regeneration in this study (Table 2.8). These stands represent 31.0% of the THLB and 23.8% of the crown forest in the sampled BEC subzones (Table 2.8). Further, these stands represent 21.3% of the THLB and 12.6% of the crown forest for the PG TSA as a whole (Appendix VI). Appendix VI details the net down table for the TSA that define the THLB and the crown forested land base.

Table 2.8: Prince George Timber Supply Area Crown forest (THLB and non-THLB) area in the BEC subzones that are considered in the case study[40].

Land base classification	leading species	BEC Subzone							
		SBSdk	SBSdw2	SBSdw3	SBSmc3	SBSmk1	SBSvk	SBSwk1	All
Timber harvesting land base (THLB)	leading pine age 0 to 60	40,292	457	97,550	47,273	91,685	6,829	36,307	320,393
	leading pine age 61 to 250	59,059	41,182	179,980	84,853	265,362	3,524	25,549	659,509
	Other leading species all ages	30,970	86,796	148,227	20,309	307,560	227,208	325,492	1,146,562
	total THLB	130,321	128,435	425,757	152,435	664,607	237,561	387,348	2,126,464
Non-timber harvesting land base	all leading species	47,703	28,015	151,667	61,411	193,702	85,592	77,190	645,280
Total crown forested land base	all leading species	178,024	156,450	577,424	213,846	858,309	323,153	464,538	2,771,744

2.4.2 Stand Level Mortality

The base case utilizes mortality projection from the BCMPB v5 model as discussed in sections 1.3.4.2 and 1.3.4.3. BCMPB v5 predicted that by 2024 stand level mortality for DPG would be approximately 70% for mature stands. One study, based on a 2008 aerial survey, estimated tree mortality in the range of 76% to 93% depending on age (Table 1.3). Another study, based on timber cruise information to 2009, estimated volume mortality at 80

[40] Note that other BEC subzones exist in the SBS Biogeoclimatic zone in the PG TSA but these were not sampled

to 85% (Table 1.4). Field data collected for the case study provide estimates of stand level basal area mortality for DPG by age class. They range between 88% and 94% (middle data cluster in Figure 2.7). Preliminary results from the field data collected in this study were used to update the BCMPB v5 mortality model for the Prince George forest district portion of the TSA in establishing the base case described above. The BCMPB model was not modified for the Vanderhoof and Fort St James portions of the TSA. For this study, mortality based on basal area was assumed to be representative of volume mortality. For DPG, BCMPB v5 predicted mortality was overridden to reflect the mortality percentages by age class reported in Figure 2.7.

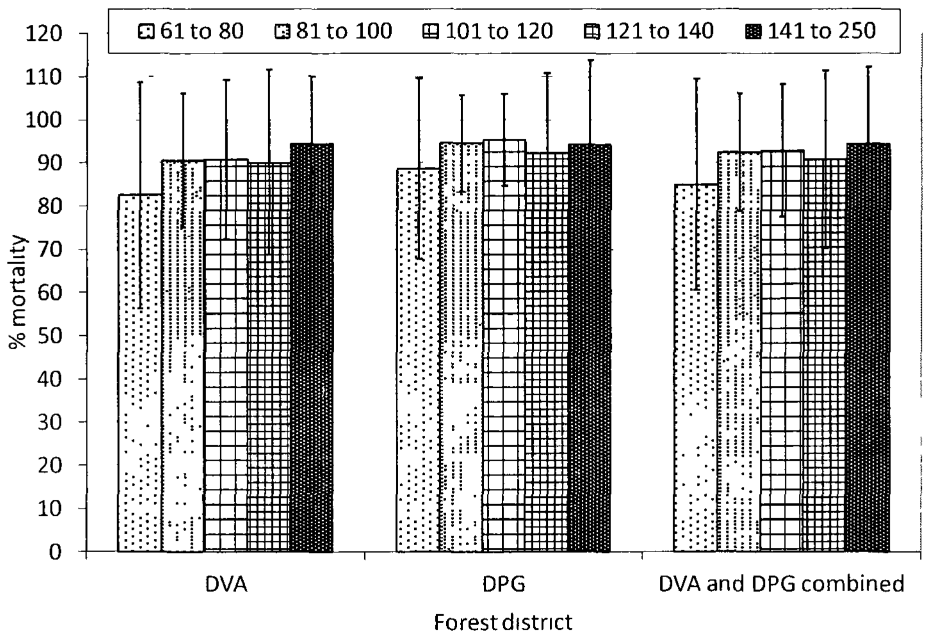

Figure 2.7: Mean and S.D. percent pine-only MPB mortality by age based on basal area (m^2/ha) for stems ≥ 12.5 cm dbh for the Vanderhoof and Prince George forest districts.

The relationship between tree diameter at breast height and mortality is discussed in section 1.3.4.1. Although not directly relevant to this case study, the relationship found for this data is reported in Appendix VII. Similarly, pre and post-MPB epidemic live basal area is also reported in Appendix VII.

2.4.3 Secondary Stand Structure

For all scenarios presented in this study, secondary stand structure is dealt with in two components. Volume accruing from understory (advanced regeneration) is added to the volume from the residual canopy level (overstory) to determine the total merchantable volume achieved upon harvest. All scenarios modelled in this case study analysis have some considerations for secondary stand structure incorporated into harvest forecasts.

A significant difference between this study and Coates *et al.* (2006) is that Coates original work assumed that the MPB epidemic was not considered to be finished and all residual canopy pine trees that made up secondary stand structure were assumed to die and were discounted. This study allows the live pine found to be remaining after the epidemic to contribute to future timber supplies. Also, Coates *et al.* (2006) estimated the quantity of stands that were believed to have adequate secondary stand structure and the anticipated future stand species composition but no timber supply modeling was published.

2.4.3.1 Contribution from the Residual Overstory (Mature) Component of Stands

The methodology used to determine volume recovered from the residual overstory in attacked mature pine leading stands is applicable to all of the scenarios in this case study including the base case. For mature stands, the Vegetation Resource Inventory (VRI) carries attributes for the overstory or mature component but does not have attributes for the understory (saplings and seedlings). During the standard pre-modeling set-up, all forest inventory polygons are put through a batch version of VDYP7 (British Columbia Ministry of Forests and Range 2009b) that creates polygon specific natural stand yield tables based on all merchantable stems 12 5 cm in diameter at breast height (dbh) VDYP7 is an empirically based growth and yield prediction system developed for use with the BC Vegetation Resources Inventory file [41] These standard yield tables are then aggregated to the site series level for use in the SELES model to predict merchantable volume based on age

When mature stands are attacked by MPB some, or all, of the pine trees will die Some pine, as well as other species such as interior spruce, sub-alpine fir, Douglas-fir and aspen will remain alive In modeling, after MPB attack, mature (greater than 60 years old) leading pine natural stand yields (m^3/ha) were reduced by the percentage that the dead pine made up of the original VRI inventory polygon label (Figure 2 8) The mature volume reduction occurs after a 15-year shelf life has passed BCMPB v5 mortality projection model provides the percentage of the pine that is killed by MPB over time to the SELES model The BCMPB v5 standard model outputs are used for Fort St James and Vanderhoof forest districts but modified to reflect the increased level of mortality observed for the Prince George Forest district As the remaining live component of the stand continues to age, it grows and accumulates a reduced volume along the trajectory of the original standard VDYP7 curves (Figure 2 8) Residual mature volume is carried forward as described above for all scenarios presented in this case study including the base case

Three approaches are described below for modeling contributions from the understory component of secondary stand structure The first describes what was done for the base case and the remaining two describe methodology employed to model the AR contribution determined in the case study scenarios

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[41] VDYP7 users guide accessed June 2010 at
http //www for gov bc ca/hts/vdyp/user_guides/volume1_vdyp_overview_revised april2010 pdf

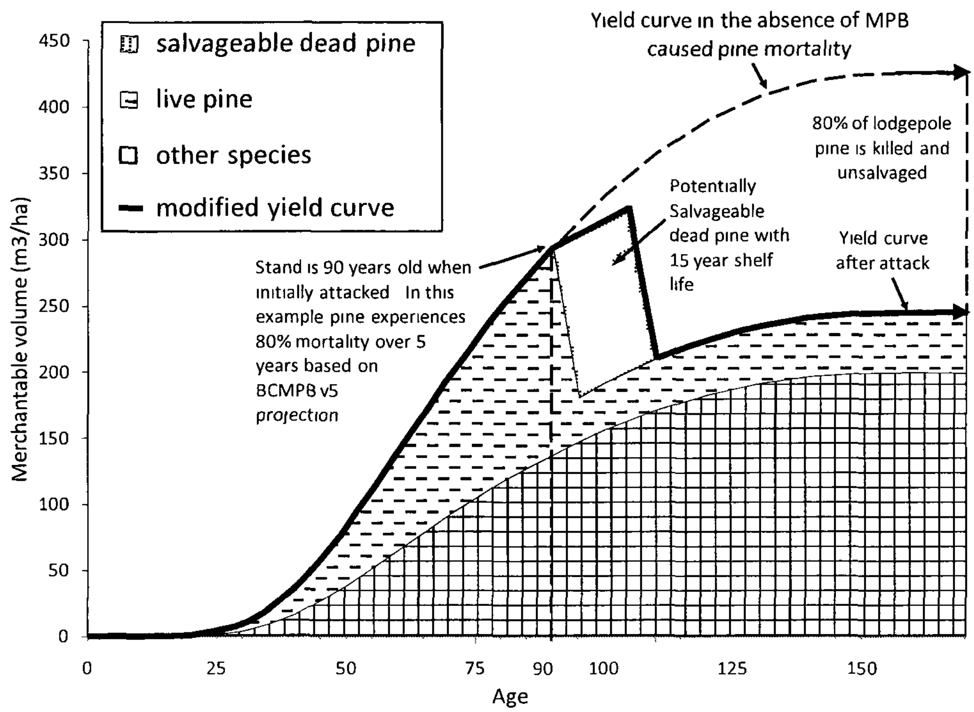

Figure 2.8: Simplified example of how mature volume adjustments are applied to future yields of MPB attacked stands to account for pine mortality. The initial species contribution is approximately 55% pine and 45% spruce (other species).

2.4.3.2 Contribution from the Understory (Immmature) Component of Stands in the Base Case

The base case (Scenario 2, Figure 2.6) is the harvest forecast to which all other scenarios are compared. The base case represents a reference timber supply scenario that reflects the best available knowledge and information available for the PG TSA. In the base case, the trigger to initiate understory secondary stand structure is when a stand reaches 50% MPB mortality in the overstory This is governed by the annual mortality predicted by the BCMPB v5 mortality model. Once this occurs, there is a 10-year regeneration delay after which the understory begins growing from age zero on the original standard VDYP7 natural stand yield curves. This means that the species contribution of the understory is assumed to be the same as the original pre-MPB overstory – leading pine. Understory stands contribute in proportion to the growing space that is made available through the death of the pine overstory. For example, if a stand experiences 60 percent overall mortality then the standard yield curve for understory is multiplied by 0.6. The base case does not recognize existing AR. Findings discussed later in this chapter do not support the assumption used in the base case that advanced regeneration does not exist under mature attacked pine stands in much of the study area.

2.4.3.3 Contribution from Advanced Regeneration using VDYP7 and SORTIE ND Growth and Yield Models

Two growth and yield models are used to capture the uncertainty in forecasting stand level growth and yield from the AR component of SSS; VDYP7 (British Columbia Ministry of Forests and Range 2009b) discussed previously and SORTIE ND (Canham 2001). SORTIE ND (Neighbourhood Dynamics) is a spatially explicit simulation model that provides growth and development predictions for trees in stands where mixed species and competition for resources might be occurring (Canham 2001). SORTIE ND was brought to British Columbia by David Coates of the MFR Research Branch to help study mixed stands in the Interior Cedar Hemlock (ICH) BEC zone and re-programmed in C++ computer language in the early 2000s (Wiensczyk 2010). As a research model, it is has been parameterized for the SBS as well as portions of the ICH BEC zone.[42] SORTIE ND models the succession that occurs in normal stand development. SORTIE ND also models interactions between individual trees and can simulate the dynamics in stands where death is occurring to some of the overstory as is the case with MPB damaged stands (Wiensczyk

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[42] To download a copy of SORTIE ND go to: http://www.bvcentre.ca/sortie-nd

2010). Results from both growth and yield models are compared in terms of yield prediction and harvest forecasts from the SELES model.

Approximately 1400 plots were used to determine the attributes of AR in leading pine stands older than 60 years post-MPB epidemic. Attributes of the AR component of SSS were compiled by BEC subzone for all healthy stems that are ≥ 1.37m tall (dbh) and < 12.5 cm diameter at dbh. For example, in the SBS dk (Sub-boreal Spruce BEC zone - dry cool subzone) approximately 25% of all understory was field classified as 'moribund' and was discarded because it was not deemed healthy enough to result in a crop tree in the long-term. Seedlings (stems < 1.37 m tall) were tallied in this field collection phase of this study but were not considered as contributing to understory secondary stand structure for the case study. Basal area of AR varies widely by plot ranging from 0 to 41 m^2/ha (Figures 2.9a, 2.9b and Table 2.9)

Table 2.9: Number of plots by basal area class for healthy advanced regeneration: trees ≥ 1.37 m height and <12.5 cm dbh.

BEC Subzone	Basal area class (m2/ha)																															Grand Total
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	29	30	34	41	
SBS dk	115	100	51	28	19	10	2	5	1	3	1	2	1		1			1			1	1				1						343
SBS dw2	24	27	23	7	12	4	4	2	1	3		1					4	1								1		1				115
SBS dw3	69	77	55	45	43	26	11	19	8	10	11	6	6	1	2	1	3	2			2	4		1	1					1	1	405
SBS mc3	12	8	8	4	2	1	2	3	3	1	1		3	2				2	1	1	1	1	1	1	1	1	1					61
SBS mk1	43	71	30	23	31	9	16	6	9	6	6	4	3	2	2	1		1	1				1	1	1	1						268
SBS vk		1	1	1	3	2	1	1																								10
SBS wk1	8	16	18	30	17	27	16	6	7	6	8	2	3	3	2					1					1				1			172
All Subzones	271	300	186	138	127	79	52	42	29	29	27	15	16	8	7	2	7	7	2	2	4	6	2	3	4	4	1	1	1	1	1	1374

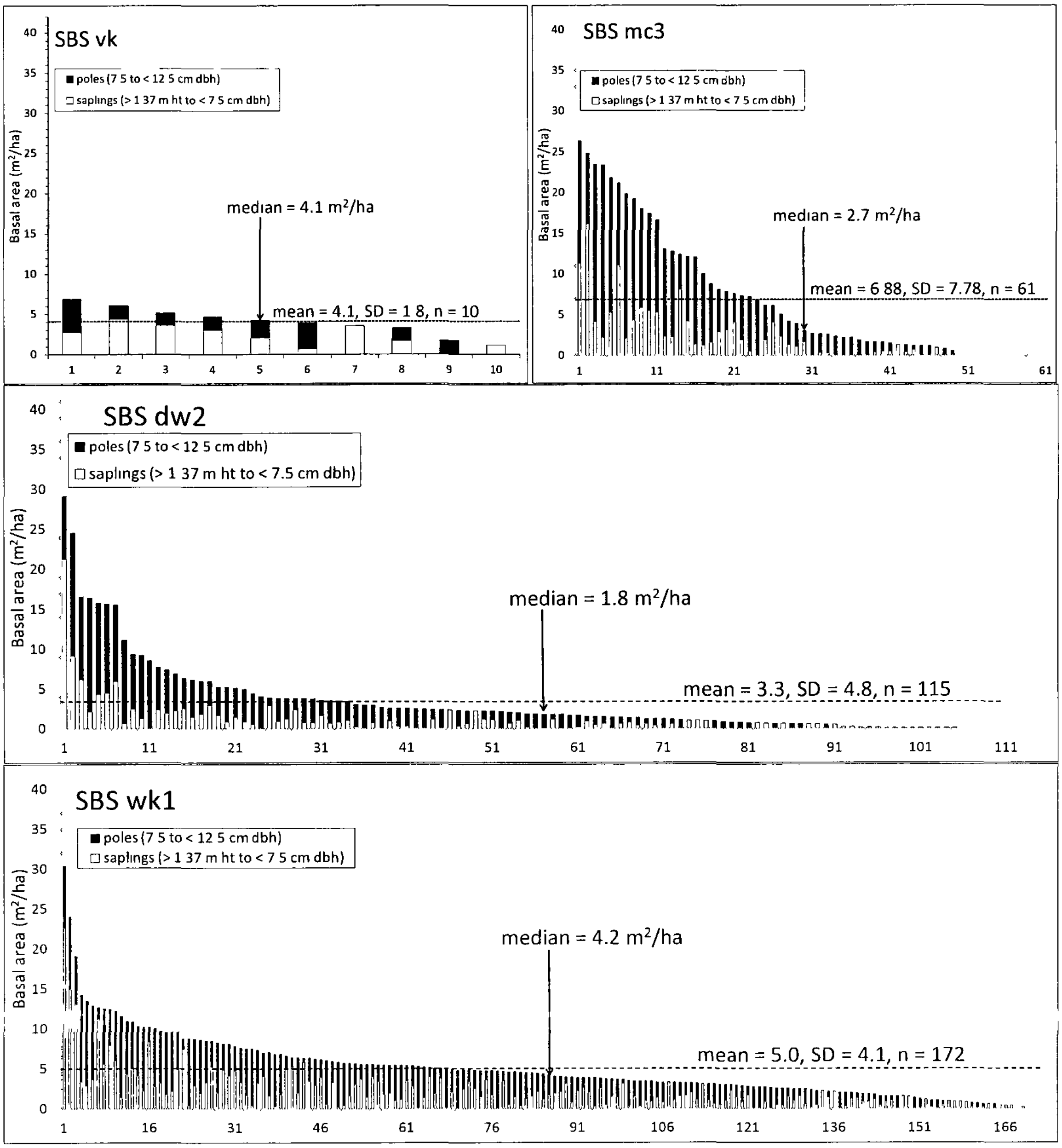

Figure 2.9a: Basal area by plot for advanced regeneration (saplings and poles ≥ 1.37 m in height and < 12.5 cm dbh) for the SBS vk1, mc3, dw2 and wk1 subzones.

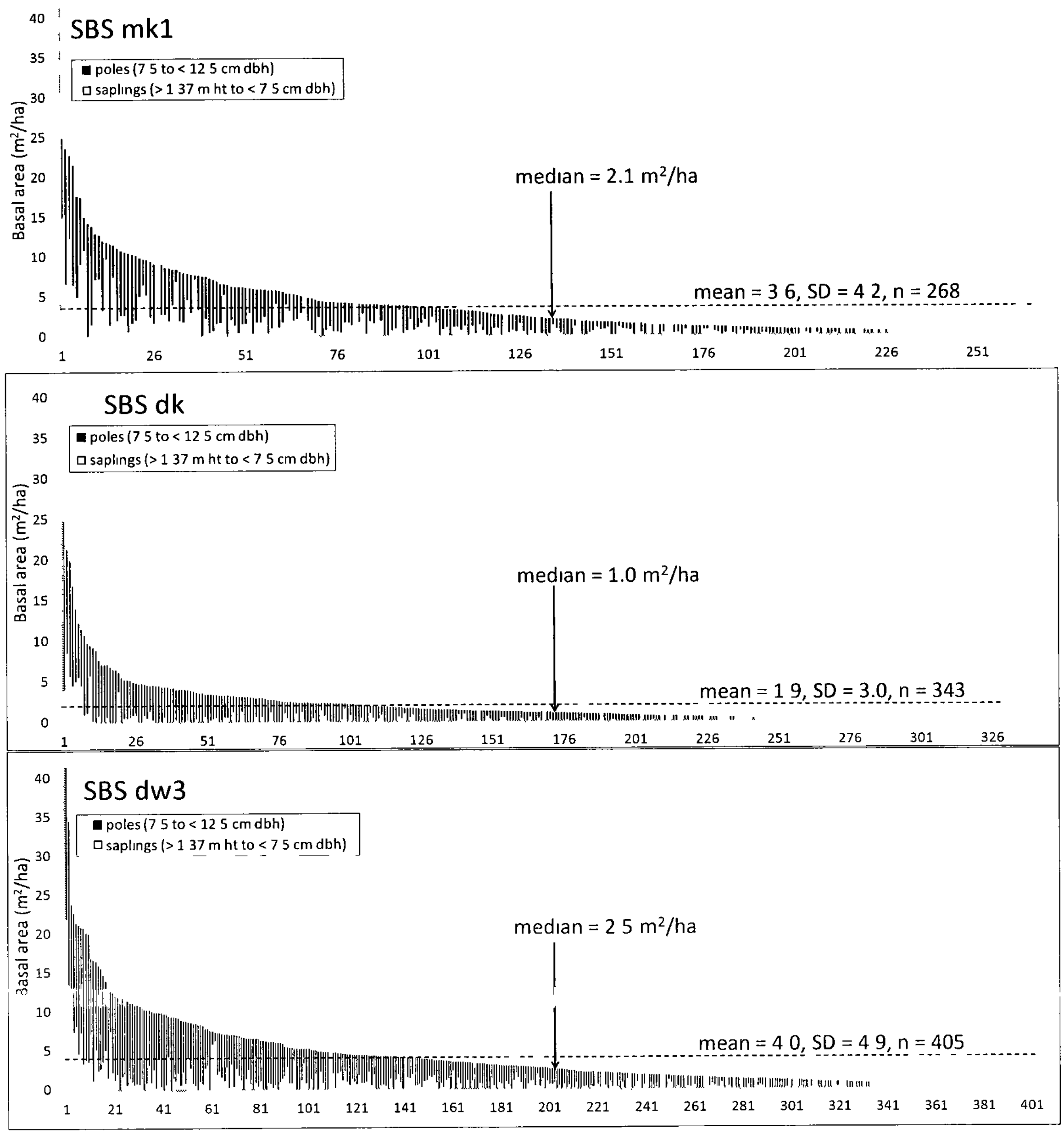

Figure 2.9b: Basal area by plot for advanced regeneration (saplings and poles ≥ 1.37 m in height and < 12.5 cm dbh) for the SBS mk1, dk and dw3 subzones.

Advanced regeneration growth modeling based on VDYP7

Table 2.10 reports relevant statistics (sample means, standard deviation of sample means and medians) for each of basal area (BA), density (stems per hectare:sph) and quadratic mean diameter (DBHg) of all plots in the various BEC subzones. Advanced regeneration stand structure attributes are variable in terms of species mix and size (diameter) (Table 2.10). Significant variability was shown in the standard deviations of basal area and density with standard deviation exceeding the mean for all subzones except SBS wk1 (wet cool subzone) and vk (very wet cool subzone).

Table 2.10: Selected attributes for healthy advanced regeneration in mature pine leading stands post-MPB epidemic in the Prince George TSA. (includes only trees ≥ 1.37 m height and < 12.5 cm in diameter at breast height)

BEC subzone	Advanced regeneration species label$_{species\ \%}$ (based on basal area)	sample size (n)	mean site index	basal area (m2/ha)			density (stems/ha)			quadratic mean diameter at dbh (cm)			effective age (years)
				mean	SD	median	mean	SD	median	mean	SD	median	
SBS dk	$Pl_{71}\ Sx_{25}\ Sb_2\ At_1\ Bl_1$	343	15.0	1.9	3.0	1.0	452	768	200	6.0	4.1	7.0	n/a
SBS dw2	$Sx_{52}\ Fd_{25}\ Pl_{21}\ Sb_1$	115	17.1	3.3	4.8	1.8	1077	1716	500	5.8	3.1	6.3	28
SBS dw3	$Pl_{38}\ Sx_{24}\ Sb_{23}\ Bl_6\ Fd_5\ At_1$	405	16.9	4.0	4.9	2.5	1066	1407	600	6.3	3.4	6.9	26
SBS mc3	$Pl_{41}\ Sb_{41}\ Sx_{14}\ Fd_2\ At_1$	61	15.1	6.9	7.8	2.7	2118	2595	1200	5.9	3.7	6.4	28
SBS mk1	$Bl_{39}\ Pl_{32}\ Sx_{17}\ Sb_8\ Fd_2\ At_1\ Ep_1$	268	17.7	3.6	4.2	2.1	1504	1764	900	5.5	3.0	5.5	24
SBS vk	$Bl_{64}\ Sx_{36}$	10	18.0	4.1	1.8	4.1	4150	2343	5050	4.0	1.6	3.3	26
SBS wk1	$Bl_{47}\ Pl_{23}\ Sx_{18}\ Sb_{18}\ Hw_4\ Cw_1$	172	18.0	5.0	4.1	4.2	2325	2152	1700	5.5	2.0	5.4	26

Because of the skewed nature of the data as expressed by the difference between the medians and the means (Figure 2.9a and 2.9b), the medians were selected as an appropriate and more conservative estimate of actual stand-level understory attributes. Species composition and mean site index were then input into VDYP7 to create representative AR volume/age tables by BEC subzone (Appendix VIII) for use by the SELES timber supply model.

Rather than starting growth of AR at age zero on the VDYP7 yield tables developed above, a methodology was derived to determine the effective age of the existing AR. TIPSY (Table interpolation program for stand yields) v 4.1d (British Columbia Ministry of Forests and Range 2007b) growth and yield simulator was used to generate natural stand yields (volumes) as well as BA, sph and DBHg by age by BEC subzone (Appendix IX). [43] For each subzone, the TIPSY model was run at sequential "initial density at establishment" until median values of BA, DBHg and Density matched the field data at the same age (Appendix IX). This is similar to a technique used by Hawkins *et al.* (2006). This age is taken as the effective age for AR secondary stand structure and is shown in the last column in the Table 2.10. For example, advanced regeneration in the SBS mk1 is determined to be the equivalent of 24 years old based on the fact that median BA is 2.1 m^2/ha., density is 900 sph and DBHg is 5.5 cm (Appendix IX). TIPSY is only used to determine effective age of AR, not to model its growth forward. VDYP7, rather than TIPSY is chosen to represent the growth of AR as it better reflects the average growth rates observed in the establishment of natural stands. VDYP7 volume curves are adjusted forward by the effective age (Figure 2.10). Note that the SBS dk BEC subzone, mostly in the Vanderhoof forest district, was not found to be stocked with sufficient AR and was not adjusted with an effective age (Figure 2.9b). In the SBS dk only 11.7% of all plots surveyed have more than 900 stems per hectare of healthy AR. For these scenarios all stands in a particular subzone are assumed to have an equal probability of having a level of AR present equivalent to what is indicated by the median values described in Table 2.10. VDYP7 volume/age curves for AR adjusted by the effective ages are shown in Figure 2.10.

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[43] TIPSY is a growth and yield computer program developed by the Research Branch of the BC MFR. Assessed on November 10, 2009 at: http://www.for.gov.bc.ca/hre/gymodels/tipsy/

Advanced regeneration growth modeling based on SORTIE ND

The SORTIE ND (Canham 2001) model was also used to create an alternate set of yield curves based on AR information using average (mean) density by 2 cm diameter class by species. Curves reflect the age of the AR and do not need adjustment by effective age in the way the VDYP7 does (Figure 2.11).

The trigger to initiate understory secondary stand structure for the VDYP7 and SORTIE ND scenarios is when a stand reaches 1% MPB mortality in the overstory as governed by the annual mortality predicted by BCMPB v5. Once this occurs, AR begins growing on a revised, age equivalent adjusted VDYP7 natural stand yield curves (Figure 2.10) and SORTIE ND curve (Figure 2.11). In the harvest forecast model, residual mature overstory volume is added to advanced regeneration volume at harvest. Advanced regeneration stands contribute in proportion to the growing space that is made available through the death of the pine overstory as discussed in detail below.

Volume curves created using VDYP7 and SORTIE ND are very different from one another when individual BEC subzones are compared (Figures 2.10 and 2.11). Using SORTIE ND the SBS dw2 and dw3 result in the greatest volume over time whereas with VDYP7 volume is greatest for the SBS wk1 and vk subzones. VDYP7 uses site productivity in the form of site index as an input. SORTIE ND is not driven by site productivity but by competition. SORTIE ND derived curves are initially much steeper than VDYP7 and show rapid growth rates of 6.5 to 9 m^3/ha/year over the next 40 years. For the same period, VDYP7 growth rates are in the 2 to 5 m^3/ha/year range. Both volume curves are tested in the timber supply modeling.

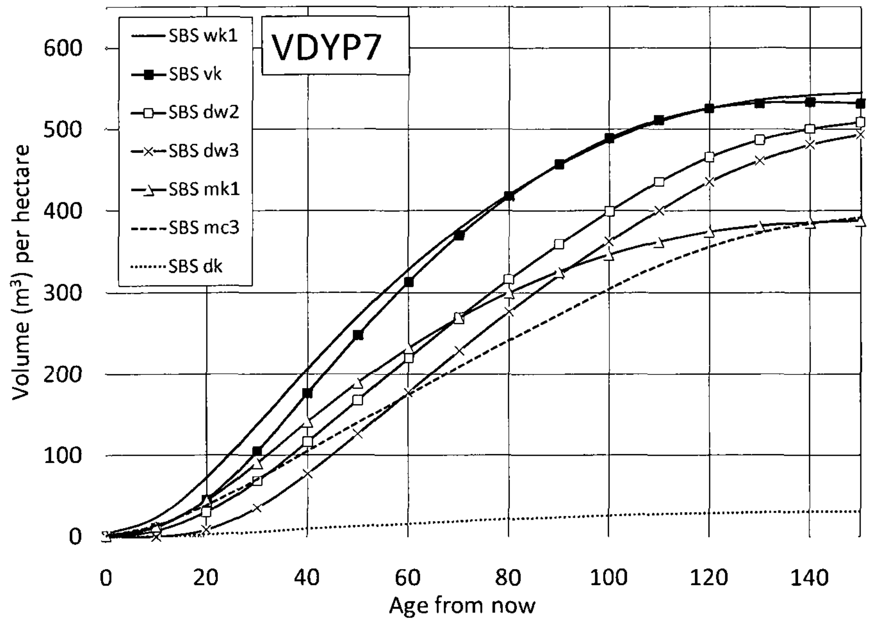

Figure 2.10: VDYP7 based yield curves (adjusted for effective age) for advanced regeneration secondary stand structure (utilization standard 12.5 cm+ dbh all species).

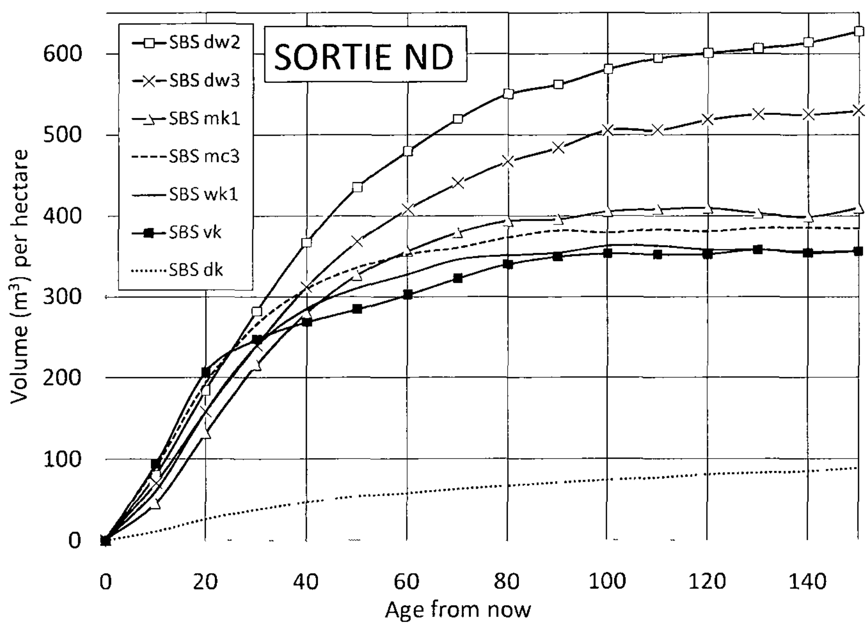

Figure 2.11: SORTIE ND based yield curves for advanced regeneration secondary stand structure (utilization standard 12.5 cm+ dbh all species).

In the SORTIE ND model, spruce tends to dominate over time at the expense of all other species if it is at all present in the AR. This occurred in the SBS dw2 and dw3 where volumes are higher for SORTIE ND derived curves. If subalpine-fir makes up the majority of the advanced regeneration as in the SBS wk1 and SBS vk, volumes at older ages tend to be reduced. Volumes achieved after 140 years are flat in both instances with VDYP7 clustered around the 400 to 550 m^3/ha range and SORTIE ND spread between 350 and 630 m^3/ha.

VDYP has been used in British Columbia to describe development of natural stands for approximately 30 years.[44] It is supported by a vast array of permanent and temporary sample plots and has become a well accepted growth and yield model. SORTIE ND, on the other hand, is fairly new to the interior of BC and is still in the calibration stage. Because volumes seem optimistic using SORTIE ND, VDYP7 was chosen as the basis for all other scenarios presented in this study. It is understood that when scenario testing, the use of SORTIE ND as the basis of the growth and yield of AR would be considered the upper bounds of what might be achievable. As discussed previously, even if release of AR occurs, it is fairly short lived and achieves a steady state growth rate after 10 to 12 years (Heath and Alfaro 1990)

Combining advanced regeneration with residual overstory yield curves

Upon harvest in the SELES model, volume yield consists of residual overstory (Figure 2 8) combined with advanced regeneration yields (Figure 2.10 or 2.11). AR yields

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[44] Nakatsu, D Personal Communication June 2009, Dick Nakatsu retired from the Inventory Officer position at the Northern Interior Forest Region in May of 2010 phone 250-596-1612

are in proportion to the growing space made available by the dead pine. Figure 2.12 is a schematic diagram showing the process for combining these two volume components.

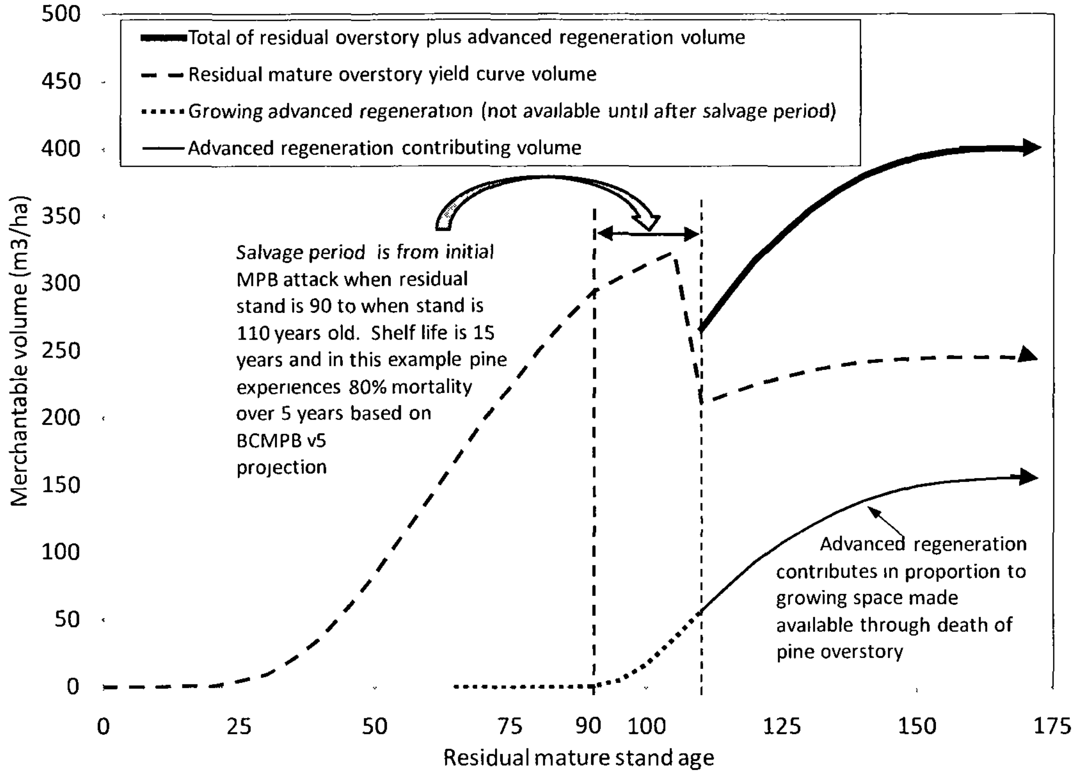

Figure 2.12: Simplified example of how residual mature overstory volume (from figure 2.8) is added to advanced regeneration volume (from SBS mk1 based on VDYP from Figure 2.10) to obtain total volume at harvest in the SELES model.
In this example approximately 40% of the total residual overstory is killed (80% of the pine) by MPB and advanced regeneration is assumed to occupy the available growing space.

These two scenarios, where alternate growth and yield models are used to predict future AR volume, do not model protection of stands with AR. They are to be considered as a refinement over the base case in that considerations for the presence of AR are incorporated. In modeling these scenarios, AR in a BEC subzone is assumed to grow along the SORTIE ND or median based VDYP7 yield curves. In this way, all stands are assumed to have an equal probability of having understory attributes as documented in Table 2.10.

This is supported by earlier findings that abundance of AR is more random and was not associated with increased site productivity (site index) or percent of pine in the original overstory. AR tends to be randomly distributed across a BEC subzone. Inherent in these two scenarios is that post-MPB unsalvaged stands have equal likelihood of having AR as stands that were salvaged. All further scenarios modeled in this study use VDYP7 as a basis for predicting growth of AR

2.4.3.4 Contribution from Advanced Regeneration: Prioritizing stands with lower levels of advanced regeneration for Salvage Harvest

The objective of these scenarios is to examine the sensitivity of the PG TSA projected timber supply to prioritizing stands with lower levels of AR for harvesting during the uplift salvage period (years one to fourteen). Theoretically, this leaves stands with higher levels of AR for harvest in the mid-or long-term. For each subzone, mature leading pine polygons in the VRI are randomly assigned an effective age based on the distribution of basal area for the study area (Table 2.11 and Table 2.12). The effective age is determined from BA as described in section 2.4.3.3. All stands with an effective age of 50 or more are assigned an effective age of 50 years. A GIS spatial layer (or surface) of effective age values was created and loaded into the SELES model (Figure 2.13). The resulting area distribution of AR for the timber harvesting land base indicates that 18.6 % (122,843 ha) of the mature leading pine stands in the selected SBS subzones in the Prince George TSA have an effective age of zero while 36.8% (242,643 ha) have an effective age of 30 or more (Table 2.12, Appendix X).

As well as providing effective age to the SELES model this GIS spatial layer is used to establish priorities for harvest during the salvage period. The priority for harvest is defined as one over the effective age. A harvest queue is created for the SELES model ranked from largest value to smallest. For example, a forest cover polygon having an AR effective age of one has the highest priority for harvest and the polygon with a value of 50 is ranked with the lowest priority. For the purposes of prioritization all polygons with an effective age of zero are re-assigned a value of one to prevent an infinite number from being generated in the formula.

Table 2.11: Percentage of advanced regeneration by BEC subzone in each effective age category.

Effective age	Biogeoclimatic Subzones						
	SBS dk	SBS dw2	SBS dw3	SBS mc3	SBS mk1	SBS vk	SBS wk1
0	33.5	20.9	17.0	19.7	16.0		4.7
17							9.3
20					26.5		
22			19.0	13.1		10.0	10.5
24	29.2	23.5			11.2	10.0	17.4
26			13.6	13.1		10.0	9.9
27						30.0	15.7
28					8.6	20.0	9.3
29	14.9	20.0	11.1	6.6		10.0	
30					11.6	10.0	3.5
31							4.1
32			10.6	3.3	3.4		3.5
33	8.2	6.1					4.7
34			6.4	1.6	6.0		1.2
35							1.7
36		10.4		3.3	2.2		1.7
37	5.5		2.7		3.4		1.2
38				4.9	2.2		
39		3.5					
40	2.9		4.7	4.9	2.2		
41				1.6			0.6
42		3.5	2.0	1.6	1.5		
43	0.6		2.5		1.1		
44		1.7	2.7		0.7		
46	1.5	0.9	1.5	4.9	0.7		0.6
47					0.4		
48	0.3	2.6	1.5	3.3	0.0		
49					0.4		
50	3.5	7.0	4.7	18.0	1.9		0.6
All Ages	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Growth of AR is based on volumes generated by VDYP7 using the stand attributes of Site Index (BHA_{50}) and species composition reported in Table 2.10. In these scenarios, VDYP7 volume tables used are not adjusted as in Figure 2.10 because the effective age is taken from the GIS spatial layer as the simulation runs. Unadjusted VDYP7 volume tables are reported in Appendix VIII.

Table 2.12: Extrapolated timber harvesting land base area (hectares) of advanced regeneration by BEC subzone in each effective age category for the Prince George TSA (all 3 forest districts).

effective age of advanced regeneration	SBS dk	SBS dw2	SBS dw3	SBS mc3	SBS mk1	SBS vk	SBS wk1	Grand Total
0	22,118	7,793	32,604	16,496	42,686		1,146	122,843
17							1,889	1,889
20					72,607			72,607
22			33,167	11,768		180	2,477	47,592
24	16,080	10,135			31,644	504	5,525	63,888
26			25,111	11,412		387	3,496	40,406
27						1,364	3,650	5,015
28					19,193	585	2,438	22,216
29	7,968	7,912	18,744	5,528		257		40,410
30					28,853	247	1,101	30,200
31							1,082	1,082
32			18,323	2,206	9,319		762	30,611
33	4,229	2,660					653	7,543
34			10,562	919	16,981		168	28,630
35							251	251
36		3,847		2,814	5,614		335	12,610
37	3,365		4,910		6,992		184	15,452
38				4,028	5,182			9,210
39		1,727						1,727
40	1,634		7,802	4,227	8,515			22,178
41				1,380			112	1,492
42		1,446	3,448	1,216	3,785			9,896
43	388		4,307		3,481			8,176
44		688	4,678		2,228			7,594
46	884	293	3,491	4,641	2,069		163	11,541
47					1,049			1,049
48	96	1,042	2,317	2,678				6,134
49					720			720
50	2,297	3,638	10,514	15,538	4,442		118	36,548
Grand Total	59,059	41,182	179,980	84,853	265,362	3,524	25,549	659,509

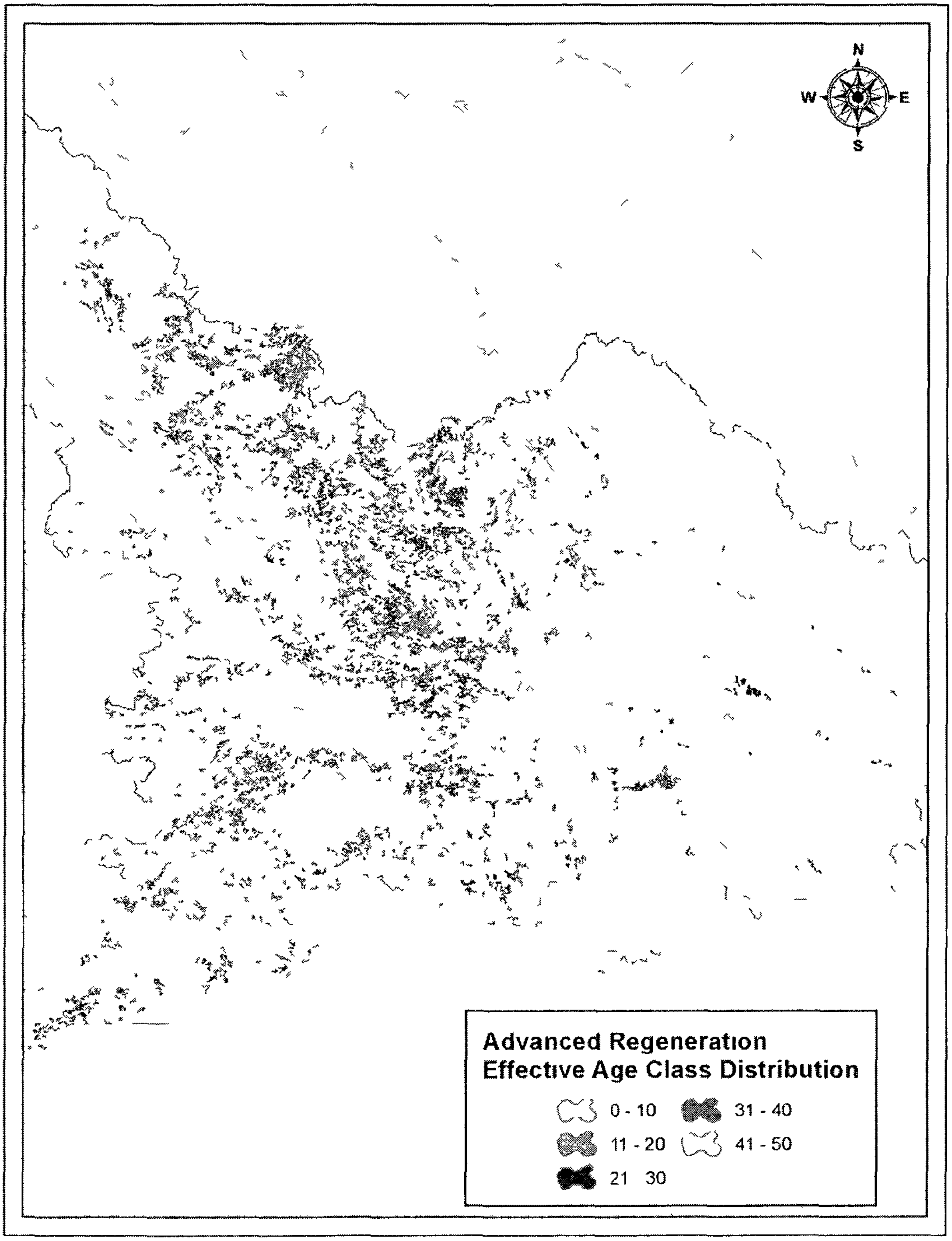

Figure 2.13: Map of assigned effective ages of advanced regeneration in mature leading pine stands in the Prince George TSA

2.4.3.5 Contribution of Advanced Regeneration: Protection of Stands with Higher Effective Ages of Advanced Regeneration

A final set of scenarios was examined where leading pine stands with higher AR effective ages are protected. These scenarios use the spatial GIS spatial layer of AR effective ages discussed in section 2.4.3.4 (Figure 2.13). The first scenario reserves all stands with AR effective age greater than or equal to 30 years in the SBS mk1 from salvage harvest in the first 15 years of the model simulation. As well as having significant area, the SBS mk1 was chosen as it represents the subzone with highest initial potential gain as indicated by the VDYP7 yield curves (Figure 2.10). The THLB area reserved is 62,038 ha in Fort St. James District and 37,194 ha. in Prince George District (Appendix X). The transfer function in SELES was used to facilitate these scenarios where reserved area is transferred into the contributing land base after a certain period of time. Similar to the methodology discussed in 2.4.3.4, the volumes recovered upon harvest are based on VDYP7 (Appendix VIII) adjusted forward based on the effective age of the AR Figure 2.13).

Two additional scenarios protect stands in the SBS mk1 where AR age is greater than or equal to 30 years old. One scenario reserves all eligible stands for 30 years and the second scenario releases the DJA area at year 15 and the DPG area after 30 years. The purpose of these scenarios is to attempt to fill the mid-term timber supply gap between 30 and 40 years. Appendix XI provides a summary of pertinent modeling assumptions used in the various timber supply scenarios.

A summary of the scenarios tested including the target salvage harvest level, brief scenario description, and section where the results are documented is shown in Table 2.13.

Table 2.13 Summary of tımber supply scenarıos tested

Scenarıo group	Scenarıo descrıptıon	Inıtıal target harvest level (mıllıons of m³/year)	Section of thesıs that scenarıo assumptıons are documented	Section of thesıs that results are documented	
				Chapter	Figure number(s)
Base Case (PG TSA Alternatıve scenarıo 2)	Replıcate TSR base case	12 5	2 4 1 (Fıgure 2 6)	3 1	3 1
	Elımınate understory contrıbutıon of secondary stand structure (only resıdual	12 5	3 1	3 1	3 1
Non spatıal advanced regeneratıon	Advanced regeneratıon modeled usıng VDYP7 growth and yıeld curves as per Fıgure 2 10	12 5	2 4 3 3	3 2	3 2 & 3 3
	Advanced regeneratıon modeled usıng VDYP7 growth and yıeld curves as per Fıgure 2 10	14 944	2 4 3 3	3 2	3 4
	AR modeled usıng SORTIE ND growth and yıeld curves as per Fıgure 2 11	12 5	2 4 3 3	3 2	3 2 & 3 3
	AR modeled usıng SORTIE ND growth and yıeld curves as per Fıgure 2 11	14 944	2 4 3 3	3 2	3 4
Spatıal effectıve ages of advanced regeneratıon (reference Fıgure 2 13)	Spatıal test reference scenarıo (no prıorıtızatıon or protectıon of AR) VDYP7 models G&Y	12 5	3 3	3 3	3 5
Spatıal effectıve ages of advanced regeneratıon scenarıos based on prıorıtızıng stands harvested ın the salvage phase wıth low effectıve ages of AR (all scenarıos use unadjusted VDYP7 based AR Appendıx VIII)	Prıorıtıze over TSA spread potentıal benefıt over entıre mıd term	12 5	2 4 3 4	3 3	3 5 & 3 6
	Prıorıtıze over TSA focus on ıncreasıng harvest ın late mıd term	12 5	2 4 3 4	3 3	3 5
	Prıorıtıze over DPG spread potentıal benef t over entıre mıd term	12 5	2 4 3 4	3 3	column 8 ın Table 3 1
Spatıal effectıve ages of advanced regeneratıon reserve all stands from ınıtıal salvage harvest that have effectıve age > 30 years ın SBSmk1 (all scenarıos use unadjusted VDYP7 based AR Appendıx VIII)	Reserve all area (99 232 ha) untıl year 15	12 5	2 4 3 5	3 4	3 7
	Reserve DJA area (62 038 ha) untıl year 15 and DPG area (37 194 ha) unt l year 30	12 5	2 4 3 5	3 4	3 7
	Reserve all area unt l year 30	12 5	2 4 3 5	3 4	3 7
	Reserve all area untıl year 30 but reduce salvage target harvest to past 5 year average	11 3	2 4 3 5	3 4	3 8

Note See also Appendıx XI for a detaıled descrıptıon of the assumptıons regardıng advanced regeneratıon used ın each scenarıo

2.5 HARVEST FORECASTING USING SELES: SPATIALLY EXPLICIT LANDSCAPE EVENT SIMULATOR

2.5.1 MODIFICATIONS TO SELES TO ALLOW MODELING OF SECONDARY STAND STRUCTURE AND ADVANCED REGENERATION

SELES is a raster based modeling platform used to build spatially explicit landscape simulation models that explore changes in landscapes resulting from natural and anthropogenic events and processes (Fall and Fall 2001). Past applications have included modeling fire ecology, grassland biodiversity, landscape ecology theory, alternative harvest techniques and endangered species risk assessments (Fall and Fall 2001). SELES STSM was modified by Andrew Fall to model the consideration of live secondary stand structure associated with MPB killed pine stands.[45] Modifications include four main components;

1. Incorporation of a GIS spatial layer that specifies stand level lodgepole pine mortality by year (BCMPB v5).
2. Ability to track growth of the remaining live mature component in MPB attacked stands separate from the growth of understory and carry both layers forward in time. The model tracks the growth of residual overstory (canopy trees) and understory (sub-canopy regeneration) on separate volume tables.
3. Ability to trigger the start of understory growth based on a specified percent of mortality of the overstory pine.
4. Incorporation of a GIS spatial layer that specifies the amount of AR in mature MPB damaged pine leading stands.

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[45] Personal communication with Andrew Fall, February 2009. andrew@gowlland.ca.

Further modifications done in the spring of 2010 include the creation of a subroutine for prioritizing stands for harvest based on the effective age of advanced regeneration. SELES STSM computer code showing modifications is shown in Appendix XII.

2.5.2 Principles used to Establish Appropriate Harvest Forecasts using SELES: Finding the Optimum Timber Supply Solution

There are a number of principles used to establish acceptable and optimal harvest forecasts when modeling timber supply for this case study: First, establishment of the long-term sustainable harvest level for each scenario is done using a 250-year planning horizon. Using current computer hardware, a single computer simulation for the Prince George Timber Supply Area often took 3 to 4 hours. In some instances, establishment of the long-term level for a particular scenario required ten simulations or more. Once the long-term level was established the planning horizon was reduced to 70 years for subsequent scenario testing. The first 30 years of the forecasts are annual to allow for refined assessment of modeling dynamics. From year 30 to 250, the model runs on a decadal harvest/grow cycle.

Second, SELES is a simulation model as opposed to an optimization model. As discussed above, this means that it is an iterative procedure to establish an acceptable harvest flow for a given scenario. The process consists of inputting target harvest levels, running the model and checking the results for an acceptable solution. If the timber forecast is not maximized over the entire planning horizon, the target harvest levels are revised and the model re-run until an acceptable solution is found. For this study, an acceptable harvest forecast is one that is maximized for timber production throughout the planning horizon – short and mid-term while maintaining a sustainable, non-declining long-term supply. This is further measured by assessing the available mature growing stock on the timber harvesting land base. For a timber supply forecast to be acceptable and maximized, in the long-term (after 100 years), growing stock must be a flat-line with only a minor wavelike perturbation. A long-term, flat-line growing stock is the general criteria of sustainability in BC.[46]

Third, in establishing the harvest forecast there are three components to consider; long, mid and short-term levels. In this study the long-term level is established first by testing levels that can be sustained from 100 to 250 years using the measure of sustainable growing stock discussed above. Once the long-term level is established, the mid-term level is established as the highest level achievable post-MPB salvage period without detrimentally affecting the previously established long-term. In this case, a step up from the mid-to long-term is based on an assessment of when the second growth managed stands begin to become available The short-term is characterized by the MPB salvage phase and is generally prescribed as the current AAC or some other appropriate level as previously discussed. The length of time that the short-term can be maintained is related to the availability of salvageable pine which is dependent on the 15-year shelf life established for the base case as discussed in detail previously

[46] Timber Supply Analysis Considerations describing acceptable Harvest flows are provided to Innovative Forest Practice Agreement (IFPA) holders in a letter from the Chief Forester dated April 6, 2001 Accessed June 1, 2010 as Appendix 3 (p 30) in the MFR Rationale for Determination of Increase in AAC for the Morice and Lakes IFPA, William J Warner, RPF Regional Manager Northern Interior Forest Region http //www for gov bc ca/rni/guidelines/Rationale%20for%20Determination%20of%20Increase%20in%20AAC%20for%20Morice%20and%20Lakes%20IFPA pdf

CHAPTER 3.

RESULTS OF CASE STUDY: IMPACT OF INCORPORATING ADVANCED REGENERATION INTO TIMBER SUPPLY MODELING FOR THE PRINCE GEORGE TIMBER SUPPLY AREA.

Comparisons were made among SELES model outputs examining the impact on the mid-term timber supply. In the course of modeling for the base case, it was found that timber supply is severely constrained between years 30 and 40 by other resource values such as old growth objectives and visual criteria. During this period, making additional volume available to the SELES model generally does not result in an increase in timber supply. Simply, the land base is locked up for use by other integrated resource management objectives that require a minimum amount of area be retained in a mature state. This is referred to as a pinch point. Although it is very common when modeling timber supply, it typically occurs later in a forecast (years 80 to 100) when the model has run out of mature timber. Because of the massive mortality caused by MPB, it occurred much earlier in the harvest forecast. After this period of time, ample additional area becomes mature and any additional volume and area that is made available to the model is harvested. As a result, timber supply impacts are reported for two components of the mid-term; the early mid-term from years 15 to 39 and the later mid-term from years 40 to 59.

3.1 BASE CASE

Despite the conservative approach to understory used in the base case, modeling suggests there is a significant contribution to long-term timber supply from unsalvaged MPB attacked stands. The contribution to the base case of understory from pine leading stands that were not salvage harvested is illustrated by a timber supply scenario in which understory was not permitted to contribute (Figure 3.1).

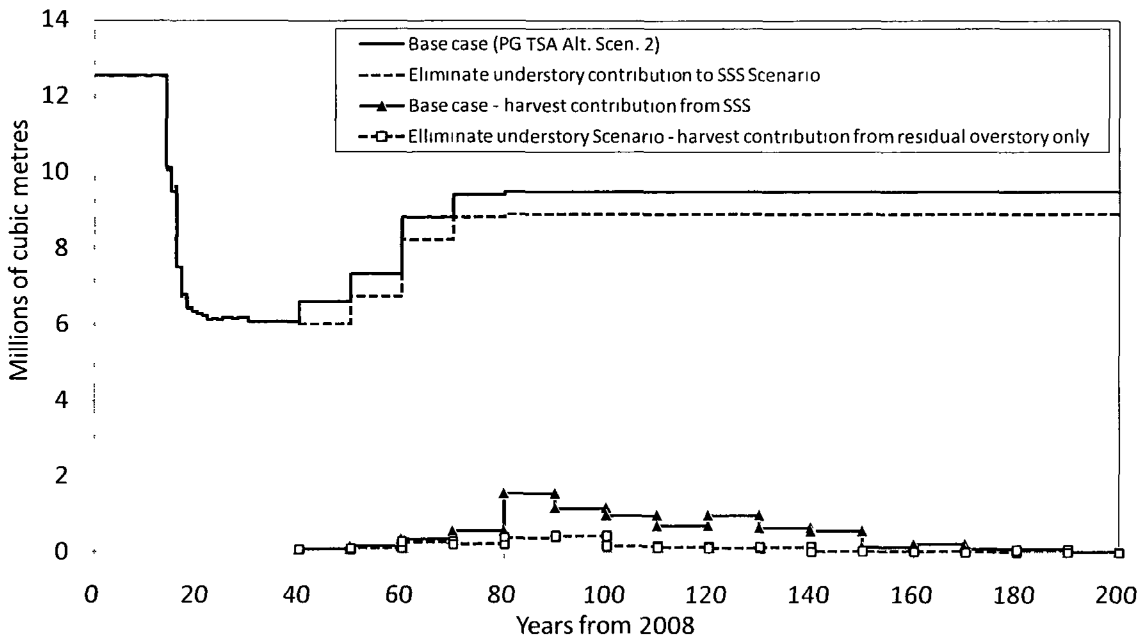

Figure 3.1: Harvest forecast showing the contribution from secondary stand structure present in attacked pine stands for both the base case and a modified base case scenario where the understory component of secondary stand structure is eliminated from contributing to future merchantable volume.

For the base case, secondary stand structure contributes significantly after year 60 and reaches a maximum contribution of over 1.5 million m^3/year (17% of forecast) between 80 and 90 years (Figure 3.1). Between years 40 and 170, harvest of secondary stand structure originating from MPB attacked, unsalvaged stands averages 625,000 m^3/year and totals over 80,000,000 m^3. In the base case, the presence of understory does not help alleviate the mid-term because merchantable volume does not begin to accrue on the VDYP7 natural stand yield tables for at least 20 years. This, combined with the 10-year regeneration delay and the delay associated with the requirement for 50% mortality of pine prior to beginning the 10-year regeneration delay ensures that most understory stands do not begin to contribute to future volume for 40 years in the base case (later mid-term).

If the understory component of secondary stand structure is eliminated the mid-term timber supply fall-down is extended for a further 10 years (to 50 years) and the forecast is reduced by approximately 600,000 m^3/year until year 150 (Figure 3.1). This demonstrates that the forecast for the base case is highly dependent on the understory component despite the fact that the modeling of understory is very conservative. On its own, the residual mature overstory contributes approximately 200,000 m^3/year to the forecast after year 60 (Figure 3.1).

3.2. SCENARIOS INCORPORATING ADVANCED REGENERATION USING VDYP7 AND SORTIE ND GROWTH AND YIELD MODELS

These scenarios assume AR exists in MPB attacked stands but is not protected or prioritized for harvest. On average, the mid-term timber supply forecast between years 15 and 60 is increased by 380,000 m^3/year when VDYP7 is used to generate AR volumes (Figure 3.2 and Table 3.1). This increase is approximately 6% above the base case mid-term harvest level of 6.64 million m^3 per year. When SORTIE ND is used to generate AR volumes the mid-term harvest level is increased over the base case by 1.5 million m^3/year (25%) to 8.14 million m^3/year (Figure 3.2 and Table 3.1). Long-term harvest level is achieved by year 70 for all scenarios and is 9.5 million m^3 per year.

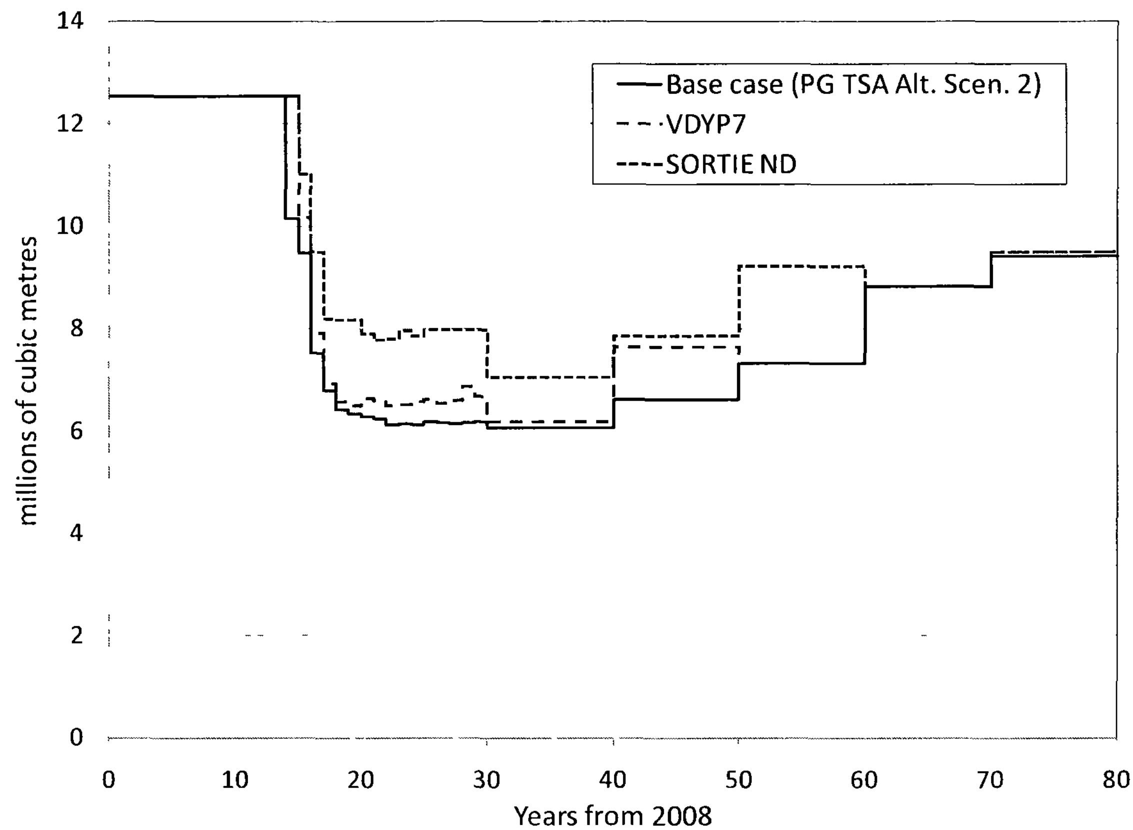

Figure 3.2: Harvest forecast for the Prince George TSA base case and scenarios where advanced regeneration is incorporated using two different natural stand growth and yield models, VDYP7 and SORTIE ND.

For the VDYP7 based scenario, contrary to expectations, the increased mid-term harvest level is not filled with secondary stand structure timber alone but is also supported by increased contribution from non-pine leading stands and managed second growth originating from pine salvage. This shows how dynamic harvest modeling can be in that the volume available from AR allows other components of the forecast to be brought forward to assist in filling the mid-term gap. Primarily, the availability of additional volume between years 40 and 150 from AR, allows additional existing mature volume (spruce and other species) to be taken earlier (Figure 3.3, middle panel).

In the case of the AR generated from SORTIE ND, the mid-term is more directly impacted by increased AR (Figure 3.3, bottom panel). This is due to the very steep accrual of initial volumes for the AR yield curves (Figure 2.11). Most of the leading pine stands in the Vanderhoof and Prince George forest districts were attacked before 2008 and the AR has already accrued significant volumes by the end of the salvage period. For SORTIE ND, several of the BEC subzones show volumes of over 150 m^3/ha accruing by 20 years from now (Figure 2.11). This volume, combined with the residual overstory, exceeds the minimum harvest volume criteria of 182 m^3/ha and significant harvest occurs. The SORTIE ND scenario shows less volume being harvested from secondary stand structure after year 70 than the base case and the VDYP7 scenario (Figure 3.3). The long-term is not detrimentally affected by this as the large volume of secondary stand structure harvested in years 13 to 30 is regenerated onto managed stand yield curves and is ready for harvest by year 70 to 80. In 80 years from 2008 over half of the harvest forecast originates from managed stands less than 60 years old.

If an initial target harvest of the current AAC (14.944 million m^3/year) is modeled, an additional 30 million m^3 is salvaged which decreases the area available for harvest in the mid-term by 120,000 ha. This results in a significantly lower forecast harvest level in late mid-term compared to the scenarios based on the base case (Figure 3.4) and the period to fall-down is reduced by two years to 12 years.

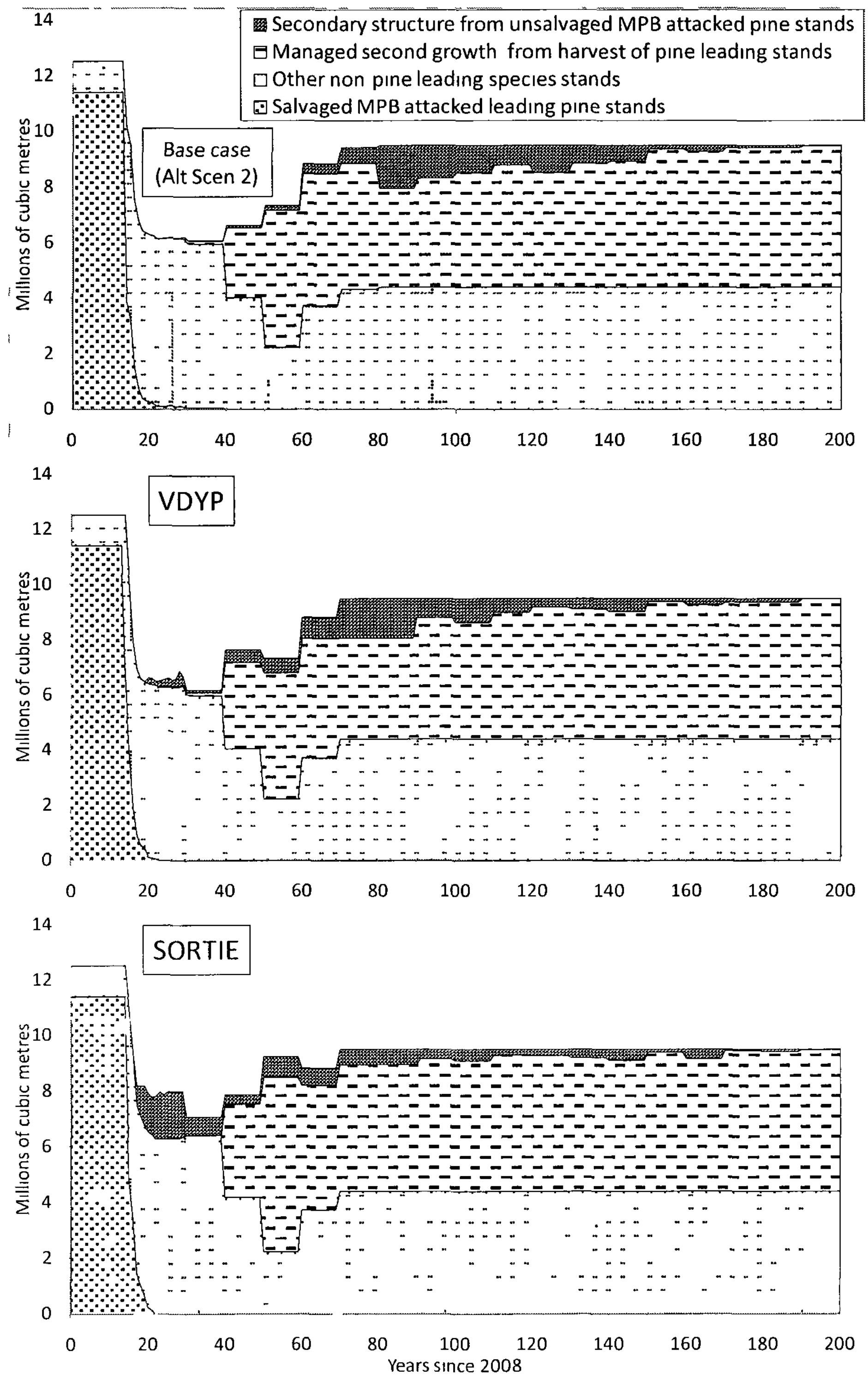

Figure 3.3: Harvest forecast for the base case, VDYP7 and SORTIE ND advanced regeneration scenarios showing the various components that support the harvest forecast including secondary stand structure from unsalvaged MPB attacked pine stands

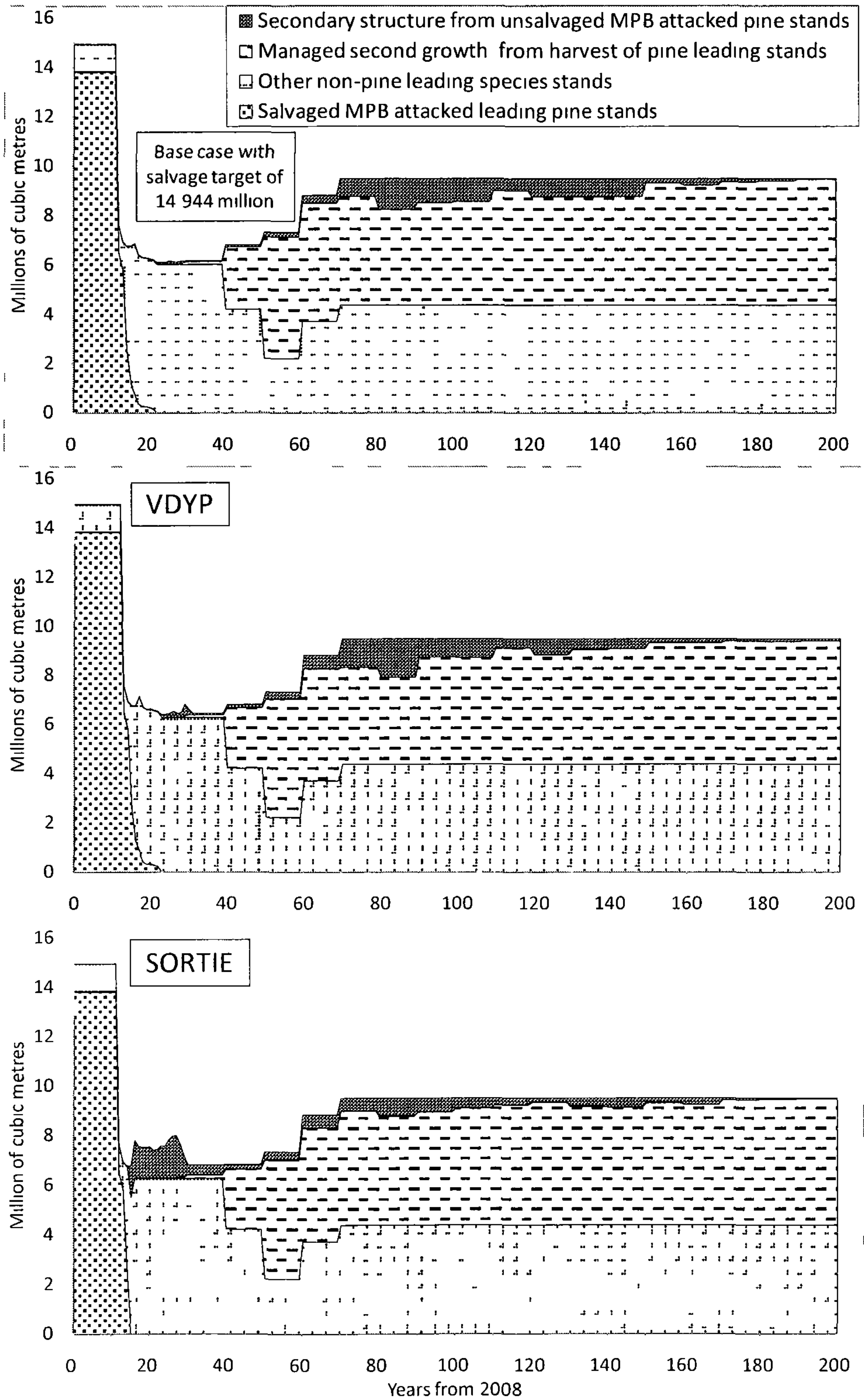

Figure 3.4: Harvest forecast for the base case, VDYP7 and SORTIE ND advanced regeneration scenarios with 14 944 million initial harvest target showing the various components that support the harvest forecast

3.3 SCENARIOS INCORPORATING ADVANCED REGENERATION CONSIDERATIONS: PRIORITIZING STANDS WITH LOWER LEVELS OF ADVANCED REGENERATION FOR SALVAGE HARVEST

Four scenarios were tested incorporating VDYP7 predictions for AR and a GIS spatial layer that specifies the effective age of AR in mature MPB damaged pine leading stands. This replaces theVDYP7 median based effective age applied across an entire BEC subzone. These scenarios were tested with an initial target harvest level of 12.5 million m^3/year. Scenarios tested include a reference scenario where no prioritization of stands was made but the GIS spatial layer for effective age of AR is employed. Three other scenarios were tested where stands with little or no AR, or young effective ages, are prioritized for salvage harvest:

1. over the entire TSA
2. over the Prince George forest district portion of the TSA only and
3. over the entire TSA but focusing on filling the late mid-term (years 40 to 59).

The reference scenario is most appropriately compared to the non-spatial median based effective age VDYP7 scenario. The only difference in the modeling of these two scenarios is the methodology for defining effective ages for the AR. For the reference spatial scenario the mean mid-term harvest level (year 15 to 59) is 6.96 million m^3/year, which is 0.06 million m^3/year (0.9%) lower than the median based VDYP7 scenario (Table 3.1). When different methodologies for incorporation of effective age of AR produce a similar result, there is added certainty that the modeling techniques used are functioning appropriately.

Results for two additional scenarios where prioritization of harvest for stands at the

TSA level and for DPG were disappointing because mean mid-term harvest levels were virtually the same as the reference scenario where no explicit prioritization had occurred. Results (Figure 3.5) show higher mid-term harvest forecast in years 15 to 29 for the scenario where prioritization occurs over the entire TSA. Similarly, the scenario where no prioritization occurred shows higher forecast in years 15 to 29 than the base case but a lower forecast for the 30 to 40 year period. For a scenario where prioritization occurred for DPG, mean mid-term level is 6.97 million m^3/year and for the scenario where stands are prioritized in the entire TSA mean mid-term achieved is 6.94 million (Figure 3.5). These mid-term levels are approximately 300,000 m^3/year higher than the base case but really are no better than the scenarios without prioritization.

When comparing the area available for mid-term harvest, model results show that for the scenario where prioritization occurred over the TSA, at the end of the uplift period (2022), an additional 15,954 ha. of stands were available for harvest that have effective ages of 30 to 39 years. The vast majority of this area (15,357 ha) is in DJA. Similarly for the category of AR with effective ages greater 39 years, an additional 16,495 ha were available to alleviate the mid-term supply, 15,095 ha. of which is in DJA. This comparison is made against the reference scenario where the spatial effective ages are incorporated into the modeling architecture but no harvest prioritization is modeled.

One reason that prioritization of stands does not produce more significant results is the complex level of SELES priority functions incorporated into base case assumptions. In modeling the PG TSA, priorities are established by forest district, leading species (deciduous, cedar, pine and other), economic radius and highest volume as well as the effective age of advanced regeneration. Other priorities overshadow the ability for SELES to focus harvest on these stands.

An additional scenario was tested where prioritization occurs over the TSA but where the focus is filling the late mid-term period. This was accomplished by lowering the early mid-term target harvest request in the SELES model and increasing the target after year 40. This allows the secondary stand structure to accumulate additional volume prior to being harvested. This increased overall mean mid-term harvest level to 7.23 million m^3/year, an increase of 0.59 million m^3 over the base case and 0.27 million m^3 over the spatial scenario where no prioritization occurs (Figure 3.5, Table 3.1). This increase is experienced mostly in the late mid-term (years 40 to 59) where the increase is 1.18 million m^3/year over the level achieved in the base case and 0.66 million over what is achieved in the spatial scenario where no prioritization occurs (Table 3.1).

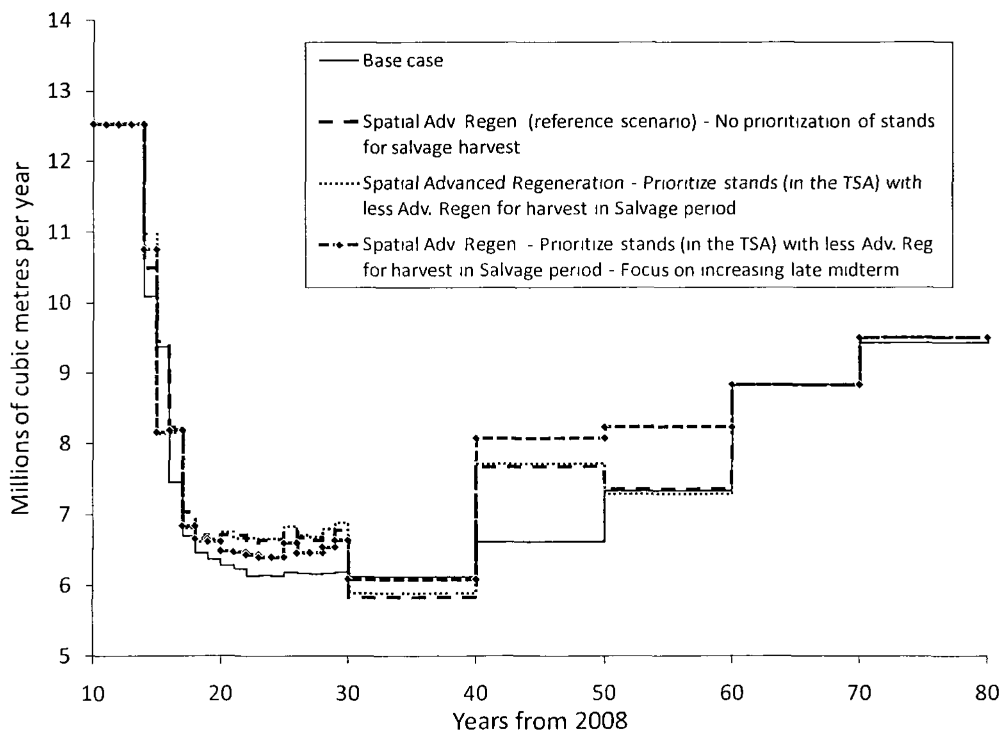

Figure 3.5: Harvest forecast for scenarios focusing on mid-term timber supply impact associated with prioritizing short-term salvage of stands with lower levels of advanced regeneration. Note that axes do not start at zero.

Results for the scenario where prioritization of salvage of stands over the TSA show that in the years immediately post-MPB salvage (up to year 30) the residual overstory component of secondary stand structure contributes the most to timber supply (Figure 3.6). After year 90 the predominant contribution is from AR (Figure 3.6). In this latter period, the residual overstory component of secondary stand structure was past culmination age and is at the flat-line portion of the volume curve. For this case study, mature stands were defined as stands over 60 years old in 2008. In 90 years from 2008 the residual component of stands are over 150 years old.

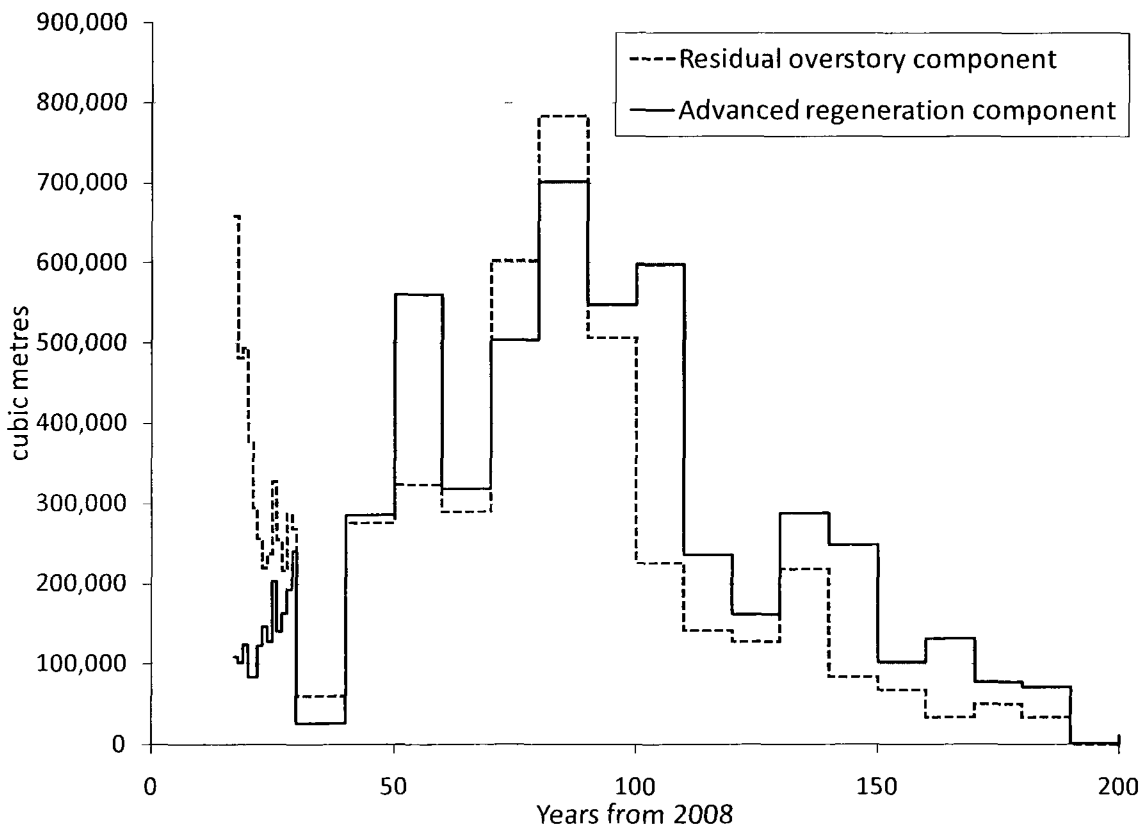

Figure 3.6: Harvest forecast components of secondary stand structure for the scenario where stands with young effective ages or no advanced regeneration are prioritized for harvest during the salvage period.

3.4 SCENARIOS INCORPORATING ADVANCED REGENERATION CONSIDERATIONS: PROTECTION OF STANDS WITH HIGHER EFFECTIVE AGES OF ADVANCED REGENERATION

Prioritization of stands with little or no AR for short-term harvest is one of the indirect techniques used in timber supply modeling to try and reserve stands with more abundant AR. The more direct technique uses the "transfer" function in SELES to reserve stands from harvest until a specified time and then transfers them back into the THLB. In this series of scenarios, all stands in the SBS mk1 with an effective age of AR of 30 or more are reserved from harvest.

Despite the fact that an abundance of leading MPB attacked leading pine stands exist, reserving some of these stands has a direct effect on the ability of the SELES model to achieve original salvage targets. For all scenarios, the salvage period was reduced to 12 years from the base case where fall-down begins in year 14 (Figure 3.7). The cost to short-term timber supply associated with reserving stands is not insignificant. Over the period from 12 to 17 years, a total of 16 million m^3 of initial salvage opportunity is foregone (Figure 3.7). This is approximately 10% less than the 160 million m^3 of salvage of leading pine achieved in the base case.

The first scenario in this series reserves all of the SBS mk1 with effective ages greater than or equal to 30 years from harvest until after year 15. The mean harvest level achieved over the mid-term period is 7.63 million m^3/year which is 0.99 million m^3/year greater than the base case. This increase is primarily seen in late mid-term where the level averages 8.65 million m^3 which is 23.9 percent above the base case (Table 3.1). Lost salvage opportunity is offset by a gain from years 18 to 59 totalling 40.5 million m^3.

Almost all of the scenarios tested in this study show a marked decrease in available timber supply between 30 and 40 years. Manipulating the harvest flow by adjusting the AAC target request in SELES by time period was generally not successful in closing the mid-term gap. The final two scenarios attempt to fill this gap and bring harvest levels back up to sustainable levels as quickly as possible.

A scenario was done where the area of SBS mk1 reserved from harvest in DJA is brought back in 15 years while the area in DPG is brought back in 30 years at the start of the deeper trough. This strategy increased the midterm in the 30 to 40 year time period by approximately 140,000 m^3/year to 6.41 million m^3/year but failed to yield a significantly higher volume overall (Figure 3.7, Table 3.1). This latter comparison is made against the previously discussed scenario where all of the reserved THLB area was released 15 years into the simulation. Overall results for the entire mid-term (years 15 to 59) yielded an average level of 7.58 million m^3/year : the early mid-term is 6.72 and the late mid-term 8.65 million m^3/year (Figure 3.7, Table 3.1). Except for the late mid-term level, all comparisons are lower than the previous scenario where all reserved area was released after year 15 of the simulation (2023).

The third scenario in this series reserved area in SBS mk1 for 30 years before allowing it to contribute to timber supply. The objective in this scenario was to test whether reserved stands can be used to fill a persistent mid-term timber supply hole beginning in year 30 and to explore the potential to climb out of the mid-term fall-down period sooner. For the entire mid-term (years 15 to 59) an average level of 7.66 million m^3/year was achieved which is 30,000 m^3/year (0.4%) higher than the scenario where stands are released after 15 years. While the average is not significantly different the level achieved from year 30 to 39 is 1.18

million higher than the scenario where stands are held for 15 years (Figure 3.7). The trade off is the harvest level achieved between year 15 and 29 which falls to almost the same level as the base case (Figure 3.7). For this scenario, the early mid-term is 6.86 and the late mid-term is 8.65 million m^3/year (Figure 3.7, Table 3.1).

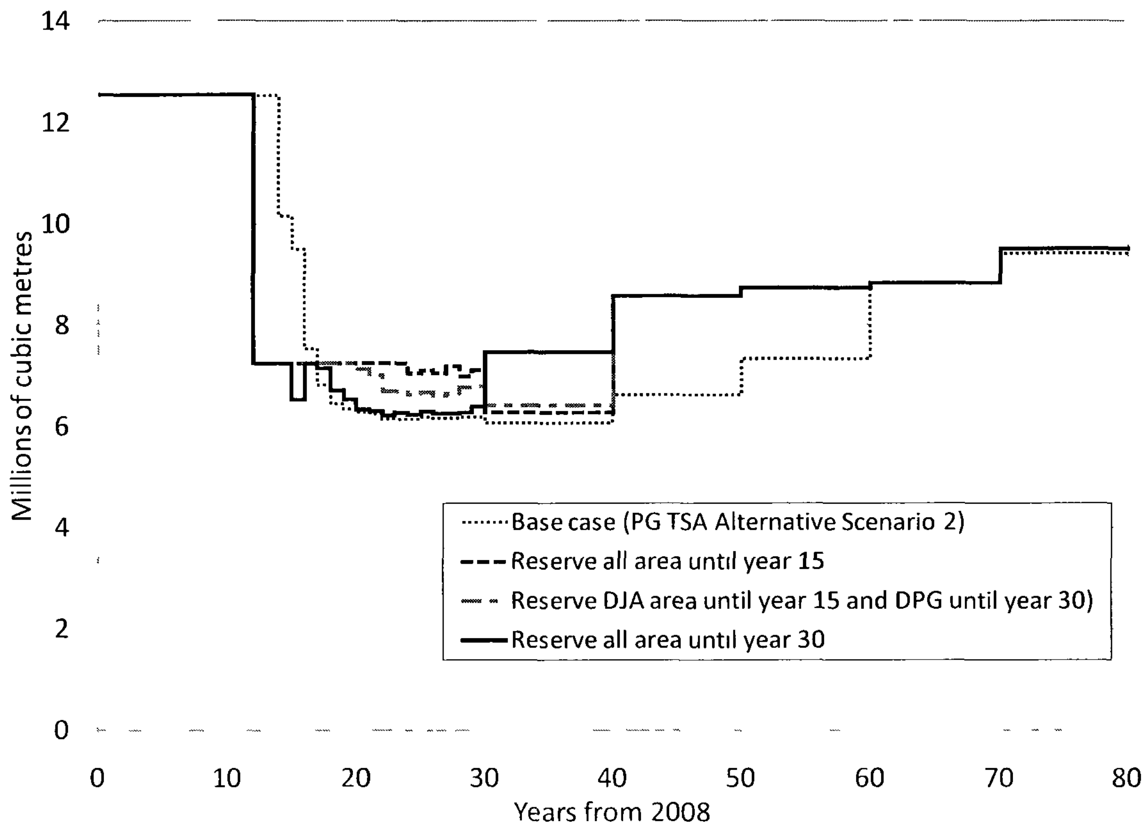

Figure 3.7: Harvest forecast comparing the base case and the scenarios where stands in the SBS mk1 with effective ages greater than or equal to 30 years are reserved from harvest until after the salvage period.

As discussed previously, in all scenarios where a portion of the SBS mk1 with the highest effective ages was reserved from harvest during the salvage period, the time to fall-down is accelerated by two years compared to the base case. A further scenario examined whether, under conditions where stands are reserved, the salvage period could be restored to the 14 years achieved in the base case For this scenario, the initial target harvest level was reduced to 11 3 million m^3 down from 12 5 million m^3 For the period between 2004 and 2008, the actual harvest level achieved in the PG TSA was 11 3 million m^3/year [47] All other assumptions are the same as used for the previous scenario where stands with an effective age of 30 or greater in the SBS mk1 are reserved for 30 years Reducing the initial target harvest to 11 3 allows the elevated harvest rate to be maintained for an additional year before it drops to 10 million m^3 in year 14, 7 2 in year 15 and 5 6 million m^3 in year16 (Figure 3 8) An additional 7 million m^3 is salvaged over the 2 additional years compared to the scenario where the initial target harvest is 12 5 million (Figure 3 8) Over the 20 year period the target level of 11 3 million m^3 results in a net decrease in harvest opportunity of just over 9 0 million m^3 (Figure 3 8)

3.5 CASE STUDY SUMMARY OF RESULTS

The Prince George Timber Supply Area timber supply review base case did not recognize the abundance of advanced regeneration that exists in mature leading pine stands in SBS BEC subzones Modeling methodologies tested in this study indicate that advanced regeneration could be considered if data were available Consideration of the presence of advanced regeneration component of secondary stand structure can have a significant effect on the modeled mid-term timber supply (Table 3 1)

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[47] Table 8 in Prince George Timber Supply Area Public Discussion Paper, January 2010, accessed at http //www for gov bc ca/hts/tsa/tsa24/tsi4/24ts10pdp pdf

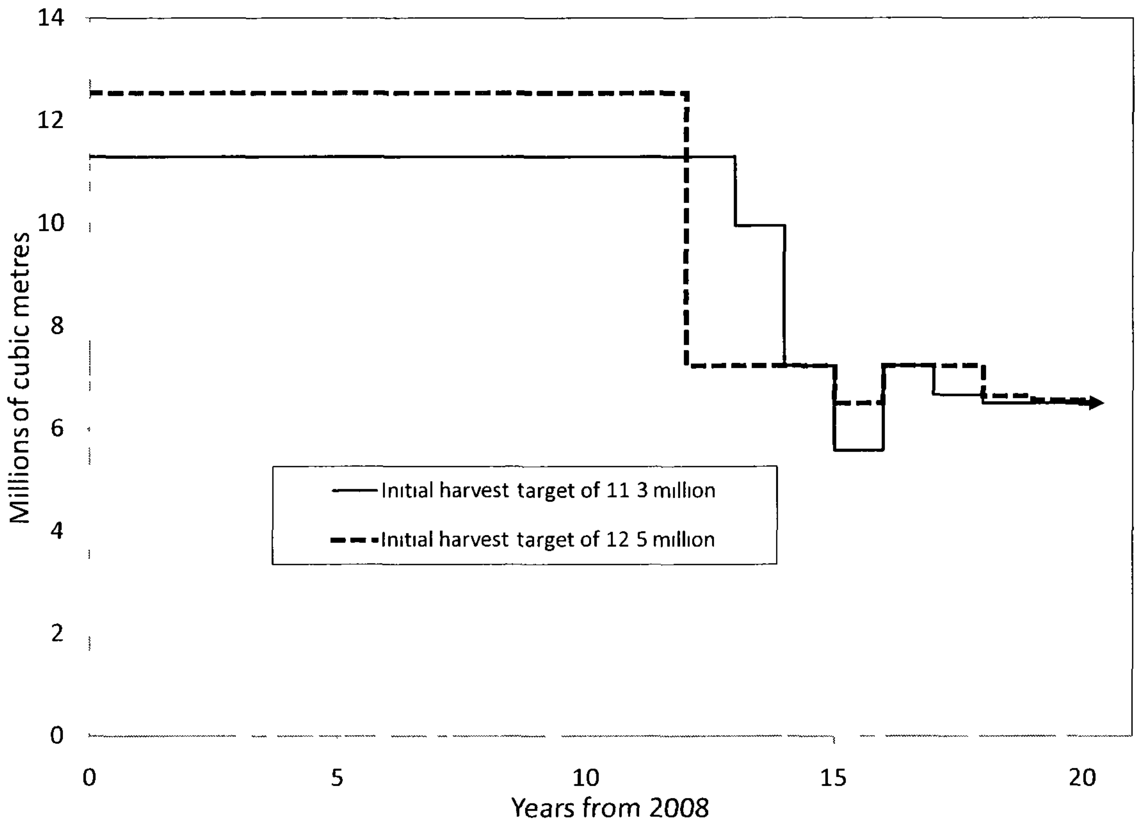

Figure 3.8: Salvage portion of harvest forecasts comparing initial target harvest levels where stands in the SBS mk1 with effective ages greater than or equal to 30 years are reserved from harvest until after 30 years.

Modifications to the SELES model allow for consideration of AR. If VDYP7 is used to generate advanced regeneration volumes, where stands are assumed to grow along a naturally established stand trajectory, the average mid-term harvest level for the PG TSA was increased by 5.7% (380,000 m^3/year) to 7.02 million m^3/year Alternatively, using SORTIE ND to generate advanced regeneration volumes, resulted in an average mid-term harvest level that was 22.6% (1.4 million m^3/year) higher than the base case. The mid-term period is defined as the period of time after accelerated salvage of pine (approximately year 15) to year 60 when the projected harvest level is expected to reach a pre-MPB sustainable level. It should be noted that these scenarios assume that all stands have equal opportunity to have AR and that stands with understory are not harvested with a greater focus than stands with no understory.

For scenarios where stands were prioritized or protected from harvest during the uplift period, AR volume over time is based on VDYP7 growth and yield model. When mature leading pine stands with low effective ages of advanced regeneration are prioritized for harvest during the salvage period the average mid-term harvest level was increased by 8.9% to 7.23 million m^3/year. These results are for the scenario where the focus of the increase is the late midterm. For three other scenarios in this series where there was no focused midterm objective the average mid-term harvest level was increased by 4.5 to 5.0% to 6.94 to 6.97 million m^3/year.

For the scenarios where stands with an AR effective age of over 30 years in the SBS mk1 (99,232 ha) are reserved from harvest until after the salvage period, the average mid-term harvest level was increased by approximately 1 million m^3/year to approximately 7.6 million m^3. The trade off is a reduction in the period to fall-down by 2 years to 12 years because less area is available to be harvested in the short-term. Reducing the initial target harvest level from 12.5 to the actual average annual harvest rate of 11.3 million m3 allowed the salvage period to be extended back to 14 years. The net result of this reduced target was a reduction in salvaged timber over the short-term of approximately 10 million m^3. However the average mid-term harvest level achieved did not benefit more than the previous scenario where levels were approximately 1 million m^3/year higher than the base case.

Table 3.1 Prince George TSA average mid-term harvest levels in millions of cubic metres per year for selected scenarios where the initial salvage rate is 12 5 million

mid term time period	Comparision attribute	Base case (PG TSA Alternative Scenario 2)	Non spatial advanced regeneration scenarios		Spatial advanced regeneration scenarios based on prioritizing stands harvested in the salvage phase with no advanced regeneration or low equ velant ages of AR (VDYP7 based)				Spatial Advanced Regeneration reserve all stands from initial salvage harvest that have equivelant age > 30 years in SBSmk1		
			Based on VDYP7	Based on SORTIE ND	No Prioritization reference spatial scenario	Prioritize over the entire TSA	Prioritize over the Prince George forest district only	Prioritize over the entire TSA forus harvest on filing late midterm	Bring stands from DJA and DPG back at year 15 (2023)	Bring stands from DJA back at year 15 and DPG at year 30	Bring stands from DJA and DPG back at year 30
early mid term (year 15 to 39)	mean harvest level	**6 37**	**6 65**	**7 80**	**6 53**	**6 48**	**6 54**	**6 49**	**6 81**	**6 72**	**6 86**
	increase in mean harvest compared to Base case		0 28	1 43	0 16	0 11	0 17	0 12	0 44	0 35	0 49
	% increase compared to Base		*4 4*	*22 4*	*2 5*	*1 7*	*2 7*	*1 9*	*6 9*	*5 5*	*7 7*
late mid term (year 40 to 59)	mean harvest level	**6 98**	**7 49**	**8 55**	**7 50**	**7 52**	**7 51**	**8 16**	**8 65**	**8 65**	**8 65**
	increase in mean harvest compared to Base case		0 51	1 57	0 52	0 54	0 53	1 18	1 67	1 67	1 67
	% increase compared to Base		*7 3*	*22 5*	*7 4*	*7 7*	*7 6*	*16 9*	*23 9*	*23 9*	*23 9*
entire mid term (year 15 to 59)	mean harvest level	6 64	**7 02**	**8 14**	**6 96**	**6 94**	**6 97**	**7 23**	**7 63**	**7 58**	**7 66**
	increase in mean harvest compared to Base case		0 38	1 50	0 32	0 30	0 33	0 59	0 99	0 94	1 02
	% increase compared to Base		*5 7*	*22 6*	*4 8*	*4 5*	*5 0*	*8 9*	*14 9*	*14 2*	*15 4*

CHAPTER 4.

DISCUSSION

The findings of the case study timber supply modeling has shown that taking AR into consideration makes a difference to the potential mid-term timber supply for the Prince George Timber Supply Area. However, significant uncertainty exist with timber supply modeling. The discussion is divided into three main sections; 1) modeling uncertainty, 2) economic considerations and 3) operational and policy considerations.

4.1 UNCERTAINTY ASSOCIATED WITH MODELING USED IN THE CASE STUDY

Jones *et al.* (2002) describe models used in forest resource management as an abstraction of knowledge. Knowledge and data support decision making processes in a continuum that generally begins with a resource management decision need (Jones *et al.* 2002). Researchers and analysts gather appropriate data based on current knowledge and formulated theory of ecosystem function, and interpret information into formats that can be utilized by models to predict future outcomes (Figure 4.1). Models inform decision makers by predicting a range of possible opportunities as well as risks associated with a certain set of assumptions and predictions (Jones *et al.* 2002).

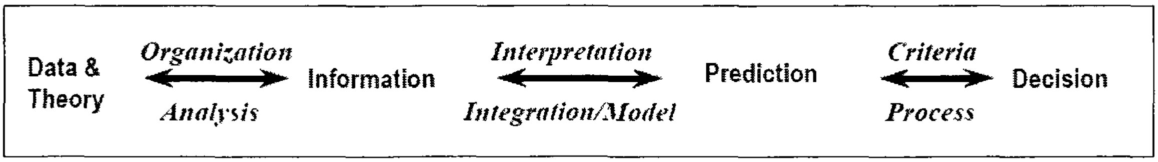

Figure 4.1: Resource management data/theory-decision continuum integrating the use of models. Adapted from Figure 1.1 in Jones *et al.* (2002).

Models help clarify ideas, refine problems and allow testing of hypotheses (theory) through continuous improvement type iterative processes based on feedback (Figure 4.1). All models are wrong because they are abstractions but some are useful (Boyland 2002). Complexity is often traded off with ease of use to focus on implications for a specific decision (McCann *et al.* 2006). Timber supply models generally do not model the complete workings of a forest ecosystem. Instead, they focus on modeling the operations and economics associated with harvesting, growth and yield of trees, and other objectives that govern the rate of extraction of trees such as biodiversity and visual quality objectives.

Nelson and Davis (2002), in discussing the level of spatial detail required in GIS inventories for use in timber supply models, suggest that there is often a tendency to incorporate data that would normally be used at the operational level to answer a strategic question. This comes from a belief that more precise data must yield more accurate results. In the case of timber supply modeling, increasing precision results in larger databases that significantly increase computer model run times and discourage further alternate scenario testing (Nelson and Davis 2002). Level of input detail must be carefully chosen to balance desired level of output precision with model efficiency and timeliness of decisions. Model utility may not be enhanced with increased input detail.

Errors in timber supply modeling arise from the main two building blocks, data and algorithms (Boyland 2002). Algorithms are abstraction and translation of processes that define rules for change over time. Boyland (2002) suggests that errors in algorithms are not easily measured because they result from inappropriate or misrepresentative process definitions. Quantification of algorithm error is often through sensitivity analysis where changes to process result in harvest forecast changes. Results are compared for reasonableness based on expert judgement of the researcher and possibly operational forestry staff. In the case study, algorithm error checking and resolution was achieved through several months of model testing.

Data, often referred to as inputs in simulation modeling, can have both accuracy errors and translational errors (Boyland 2002). An example from the case study is the methodology used to derive an appropriate growth and yield curve and assign an effective age for advanced regeneration. To derive growth and yield predictions based on the VDYP7 model, median values were selected over mean values because of the skewed nature of the AR data. Using mean values would result in a different VDYP7 prediction. Further, two alternate growth and yield models were tested to scope out the range of possible predictions: SORTIE ND and VDYP7. Sattler (2009) combined regeneration outputs from SORTIE-ND with Prognosis^{BC} to predict natural regeneration in unsalvaged MPB attacked stands. The 'correct', or best model for growth following death of the overstory layer will remain unknown until further, future data collection and analysis is done. Employing two different but generally accepted growth and yield models helps to limit or set bounds on the potential error.

Uncertainty in modeling has ramifications for decision making. Uncertainty is defined as a lack of information or knowledge brought about by limitations in understanding which can lead to incorrect algorithms (Jones *et al.* 2002). Uncertainty means that resulting decisions may be questionable or suspect.

As discussed above, errors are not easily quantified in timber supply analysis processes. The uncertainty and risk inherent in the case study are identified and documented below.

Five models were used at various stages of the case study:

- BCMPB v5 MPB mortality model (Walton *et al.*2008)
- SELES STSM (Fall and Fall 2001)
- VDYP7 (British Columbia Ministry of Forests and Range 2009b)
- SORTIE ND (Canham 2001)
- TIPSY (British Columbia Ministry of Forests and Range 2007b)

BCMPB v5 provides annual stand mortality in the form of a spatial GIS layer to the SELES model. Two growth and yield models (VDYP7 and SORTIE ND) are used to create alternative volume tables that SELES references to determine the merchantable volume expected upon harvest, and TIPSY is used to generate effective age for advanced regeneration. As discussed, in the absence of hard data, models are used to approximate or describe reality or to explore the effects of changes to variables on future outcomes. All of the models used in this study are designed to predict future states of the forest. The goodness of fit of model predictions depends on the integrity and accuracy of the original data used for calibration as well as the intended model range and scope. This study tries to limit uncertainty in modeling by limiting inputs, especially in the timber supply modeling component.

An uncertainty often overlooked when modeling timber supply is the accuracy of forest inventory data. In this case, it is the provincial vegetation resource inventory (VRI) database This database includes attributes of the forest such as species, age, height, stems per hectare, site productivity, and ecosystem site series, all of which are based on forest cover typing from air photos, supported by a small sample of ground plots. Overall accuracy of the merchantable volumes predicted in the BC VRI file is +/- 10% at the scale of the forest management unit (timber supply area).[48] This level of accuracy is deemed to be adequate for the decision making processes it supports

4..1.1 TIMBER SUPPLY

Timber supply modeling depends on a suite of forest management assumptions that define scenarios which predict possible future outcomes regarding the flow of timber from an area Because of the complexity of these models, small changes to assumptions like shelf-life of dead MPB-attacked timber can result in large changes in forecast supply Current BC policy recognizes uncertainty by requiring AACs to be revisited and re-determined, at minimum, every ten years.[49] A striking example of this is that, 15 years ago the 1995 timber supply review of the PG TSA predicted a flat-line harvest forecast of just over nine million m^3/year for 250 years No mention was made of possible mid-term fall-down associated with a future MPB epidemic [50] Over 15 short years, the MPB epidemic has come and gone leaving predictions of significant short falls in mid-term timber supply Uncertainty in prediction increases with time from the present as factors that influence forest management arise, change, or disappear (Figure 4 2) Changes can include refinements in biophysical

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[48] Nakatsu, D Personal Communication March 2007, Dick Nakatsu retired from the Inventory Officer position at the Northern Interior Forest Region in May of 2010 phone 250-596-1612

[49] British Columbia Forest Act sec 8 Accessed on June 20, 2010 at http //www bclaws ca/EPLibraries/bclaws_new/document/ID/freeside/96157_00

[50] Documented in the executive summary of the PG TSA Timber Supply Analysis Report Accessed on June 10, 2010 at http //www for gov bc ca/hts/tsr1/tsasea/tsa/tsa24/httoc htm

attributes as well as social values and product requirements.

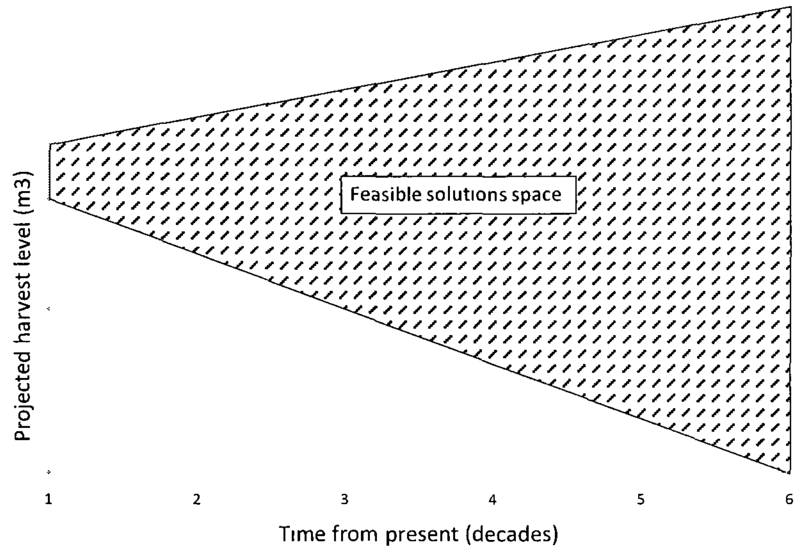

Figure 4.2: Hypothetical harvest forecast showing uncertainty in feasible solutions with time.

Underpinning this study is acceptance of the PG TSA Scenario 2A: *Shift to Fort St James to Salvage.*[51] This is a reasonable starting point, realizing that results are unique to the forest management unit and assumptions modeled. Results will be different for each forest management unit analysed as age class distribution, land base productivity, shelf life, species composition, amount of mature dead pine, definition of the economic timber harvesting land base, regeneration delay, objectives for other non-timber values, and other critical factors will likely be different.

The only factors varied in this case study analysis were initial target harvest level and those directly relating to testing different methodologies for incorporation of advanced

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[51] Documented in the Prince George TSA Timber Supply Review Public Discussion Paper, January 2010. Accessed on June 20, 2010 at: http://www.for.gov.bc.ca/hts/tsa/tsa24/tsr4/24ts10pdp.pdf

regeneration. Changing any one assumption could result in significantly different results in the PG TSA. Using a minimum merchantable volume limit of 140 m^3/ha, as used in the 2010 Lakes TSA Timber Supply Analysis[52] for example, allows second-growth managed stands to be harvested sooner and alleviates mid-term timber supply shortfalls quicker than in the PG TSA where the minimum harvest volume modeled is 182 m^3/ha.[53] Minimum harvest volume criteria are based on current licensee harvest performance in each forest management unit. In the case of the Lakes TSA, timber supply modeling may suggest that it is more advantageous to harvest all attacked leading pine stands and convert them to managed stands, rather than reserving some with higher amounts of AR.

This study is primarily about defining methodology and testing techniques for incorporating AR into timber supply modeling. In the process of exploring these techniques, and under a specific set of assumptions, there is an impact on mid-term timber supply associated with protection of stands with increased levels of AR.

4.1.2 SELES Spatial Timber Supply Model

SELES is a simulation model, as opposed to an optimization model. It depends on the modeller to assess acceptability of outputs after each run. Optimization models search out solutions through a series of runs based on a maximizing and/or minimizing specific output values. There are risks and uncertainty associated with simulation models in that the modeller or analyst decides when a solution is sufficiently optimized. One advantage is that optimal solutions can be found quickly if the modeller has advanced knowledge of the

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[52] Table 11 (p. 13) in Lakes TSA Timber Supply Review Updated Data Package. June 2010. Accessed at: http://www.for.gov.bc.ca/hts/tsa/tsa14/current_tsr_2009/14ts10dp_update.pdf
[53] Figure 3 (p. 9) in Lakes TSA Timber Supply Review Discussion Paper. May 2010. Accessed at: http://www.for.gov.bc.ca/hts/tsa/tsa14/current_tsr_2009/14ts10pdp.pdf

expected or desired outcomes of scenario being tested. This is also advantageous when running SELES using a database the size of the Prince George TSA where a typical model run currently takes between two and five hours. An optimization model may take several days to establish the best solution for a problem as large as the PG TSA. A disadvantage with simulation models is that care must be taken to ensure the solution identified is optimal for all time periods.

Results for spatial AR scenarios where stands with low effective ages are prioritized for harvest during the salvage period generally did not show improvement in mid-term timber supply over scenarios where no prioritization occurs. In modeling the PG TSA base case scenario, the SELES priority function is utilized to queue the harvest of stands with the highest volume per hectare, greatest economic return (closest to milling centre), leading species, and forest district. The AR priority function for advanced regeneration adds a further layer of complexity. Priority functions for AR may not have been great enough to overcome other priority queuing factors.

4.1.3 Growth and Yield

Growth and yield models are one of the main building blocks of timber supply modeling. In the various scenarios tested, well over half of the secondary stand structure contribution to the harvest forecast originates from advanced regeneration (Figure 3.6). Understanding the methodologies used to determine growth and yield estimates of advanced regeneration are critical to assessing uncertainty.

To facilitate SELES modeling, all stands in a subzone were assigned the same growth curve for AR. In the case of the non-spatial VDYP7 based scenarios, AR yields are based on median SI and species composition based on BA contribution. In reality, every stand is different in terms of species composition and BA (Figure 2.9a and 2.9b, Table 2.10). Modeling each stand uniquely may decrease uncertainty and risk but would increase the model run time given that there are 6.9 million raster polygons being evaluated by the model at each time period.

The techniques used to derive AR effective ages are not precise because the TIPSY growth and yield model reports BA to the nearest 1 m^2/ha (Appendix IX). This results in no subzones having effective ages below 17 years and median effective ages grouped between 24 and 28 years, other than for stands with no AR which have a zero value for effective age (Table 2.12). This is much less of a concern for the spatial scenarios where stands are protected and where assignment of effective age is based on the distribution of BA (Tables 2.9 and 2.11, Appendix X). In these scenarios, effective age ranges from 0 to 50.

The TIPSY model also reports top height (mean height of largest 100 trees per hectare) (Appendix IX). Alternatively, height could have been used to estimate effective age of AR but a model would be required to describe the height/diameter relationship for poles between 7.5 and 12.5 cm dbh. All sapling (1.37 m tall and < 7.5 cm dbh) heights were measured but for trees 7.5 cm dbh and above, heights were only taken on selected site trees to determine potential stand productivity. A noticeable difference was observed between the height diameter relationships for all saplings compared to sampled site trees (Figure 4.3). Employing an additional model to estimate height, so that top 100 tree heights could be determined, would have added further complexity and uncertainty to the study.

The randomly generated effective age spatial layer is created only once (Figure 2.13) and is based on the distribution of advanced regeneration found at the subzone level (Table 2.12). The abundance of AR may be better correlated one BEC level down to site series (moisture and nutrient regime), but this was not explored in this study. Harvested volume is the AR volume plus residual overstory volume. Creation of several versions of the spatial layer reduces the risk that might result from stands with high effective ages of AR paired to stands with abundant residual overstory, or vice versa. Testing and comparing scenarios using several randomly generated spatial layers would reduce the risk and uncertainty associated with this concern.

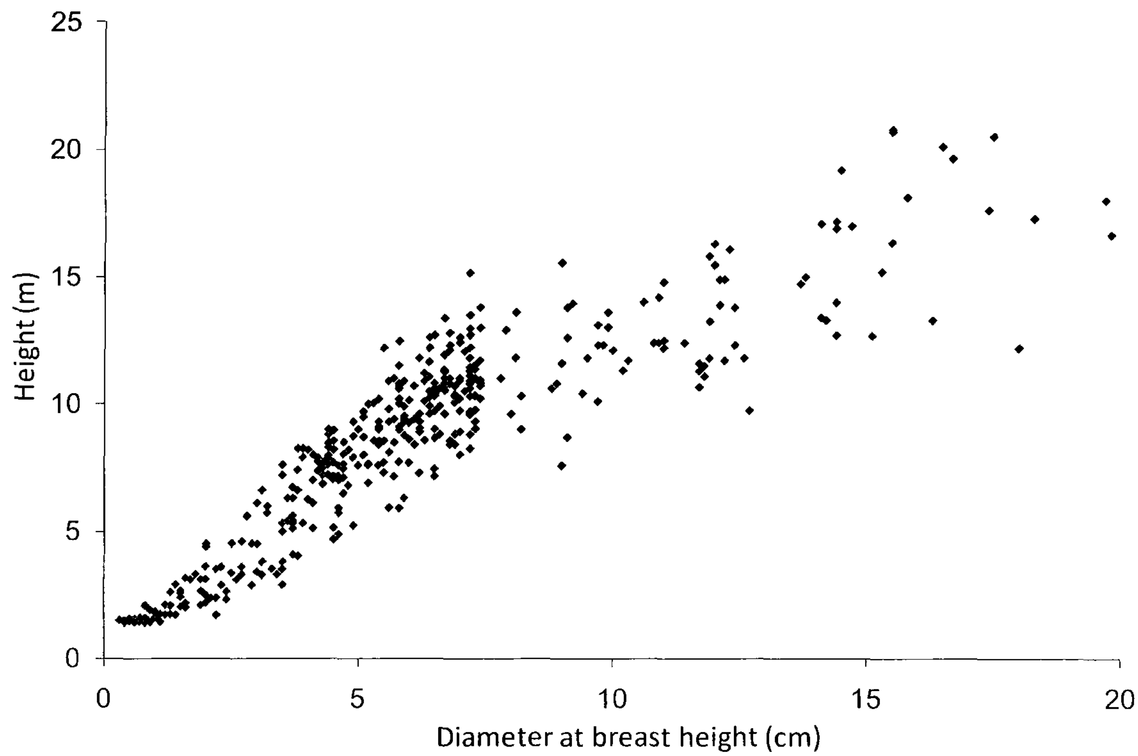

Figure 4.3: Height diameter relationship for pine saplings (≥ 1.37 m tall and < 7.5 cm dbh) and pine site trees (≥ 7.5 cm dbh).

To facilitate ease of modeling in the spatially based scenarios, all stands with no advanced regeneration, as indicated by no BA, were re-assigned an age of one year old. This was done so that the formula for priority ranking queue discussed in section 2.4.3.4 does not result in a negative number which would occur if zero was a value assigned to effective age.

The risk associated with this assumption is that stands with no advanced regeneration in the layer between 1.37 m height and 12.5 cm dbh are assumed to have adequate seedlings (less than 1.37 m tall). This may not be the case. These stands are considered to be growing from age zero on the median based VDYP7 yield tables (Appendix VIII). An examination of the unadjusted VDYP7 yield tables indicates AR does not accumulate appreciable volume before age 40 at which time volume increases slowly. It is likely that the risk associated with the above assumption is very low in the mid-term.

As discussed previously, modeling the growth and yield of stands following MPB infestation is difficult (Kimmons *et al.* 2005; Griesbauer and Green 2006; LeMay *et al.* 2007; Sattler 2009). In this study, it was assumed that advanced regeneration contributes volume in proportion to the growing space made available in the residual overstory after MP attack. No consideration was given for the reduced light availability that occurs as a result of the standing dead pine. Previous studies have shown enhanced growth rates of advanced regeneration after MPB attack (Amman 1977; Heath and Alfaro 1990; Coates 2006). Significant uncertainty exists regarding the extent of release but in accepting VDYP7 as the model to reflect growth of AR, the uncertainty may be reduced. Calibration of the VDYP7 model is done with temporary and permanent sample plots which incorporate stand development under natural disturbance processes. The assumption that PSP and TSP data collected in the past is used to predict the future carries risk because it assumes that the forest grows the same tomorrow as it did yesterday. Climate change may alter future moisture regimes and result in acceleration or slowing of growth.

4.1.4 BCMPB v5

The BCMPB v5 mortality model provides information to the SELES model regarding the amount of dead pine available for salvage over time and the growing space that can be occupied by AR. As discussed in section 1.3.4.2, Walton *et al.* (2008) indicate that significant uncertainty exists in the projection of mortality because issues encountered with data collection during overview aerial surveys. To reduce this uncertainty, Prince George forest district mortality was revised in the PG TSA timber supply review based on the preliminary findings from this study presented at the January 2009 Northern Silviculture Committee Winter Workshop (Figure 2.7).[54,55]

4.2 ECONOMIC AND OPERATIONAL CONSIDERATIONS

Assessments regarding the benefits of AR to mid-term timber supply are made solely on the basis of predicted available merchantable volume. When harvesting stands originating from secondary stand structure, merchantable volume is made up of two cohorts: larger piece size mature residual overstory volume, and smaller AR volume. Further, there may be older dead pine trees in the stand that have either fallen or are at risk of falling, creating safety issues for logging. Smaller piece size increases logging costs as does increased amounts of snags and blow down.

SELES model output shows volume being harvested from natural stands with secondary stand structure up to 180 years into the future (Figure 3.3 and 3.4). There is uncertainty related to the ability of the current mature residual overstory to remain standing until then. Some less wind-firm mature residual overstory may be blown or knocked down when the pine component of stands begins to deteriorate or when residual trees become over-

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[54]Presentation accessed June 2009 at: http://www.unbc.ca/assets/continuingstudies/events/nscwinter2009/john_pousette.pdf

[55] Adjustments made to the BCMPB v5 mortality documented on page 19 of the 2010 PG TSA Public Discussion Paper can be accessed at: http://www for gov.bc.ca/hts/tsa/tsa24/tsr4/24ts10pdp pdf

mature. Advanced regeneration may also be at risk from falling overstory trees.

Bogdanski *et al.* (2010) report that, to date current industry (focused on lumber and panel products) has not been able to take advantage of the increased AAC due to market demand, industry capacity, industry cost structure and deteriorating log quality. For almost all scenarios modeled, 12.5 million m^3 was chosen as the annual target harvest level during the salvage period. There are two reasons 12.5 million m^3/year was chosen:

- To be consistent with the PG TSA TSR analysis and facilitate initial error checking and comparison to previous modeling work done.
- Forest policy allows licensees to make up previous shortfalls by over harvesting over subsequent years. Licensee cut control policy states that harvest and AAC are rationalized over a 5 year cut-control period.

As previously discussed, actual harvest averaged 11.3 million m^3/year between 2004 and 2008. In 2009, PG TSA harvest was approximately 9.5 million m^3. The choice of the initial target harvest has an effect on modeled outcomes (Figure 3.8). A reduced AAC may also decrease impacts on criteria such as biodiversity and other non-timber forest stewardship values.

4.3 OPERATIONAL AND POLICY CONSIDERATIONS

Protection of Secondary Structure Regulation

The scenarios that show the most favourable results for mid-term timber supply advocate reserving stands with more developed AR. This supports in principle Section 43.1 and 43.2 of the Forest Practices and Planning Regulation regarding *Secondary structure retention in mountain pine beetle affected stands* (Appendix XIII). This regulation protects secondary stand structure that is deemed to be sufficiently developed that it would achieve

150 m^3/ha faster than if the area was clearcut and planted.[56] The regulation was also designed to encourage salvage of stands with little or no secondary structure leaving those with more developed secondary structure for future harvest. A stated primary objective of the regulation is to ensure that stands not salvaged will not require costly rehabilitation.[57] The current regulation has a very high standard of suitable secondary structure (Table 4.1).

Table 4.1: Minimum stocking and height criteria to define adequate stocking density of suitable secondary structure in Section 43.1 of the Forest Practices and Planning Regulation.

Minimum # of Well Spaced Tree/Ha	Minimum Height
700	6 meters
900	4 meters

The regulation also states that there must be a contiguous five hectare patch of suitable secondary structure before protection is required. Forest Licenses have stated that, due to the variability of secondary structure, the five hectare requirement excludes almost all areas.[58] The other requirement that ensures most stands are excluded from qualifying for protection is that only trees "likely to survive an attack from mountain pine beetle" can be counted. A case could be made that any live pine trees over 8 cm dbh has a risk of being attacked under epidemic condition (Figure VII.1 in Appendix VII). This study found that for six of the seven subzones sampled, on average, pine made up over 20% of the live remaining BA of the advanced regeneration portion of the secondary structure (Table 2.10). Further, the average diameter of the live pine trees ($\geq$ 7.5 cm dbh) post MPB attack was 12.4 cm dbh. Approximately 23.1% of the pine trees ($\geq$ 7.5 cm dbh) were alive post MPB epidemic (Table

[56] Waters, A. Personal communication June 2008. alanwaters@shaw.ca See also PowerPoint© presentation under heading ***Silviculture Survey Reference Documents: Secondary Structure surveys*** at: http://www.for.gov.bc.ca/hfp/silviculture/Silviculture_Surveys.html

[57] See footnote 56.

[58] Gray, C. Personal Communication July 2009. Cecil Gray is the Silviculture Forester for Lakeland Mills Ltd. Prince George, BC. cecilg@lakelandmills.bc.ca

2.4). Now that the epidemic has passed the regulation may need to incorporate the remaining live pine into the tally of acceptable secondary structure.

AAC uplift policy:

Lowering the initial target harvest level to 11.3 million m^3 extended the period to fall-down by almost two years and allowed reserved stands with the most abundant AR to increase mid-term harvest levels by one million m^3/year over the base case (Figure 3.8). For a scenario where VDYP7 was used to generate AR volumes, and the initial target harvest level is 14.944 million m^3, the period to fall-down was reduced by 2 years and the late mid-term (years 40 to 59) was reduced by approximately 300,000 m^3/year. Both of these examples illustrate that higher short-term harvest results in the loss of flexibility in the later part of the short-term and the mid-term. Thus there are trade-offs between available harvest across decades.

CHAPTER 5.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

5.1 SUMMARY

The case study suggests that there may be a significant benefit to mid-term and long-term timber supply through incorporation of advanced regeneration into timber supply modeling. This study accomplished the following objectives:

1. Quantification of post-MPB epidemic AR data collected in the Prince George Timber Supply Area such that it could be used in growth and yield models.
2. Development of two different approaches to modeling growth and yield information from AR including using the VDYP7 and SORTIE ND models.
3. Development of techniques and modifying the SELES model to allow harvest prioritization of stands with various abundance of AR.
4. Quantification of timber supply impacts of incorporating various approaches to protection of stands with abundant AR.

Despite the fact that timber supply modeling techniques are approximations of reality, resource managers have relied on them to make important decisions that impact future social, economic and environmental well being. Timber supply techniques have benefited from adaptive management principles but improvements in precision does not necessarily provide more robust answers. In timber supply modeling, analysts have tended to try and maximize predicted timber flow while considering all other recognized forest values as constraints. The result of this approach was that solutions restrict flexibility of other forest values.

The SELES STSM timber supply model had been previously modified by Fall (2007) allowing harvest volume to incorporate contributions from both residual overstory and AR. Further modifications were made to allow prioritization of stands with poorly developed AR to be harvested during the salvage period.

Incorporating AR into timber supply modeling for the Prince George TSA resulted in an average annual mid-term (years 15 to 59) timber supply increase of 5.7% using VDYP7 and 22.6% using SORTIE ND (Table 3.1). Timber supply modeling results using the SORTIE ND model may be considered the upper bounds of release that may be experienced. On the other hand, VDYP7 may represent a conservative approach or the lower bound to growth of advanced regeneration post MPB.

Scenarios where stands, with more abundant AR, reflected by higher effective ages, were reserved from harvest until after the salvage period resulted in the greatest mid-term timber supply impact. Mid-term timber supply was increased by approximately one million m^3/year to 7.6 million m^3. Further results from analyses of scenarios indicate there could be significant trade-offs between available harvest across decades. Reducing the current salvage rate to 11.3 million m^3 and focusing current harvest on stands with lower levels of AR results in extending the period to fall down and increasing the average annual mid-term available harvest by over a million m^3/year compared to the base case where no advanced regeneration was incorporated. The trade off is a reduced opportunity in the short term harvest of approximately 1.2 million m^3/year. The current AAC for the PG TSA is 14.944 million m^3 which is approximately 5.5 million m^3 above the actual harvest level for 2009 (Bogdanski *et al.* 2010). Average harvest over the period 2004 to 2009 was 11.3 million m^3. Reducing the AAC now would not result in social or economic hardship and may increase mid-term harvest opportunity while allowing for increased harvest flexibility in the future.

5.2 CONCLUSIONS

This thesis proposes and successfully demonstrates methodologies used to capture the growth of secondary stand structure post-MPB epidemic. Growth of SSS has not been successfully modeled in timber supply analysis procedures previously. SELES predicts that for a scenario where VDYP7 is used to predict growth, protection of stands with well developed AR results in 14% to 15% higher mid-term harvest level compared to the base case. Modeling results confirm that the current regulation protecting secondary stand structure (Appendix XIII) has merit in principle but that it may be unnecessarily restrictive in its definition of what constitutes adequate secondary structure. The regulation allows trees that may be at risk to further MPB attack to be discounted from contributing to future harvest. The case study of this thesis used all remaining live trees as MPB mortality is believed to be complete in the PG TSA. A simple change to the regulation might be to allow remaining live pine to contribute in forest management units where the epidemic is over. A further restriction preventing meeting the regulation stipulates that adequate secondary structure areas must be larger than five hectares. The regulation does not allow for occasional gaps and voids in AR that naturally occur.

Provincial timber supply projections have predicted that mid-term timber supply may be reduced by as much as 20% (Figure 1.13). To date, between 630 and 710 million m^3, roughly one half of the merchantable mature timber inventory, has been killed by MPB (Table 1.1). As communities experience reduced timber supply, there will be increasing pressure to mitigate through relaxation of forest management objectives for other values such as visual quality, biodiversity, wildlife and riparian. Before sacrificing these environmental and social values a concerted effort must be made to examine other mitigation strategies. Included in these are the biologically based solutions increasing productivity such as fertilization and thinning, as well as an examination of policies that protect stands with more abundant SSS that can contribute in the mid-term. Timber supply modeling can assist policy makers with exploration of these issues just as this thesis has demonstrated. Although SELES STSM was used for this analysis, it is anticipated that similar results would be achieved with other spatial models.

This thesis has shown that how stands are prioritized and queued for harvest matters. How we harvest now, during the salvage phase will affect the future; more salvage harvest reduces future management options. It is important to take results from timber supply modeling and use them in strategic planning and policy development. The current global recession and depressed lumber market conditions generate worry but may also provide opportunity to create flexibility. Projected low raw material (timber) demand means that reduced AACs should not currently be felt. Reduced AAC allow more stands, such as those with well developed secondary stand structure to be reserved for harvest in the mid-term.

5.3 CONSIDERATIONS FOR FUTURE RESEARCH

There are several weaknesses identified throughout this thesis that would benefit from additional research and study.

It was assumed that AR will release and grow to take over the space (light, nutrients and moisture) that has been made available from the death of the pine overstory. Stand dynamics following MPB must be documented to verify release rates by species and strata.

In this study AR was assumed to grow based on SORTIE ND or alternatively, the empirically based VDYP7 growth and yield model. Using SORTIE ND, the mid-term harvest increases by 22.6% while employing VDYP7 the mid-term increased by only 5.7% over the base case. Research into appropriate growth and yield models for multilayered and multispecies stands resulting from the MPB epidemic is needed to provide better estimates of future growth. SORTIE ND may need additional calibration for certain subzones in the SBS as it is currently predicting higher than actual spruce volume.

AR growth and yield curves were generalized to a single BEC subzone. Timber supply modeling may benefit from creating yield curves at the site series (moisture and nutrient regime) level. Also, the presence of AR may be better correlated to the site series level. However, this would require additional data collection in some subzones.

In modeling timber supply, no consideration was given to prioritizing based on the abundance of residual overstory. Modeling prioritization of residual overstory abundance may have just as significant an impact in the beginning of the mid-term as AR does on the later mid-term. Research is needed that examines the contribution of AR in relation to the contribution of residual overstory. Results of this research could be used in timber supply modeling to refine policy regarding protection.

The SBS dk is dominated by pure pine stands. Field data indicated very little AR present. Foresters working in this area indicate that some residual overstory pine survived the MPB epidemic especially in the southern part of the district.[59] Survival of residual overstory should be assessed to see if some areas have sufficient healthy live trees remaining that might create a mid-term harvest opportunity. As a first step, this could be assessed with growth and yield modeling.

To facilitate timber supply modeling in the scenarios where the spatial layer of

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[59] DeGagne, J. Personal communication May 2008. John DeGagne is the Stewardship Officer for the MFR in the Vanderhoof forest district. john.degagne@gov.bc.ca

effective age of AR was employed, stands with less than 0.5 m^2/ha of BA were assigned an effective age of one year. Data for seedlings should be assessed to see if sufficient quantities exist to validate this assumption. If not, stands with little or no chance of adequate regeneration should be modeled correctly through additional modification to SELES.

Effective age was assigned based on median attributes of AR including BA, stems per hectare and quadratic mean diameter. Height may be a more appropriate way to assess effective age. Field data collection methods would need to include collection of heights for all trees up to 12.5 cm dbh.

Spatial AR scenarios where stands with poorly developed advanced regeneration (low effective ages) were prioritized for harvest during the MPB related salvage period (year 2008 to approximately year 2022) yielded disappointing results. The modeled mid-term timber supply was not increased appreciably over scenarios where no prioritization occurred (Table3.1). It is suspected that the prioritization function written into the SELES model did not result in priorities that were higher than those established for other values such as species, forest district, proximity to milling centre (myzone) and volume per hectare (AppendixXII). More favourable results may be obtained through additional modeling scenarios that examine the SELES priority function.

Although not specifically addressed through timber supply modeling, shelf life continues to be a main driver regarding the length of time that licensees can process dead pine into lumber. Shelf life must be monitored as it governs the period to fall down.

For mature stands, current forest inventory policy does not include the collection of all of the layers of advanced regeneration including seedlings and saplings. Policy and field procedures should be examined to explore the costs and benefits of collecting this data with the view to better understanding forest dynamics and stand development. This information would also be useful in describing future forest condition.

The current regulation protecting secondary stand structure needs review to see why no stands have met the criteria but yet research plots done in this study and many others suggests that significant levels exist. One of the stated main purposes of the regulation is to prioritize salvage harvest so that expensive rehabilitation programs are not required. The current regulation does not facilitate prioritization of harvest based on the amount of existing secondary structure. To be effective, the regulation may need to be based on live basal area instead of well spaced stems or a combination of factors including % mortality in the overstory, BA, and species. If the latter is not feasible, the regulation may only need to establish a priority ranking system that ensures stands with little or no secondary structure are harvested before stands with higher levels of secondary structure. In this way, at some point in the future, if shelf life deems that the pine trees in a stand are no longer usable the stand that is left has a higher probability of not requiring expensive rehabilitation.

Pressure on timber supplies will increase as a result of the current MPB epidemic. Modeling techniques developed in this study demonstrated that mitigation of mid-term supply shortfalls can likely be made through strategic salvage harvest. MPB attacked pine stands with little or no secondary stand structure must be prioritized for short term harvest and stands with abundant secondary structure should be reserved for future harvest.

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Appendix I: Cumulative Mountain Pine Beetle Caused Mature Pine Volume Mortality Based on Summary of Forest Health Conditions in British Columbia (1999 to 2007)

and

BCMPB v5 Model Predictions (2008 to 2024)

Forest Managment Unit	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2015	2020	2024
100 Mile House TSA	228,512	366,096	586,992	889,760	1,852,368	5,590,416	14,205,840	32,166,448	39,307,680	41,999,136	43,333,616	44,058,928	45,204,992	45,647,472	45,902,752
Arrow TSA	56,752	117,104	148,704	209,328	347,584	749,680	1,260,784	1,826 224	1 980,176	2,261,600	2,845 680	3 656 416	5,932,368	6,228,032	6,350 320
Boundary TSA	8,864	14,608	19,600	23 856	37,712	108 896	225 872	402,896	483,344	691 616	1,247,920	2,528,672	9,923,616	10 663,952	10,793,728
Bulkley TSA	74,768	134,640	181,296	203,216	237,520	286,048	394,192	456,544	640 240	1,281,440	2,764,672	4 955 136	10,152,912	10,573,104	10,676 992
Cranbrook TSA	*108,480*	*180,160*	*232 064*	*352 368*	*513,632*	*858,256*	*1 449 456*	*1,963,312*	*2,158,544*	*2,514 704*	*3,328,096*	*5,182,448*	*18,593,184*	*21 122,352*	*21,522,816*
Dawson Creek TSA		1,648	6,064	6,208	6,208	27,472	56,672	167,056	2,869,184	6,257,984	10,565,056	15,162,848	23,660,864	24,328,416	24,537,248
Ft. St. James Forest District	936,256	2,209,632	3,390,256	4,666,864	6,968,912	10 681,840	21,424,192	30,316,736	45,001,488	55,772,160	65,029,392	72,701,088	89,200,448	90,688,592	91,103,760
Golden TSA	88,688	162,464	196,208	235,072	286,464	342,064	501,296	753,216	823,280	932,976	1,141,920	1,530,384	3,222,528	3,547,392	3,640,208
Invermere TSA	38,976	76,896	99,456	144,880	207,488	355,376	567,536	843,792	1,016,800	1,334,288	2,038,736	3,115,408	7,118,624	7,570,016	7,694,784
Kamloops TSA	210,352	324,464	600,336	1,094,304	1,902,704	4,585,632	10,634,880	19,706,048	26,510,208	31,636,176	35,539,360	38,234,176	42,777,312	43,664,048	44,002,720
Kootenay Lake TSA	12,336	26,336	62,128	111,056	191,664	356,544	650,528	1,091,584	1,316,208	1,704,256	2,413,888	3,507,840	8,752,736	9,396,864	9,580,368
Lakes TSA	83,792	477,168	3,031,600	9 021,040	15,286,624	19,645,584	34,677,264	44 600,048	50,768,384	54,184,832	55 603,408	56,259,088	57,112 880	57 356,720	57,426,800
Lillooet TSA	16,576	34,000	67,728	113,728	160,736	252,688	656,272	1,559,920	2 808,608	4,962,800	7,822,864	10,515,328	15,088,080	15,499,792	15,600 656
Mackenzie TSA	75 936	219,088	248,064	322,160	545,744	688,480	1,321,472	3,404 848	8,242,592	13,705,632	21,625,296	33,215 952	81,064,720	85,340,928	86,234 480
Merritt TSA	260,896	526,400	904,144	1 210,400	1,447,040	2,096,384	3 357 968	5 854,480	9,755,824	15,843,888	23 595,936	31,851,408	47,892 736	48 900,896	49,138,448
Morice TSA	407 344	901,952	1,862,592	2,202,640	2 441,072	2 889,872	6,606 704	13,018,048	18 794 624	25,253,392	31,208 352	35,459 312	41 482 528	42,224 880	42,505 568
Okanagan TSA	75,760	141,632	293,712	467,056	717,824	1,425,152	2,467 280	3,859,456	5,539,904	8,121,808	12,647,264	18,959,136	38,649,152	40,377,792	40,797,280
Prince George Forest District	414,896	985,200	1,693,088	4,570,736	10,311,584	17,404,880	29,951,552	38,265,712	45 981,280	49,241,552	51,062,992	52,049,888	53,832,784	54,470,736	54,775,024
Quesnel TSA	1,066,000	2,584,848	5,433,168	11,678,464	26,106,896	48,010,016	71,791,856	83,537,664	88,588,000	90,300,560	90,839,472	91,065,584	91,368,752	91,492,880	91,563,424
Robson Valley TSA	28,736	76,496	143,616	208,736	236,896	294,784	435,840	644,912	944,672	1,391,392	2,033,184	2,711,536	4,353,600	4,562,960	4,650,512
Vanderhoof Forest District	414,480	1,040 384	2,060 624	8,422 336	21,761,712	34,683,792	59 645 184	66,814,624	70,714,288	72,712 032	73 596,496	74,008,832	74,690 320	74 915,952	75,010,352
Williams Lake TSA	461,616	899,840	1,979,648	4,114,368	9,942,208	22,126,400	41,495,680	62,276,704	79,798,512	92,722,816	101,282,384	106,306,064	111,544,288	112,111,456	112,383,952
Cummulative Total	5,070,016	11,501 056	23,241,088	50,268,576	101,510,592	173 460,256	303,778,320	413,530,272	504,043,840	574,827,040	641,565,984	707,035,472	881,619,424	900,685,232	905,892,192

← Measured Values | Predicted Values →

Notes to table:
All crown and private land is incorporated into these estimates. These estimates are cumulative and do not incorporate logging. For measured values mortality reported for any given year is what was indicated by red and gray attack during the summer aerial overview. Green attack was not estimated and would show up as red attack in the following summer.

APPENDIX II: CUMULATIVE MOUNTAIN PINE BEETLE TASK FORCE MATURE PINE VOLUME MORTALITY ESTIMATES TO 2007

Managment Unit Designation		attacked mature pine volume (cubic metres)							
Timber Supply Area	**Forest District**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
100 Mile House	100 Mile	-	518,485	925,988	3,396,597	11,738,015	16,784,786	41,195,719	49,289,894
Arrow	Arrow Boundary	-	-	-	5,426	24,209	89,140	243,881	315,516
Boundary	Arrow Boundary	-	-	-	1,044	28,245	32,136	281,870	384,632
Bulkley	Skeena Stikine	-	27,203	27,356	52,635	115,299	152,225	168,679	576,549
Cranbrook	Rocky Mountain	-	-	436,668	836,210	1,405,460	2,450,352	2,954,158	4,039,152
Dawson Creek	Peace	-	-	-	-	56,414	144,941	2,625,507	5,638,204
Fort St. John	Peace	-	-	-	-	-	-	26,500	820,369
Golden	Columbia	-	-	-	9,298	19,884	23,750	86,709	130,682
Invermere	Rocky Mountain	-	-	-	24,076	179,603	181,043	421,883	580,371
Kamloops	Kamloops	-	-	1,738,218	3,230,075	14,325,844	21,250,650	31,758,973	52,764,562
Kootenay Lake	Kootenay Lake	-	-	-	2,032	45,013	88,118	336,281	499,065
Lakes	Nadina - East	8,848,813	15,440,143	18,531,217	27,444,964	33,730,138	45,068,473	54,577,993	65,025,791
Lillooet	Cascades	-	-	-	5,018	101,421	184,689	1,271,485	2,834,307
Mackenzie	Mackenzie	-	14,569	56,062	197,600	773,628	1,482,757	6,249,834	9,658,361
Merritt	Cascades	-	-	-	704,503	1,626,219	2,706,672	11,357,050	22,881,367
Morice	Nadina - West	3,150,000	2,565,132	2,575,712	3,549,036	5,553,220	7,313,783	16,905,440	22,324,485
Okanagan	Okanagan-Shuswap	-	-	-	234,733	1,113,811	1,392,960	3,123,044	5,373,995
Prince George	Fort St James	5,090,565	5,436,706	4,810,228	7,307,651	9,986,305	19,599,310	35,122,370	43,921,679
Prince George	Prince George	2,083,375	3,447,978	4,169,009	10,262,976	17,545,053	26,486,603	39,835,273	46,431,368
Prince George	Vanderhoof	5,940,067	11,802,559	20,869,724	41,344,702	58,717,695	89,511,297	91,329,542	94,713,219
Quesnel	Quesnel	13,297,500	27,973,523	43,786,127	59,629,251	94,109,889	120,381,079	137,890,865	146,289,592
Robson Valley	Headwaters	-	-	-	19,317	42,774	71,941	138,456	195,774
Williams Lake	Chilcotin	-	466,708	3,715,410	4,329,974	11,891,912	25,086,169	56,641,178	80,039,594
Williams Lake	Horsefly	-	521,243	721,819	873,332	4,060,985	7,237,587	8,659,507	11,207,006
Williams Lake	Williams Lake	2,668,320	3,609,423	5,363,803	10,083,846	16,269,039	23,255,210	38,638,584	44,214,477
All Units		**41,078,640**	**71,823,672**	**107,727,341**	**173,544,295**	**283,460,075**	**410,975,671**	**581,840,781**	**710,150,009**

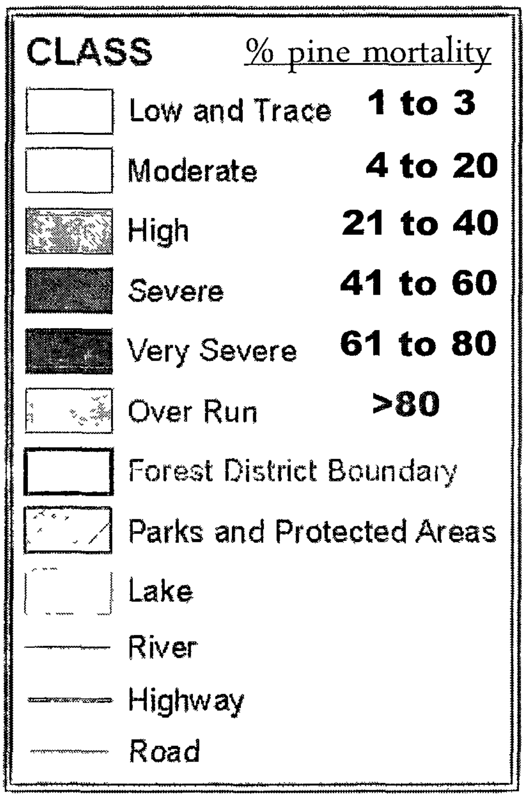
All crown and private land (with the exception of parks and ecological reserves) is incorporated into these estimates. Mortality includes green, red and gray attacked pine older than 61 years. These estimates are cumulative and do not incorporate logging. Source: Council of Forest Industries, Mountain Pine Beetle Task Force – Table used with permission.

APPENDIX III:

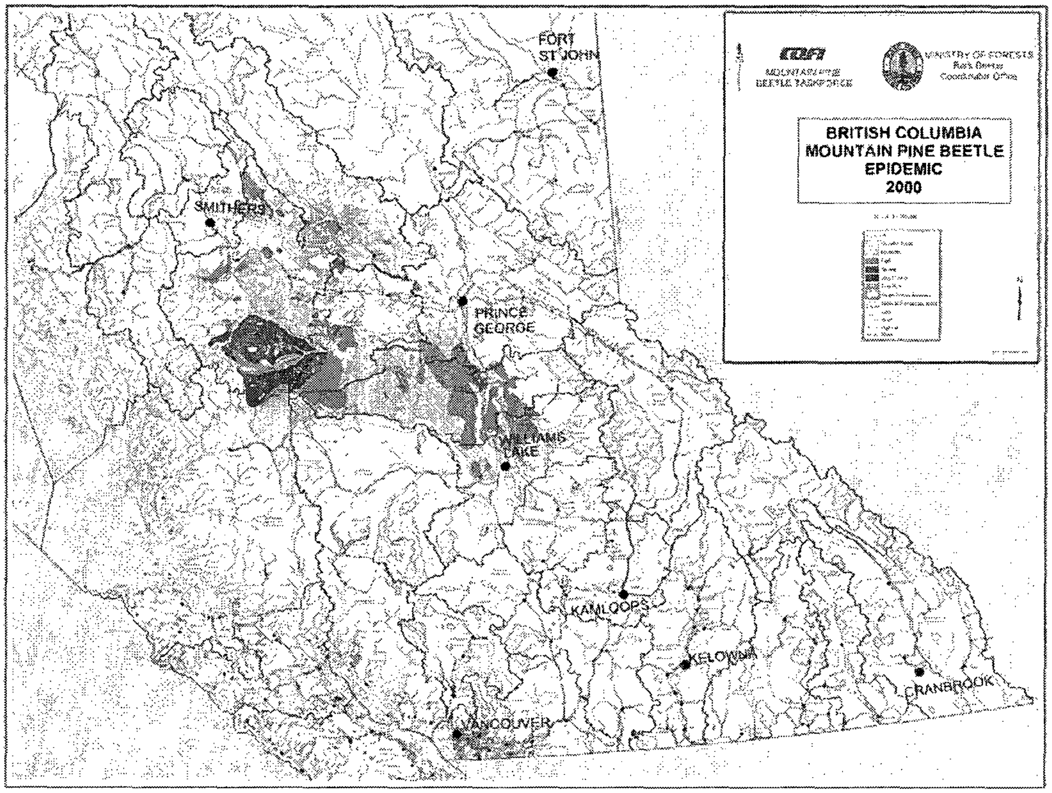
MOUNTAIN PINE BEETLE TASK FORCE MATURE PINE MORTALITY SPREAD MAPS: 2000 TO 2007

The Mountain Pine Beetle Task Force was a joint BC Council of Forest Industries and Ministry of Forests and Range Task Force established to address MPB issues of common concern. Maps used with Permission.

Legend for maps:



Note: Data for mortality maps compiled under contract. Project directed by Chris Bailey of Industrial Forestry Service Ltd. Prince George. BC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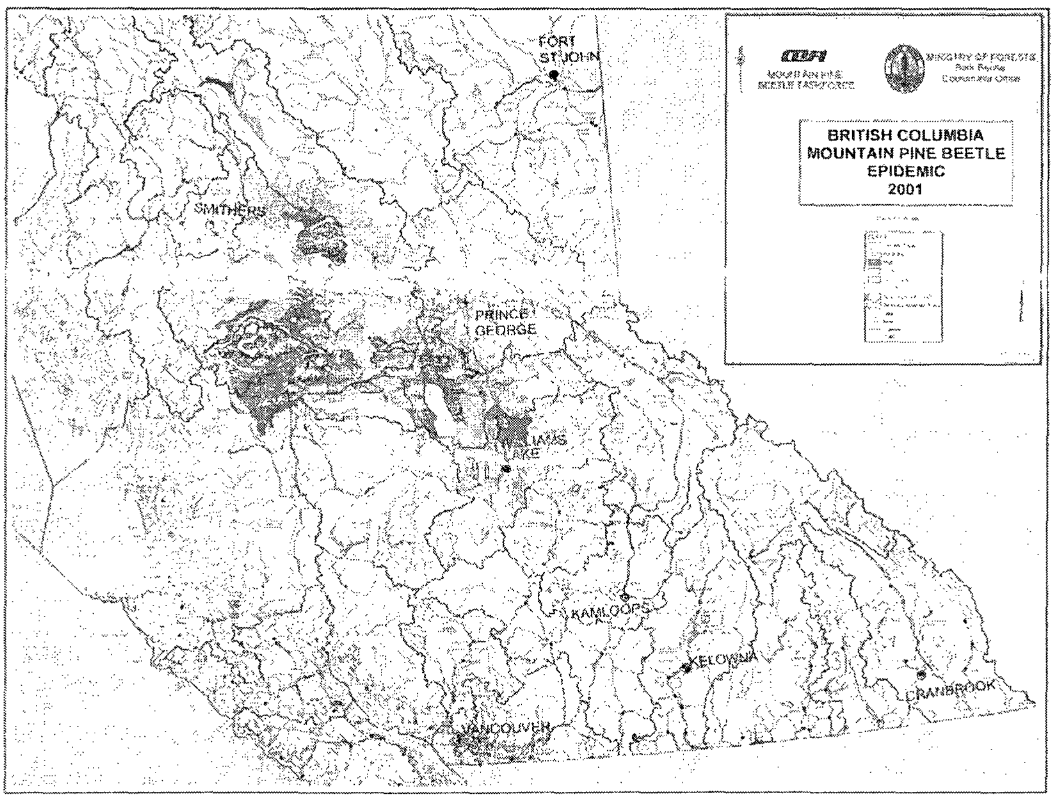
MOUNTAIN PINE BEETLE TASKFORCE
MINISTRY OF FORESTS
BRITISH COLUMBIA
MOUNTAIN PINE BEETLE
EPIDEMIC
2000
SMITHERS
PRINCE GEORGE
WILLIAMS LAKE
KAMLOOPS
KELOWNA
CRANBROOK
VANCOUVER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MINISTRY OF FORESTS
BRITISH COLUMBIA
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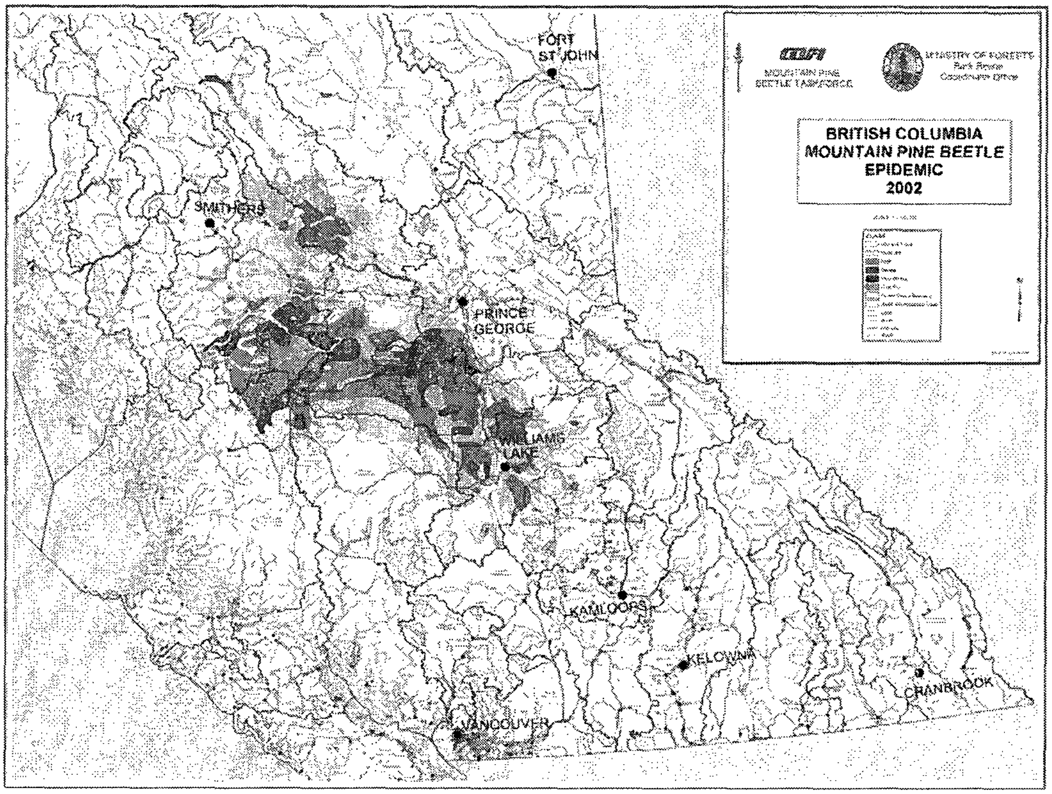
PRINCE GEORGE
KAMLOOPS
KELOWNA
CRANBROOK
VANCOUVER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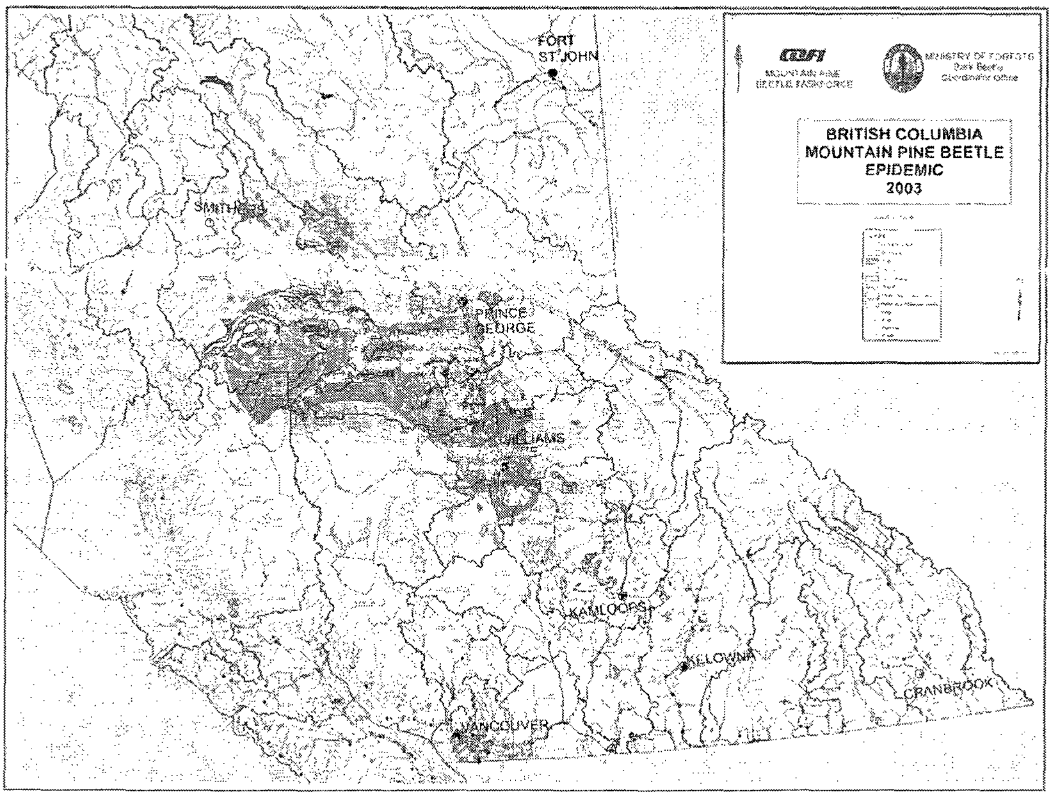
WILLIAMS LAKE
KAMLOOPS
KELOWNA
CRANBROOK
VANCOUVER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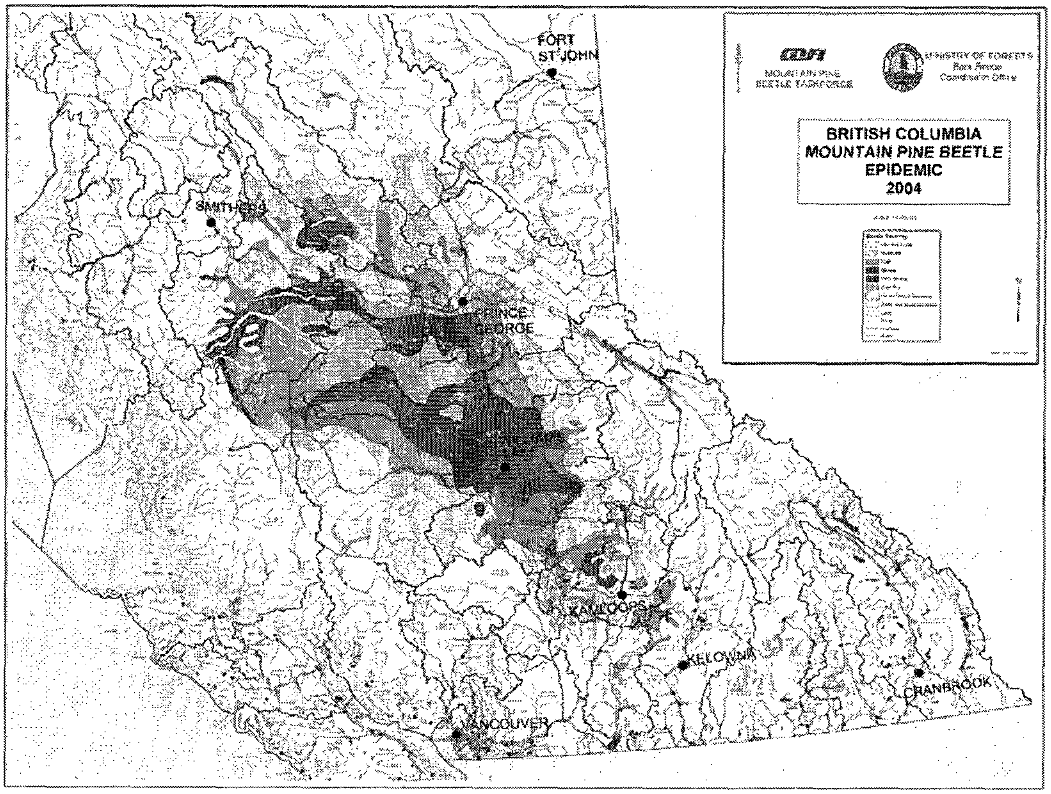
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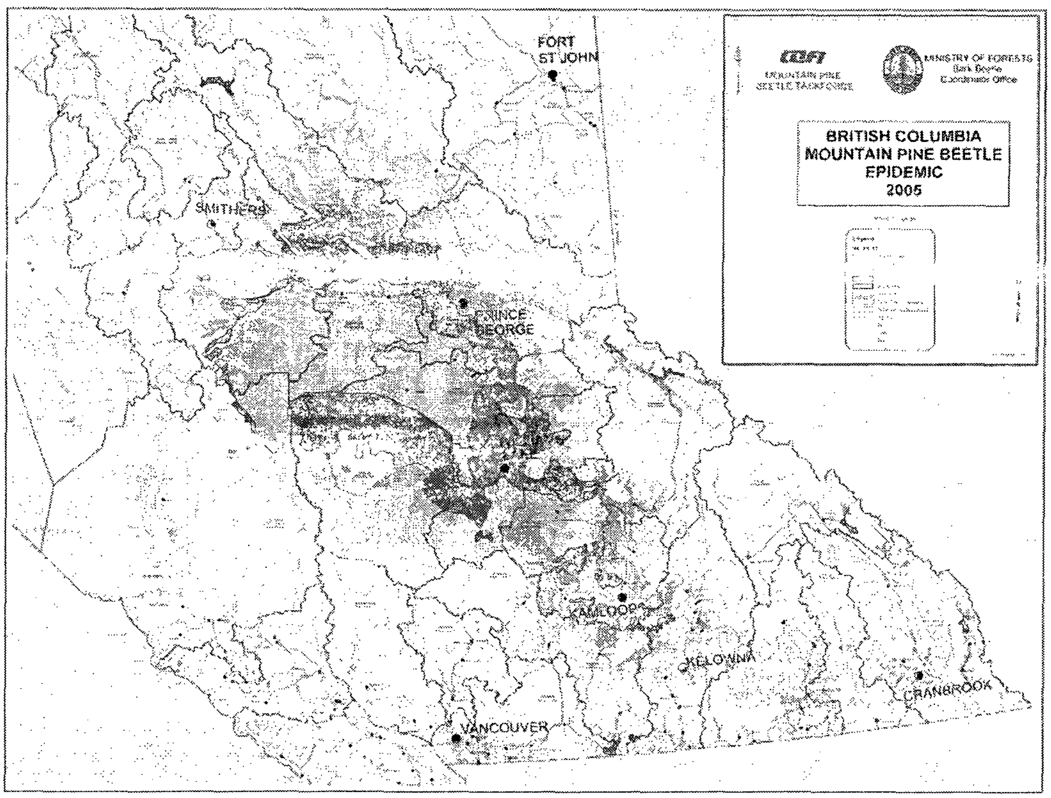
KELOWNA
CRANBROOK
VANCOUVER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MINISTRY OF FORESTS
Bark Beetle Coordination Office
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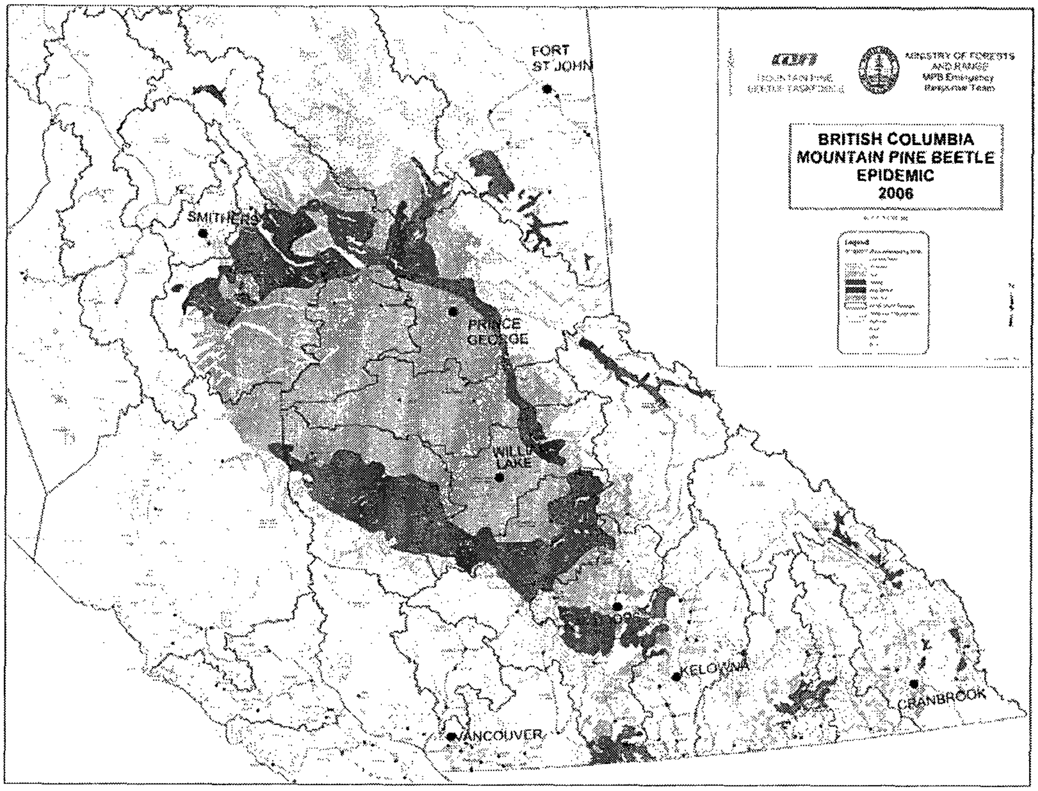
CRANBROOK
VANCOUVER


MINISTRY OF FORESTS AND RANGE
MPB Emergency Response Team
BRITISH COLUMBIA
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EPIDEMIC
2006
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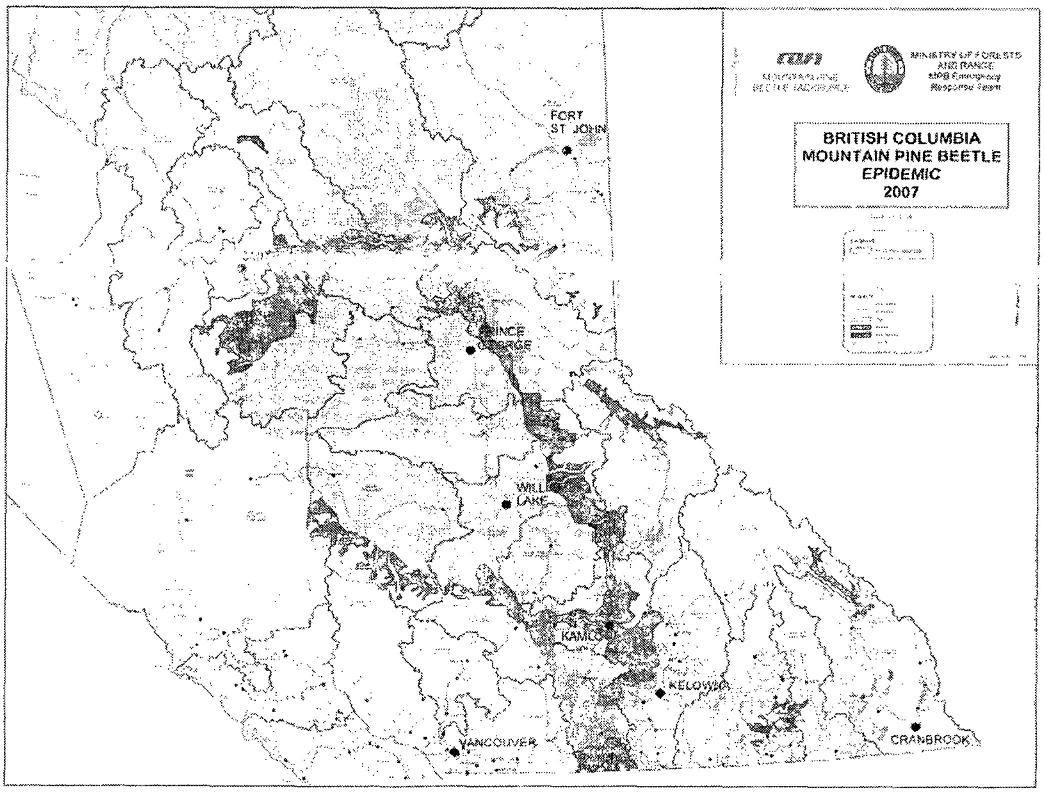
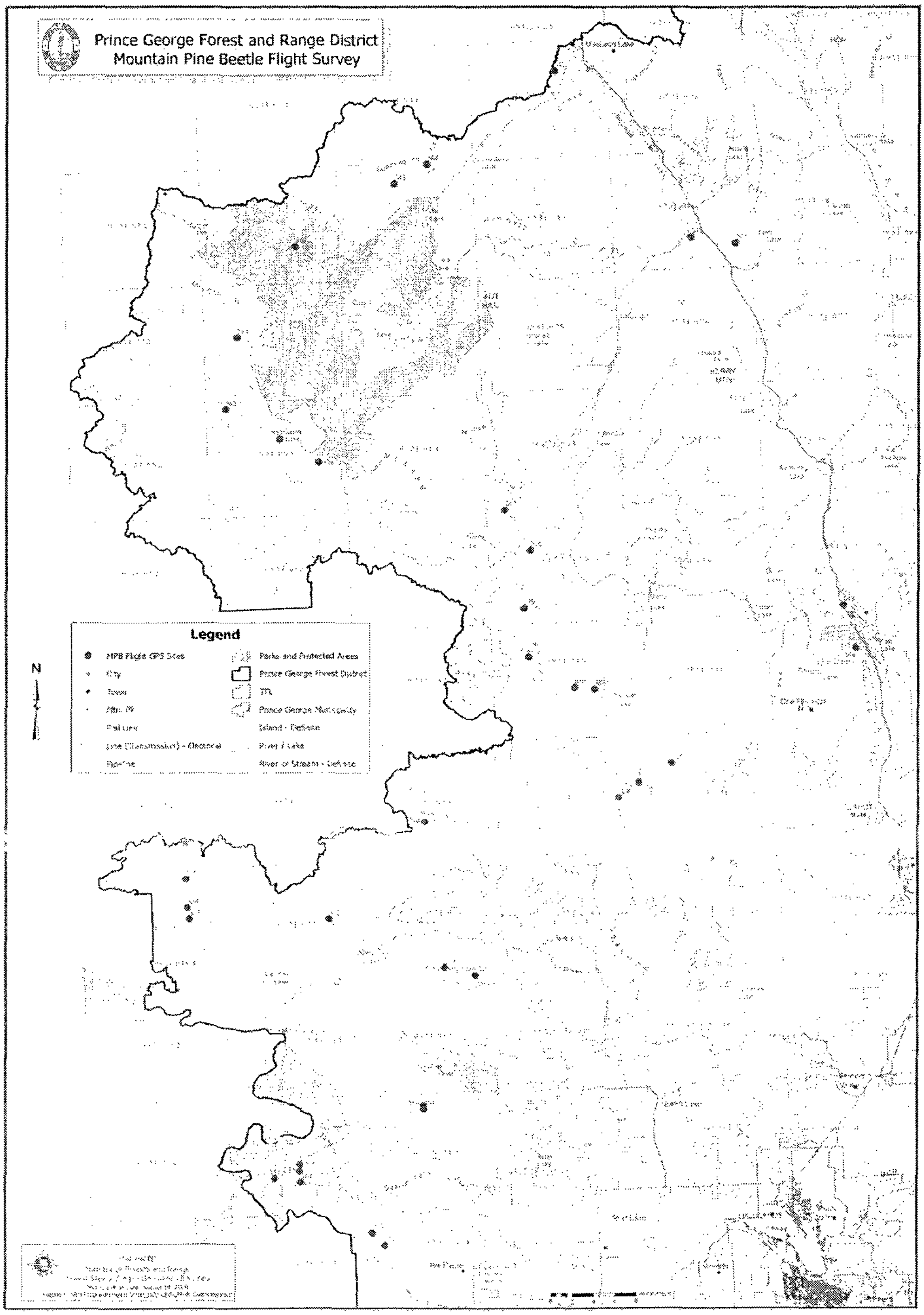
SMITHERS
PRINCE GEORGE
KELOWNA
CRANBROOK
VANCOUVER


MINISTRY OF FORESTS AND RANGE
MPB Emergency Response Team
BRITISH COLUMBIA
MOUNTAIN PINE BEETLE
EPIDEMIC
2007
FORT ST JOHN
WILLIAMS LAKE
CRANBROOK
VANCOUVER

APPENDIX IV: PLOT LOCATION MAP AND SPECIES COMPOSITION REPORT OF PRINCE GEORGE DISTRICT MINISTRY OF FORESTS AND RANGE 2008 MPB AERIAL SURVEY



DPG MPB Flight 2008 - Species Composition Report

MPB Site Number	Species Label	Age/height/stock class label-SiteIndex (BHA_{50})	Est. % pine Mortality
312	Pl(Sw)	6315-18	95
313	Pl(Sw)	5304-19	85
314	Pl	8315-18	95
317	PlSw	8414-21	95
316	Pl	8316-19	75
315	Pl	8316-19	95
318	Pl	4306-19	40
319	Pl	4306-19	90
320	Pli(Sw)	5307-17	80
321	Pl(Sxw)	5305-16	95
322	Sw(Pl)	8412-14	95
323	Pl(Sxw)	8415-21	95
324	Pl	7317-16	75
325	Pl	5338-19	65
326	Pl	5207-14	50
327	Sb	8220-6	95
328	Pl	6336-17	80
329	Sb	7100-2	80
330	Pl	5306-16	40
331	Pl	8416-19	100
332	Sxw(PlAt)	8415-23	95
333	Pl(Sxw)	8415-22	95
334	Pl(Sxw)	8415-21	95
349	Pl	7311-18	95
335	AtSxw(Pl)	4303-20	70
348	Pl	4304-23	90
336	Pl(Sxw)	8415-21	95
337	Pl	7316-18	95
338	Pl(Sxw)	8314-15	90
339	LAKE		
340	Pl(Sxw)	7316-18	80
341	Pl	8235-11	80
342	Pl(SxwAt)	4305-23	95
347	Pl	4307-19	90
346	Pl	7317-20	90
343	Sxw(BlPl)	8413-15	95
344	Pl	5335-15	80
345	Pl	5314-17	95

APPENDIX V: FIELD SAMPLING METHODS

The following sampling methods are adapted from Runzer *et al.* (2008).

Candidate stand selection

Candidate stands were identified on forest cover maps. A reconnaissance was completed to ensure stands met the following criteria: lodgepole pine leading, age class 1 to 8 (10 to 250 years of age) in the south west, south east and central portions of the Prince George forest district and the south eastern portion of the Vanderhoof forest district, 0-9 years since green attack, SBS BEC zone, dw2, dw3, dk, mc2, mc3, mk1, wk1 and vk sub-zones, on mesic and sub-mesic site series, less than 1 kilometer from the nearest access point. Stands for initial assessment were selected randomly from the pool of stands that were identified by the reconnaissance.

Plot establishment method

A minimum of 5 and a maximum of 10 temporary sample plots (TSP) were established on transect lines in each stand (polygon). A transect bearing was chosen based on shape of the forest cover polygon shown on the forest cover map. TSPs were established 50 metres or at least two tree lengths from any given change in timber type or man-made disturbance. Plots were located every 50 metres on the transect. If an unsuitable or an atypical TSP was encountered at 50 m the plots were moved an additional 25 metres along the transect. At 50 m on the transect, the nearest tree to the surveyor was chosen as the plot center. TSPs are circular plots with a 5.64 m radius for trees ≥7.5 cm dbh and a 3.99 m radius for regeneration and other vegetation. The plots share the same plot center tree.

Attributes collected for trees (>7.5 cm diameter measured at dbh)

Forest cover polygon number, Global Positioning System (GPS) location, moisture code, site index, macro slope, macro aspect, and crown closure were used to identify and characterize each TSP. Species, crown position (dominant, co-dominant, intermediate or suppressed) diameter at breast height (dbh = 1.37 metres), and vigour of trees greater than 7.5 cm in dbh including recently downed (not in an advanced state of decay) trees. Tree vigour and time since attack were evaluated using visual characteristics: alive and well, alive but moribund, green attacked, fading or yellowish foliage, 50-100% red foliage, 10-49% of foliage remains, 10% or less of needles remaining (grey attack), dead from causes other than MPB either standing, leaning, or fallen. Presence of checking was recorded for MPB attacked trees. Mature trees were also classified based on the Province's Wildlife and Danger Tree Assessment (Anonymous 2001).

A spherical densiometer was used to determine crown closure. Crown closure was measured at a randomly located point which was pre-determined to be at 1, 2, 3, 4, or 5 m and N, S, E, or W from the plot center.

A suitable site tree was selected inside or outside of the temporary sample plot. Criteria for suitable site trees were; no damage, co-dominant, and leading species. Species, height, dbh, MPB attack status, and British Columbia Workers Compensation Board (WCB) danger tree assessment code was recorded. A wood core was taken at breast height and analyzed in the UNBC Dendrochronology lab to accurately calculate the age and determine the site productivity (SI_{50}).

Attributes collected for regeneration layer (<7.5 cm diameter measured at dbh)

Tree species which were considered regeneration were Pl, Hw, Cw, Sx, Sb, Fd, Bl, At, Ac, and Ep. Regeneration was described as being trees less than 7.5 cm in dbh. Seedlings were <1.37 m in height while saplings were classified as ≥ 1.37 m in height. For seedling regeneration, height and vigor (alive, moribund, and dead) was recorded. For AR height, dbh, and vigor was recorded.

Attributes collected for moss, lichen and herb layers

The species and percent cover of the moss, lichen, and herb layers was described in a 1 m by 1 m quadrant. The species, percent cover, and height of the shrub layer were described within the 3.99 m radius regeneration plot.

Plot re-measurements

Plots sampled in 2005 were revisited and re-measured in 2006 if they were not logged and if not all lodgepole pine trees (>7.5 cm diameter at dbh) were attacked when the plot was initially established. Similarly, plots established in 2005 and 2006 were re-measured again in 2007 using the same criteria.

Initial Data Entry

The field data was entered into Microsoft Excel and organized into files by age class for the trees data and the regeneration data. Basic statistics module of SYSTAT Version 11 (2004) was used to summarize the data at the stand and landscape level. Rigorous error checking was done over several months/years to ensure data integrity. The mature tree layer data was summarized by MPB attack and age class, MPB attack and dbh classes, MPB attack and initial stand density, MPB attack and sub-zone, MPB attack and site productivity, MPB attack and attack stage, and MPB attack and residual density.

APPENDIX VI: NET-DOWN TABLE FOR EACH FOREST DISTRICT AND THE PRINCE GEORGE TSA.

Area(ha)	Districts			TSA
	Fort Saint James	Prince George	Vanderhoof	
Gross Area	**3,180,864**	**3,396,671**	**1,387,969**	**7,965,504**
Netdowns				
Area based tenures, private land etc.	104,014	523,948	172,457	800,419
Non-forest *(rock, ice, alpine, water etc)*	1,051,256	651,826	163,225	1,866,307
Roads, Rail, Transmission lines	12,605	28,034	15,658	56,297
Contributing Forest Land Base	**2,012,989**	**2,192,863**	**1,036,629**	**5,242,481**
Netdowns				
Parks etc.	128,253	125,290	78,601	332,144
Unstable Terrain etc.	80,244	75,018	6,887	162,149
Problem Forest Types	38,373	57,233	48,340	143,945
Ungulate Winter Range *(w 100% exclusion)*	15,202	97,471	15,267	127,941
Resource Management Zones *(w 100% exclusion)*	4,305	11,851	327	16,483
Preservation VQO *(w 100% exclusion)*	1,252	532	-	1,784
Recreation *(w 100% exclusion)*	674	1,501	1,893	4,068
Old Growth Management Areas	-	15,361	-	15,361
First Nations *(w 100% exclusion)*	5,458	18,860	-	24,318
Agricultural Development and Settlement Reserve Areas	5,290	14,037	5,686	25,013
Not Economic *(based on past performance)*	621,532	246,708	71,150	939,390
WTPs and Riparian	133,489	151,549	68,721	353,759
Timber Harvesting Land Base	**978,917**	**1,377,451**	**739,757**	**3,096,125**

Appendix VII: Selected Mortality and Pre and Post-MPB Live Basal Area Figures

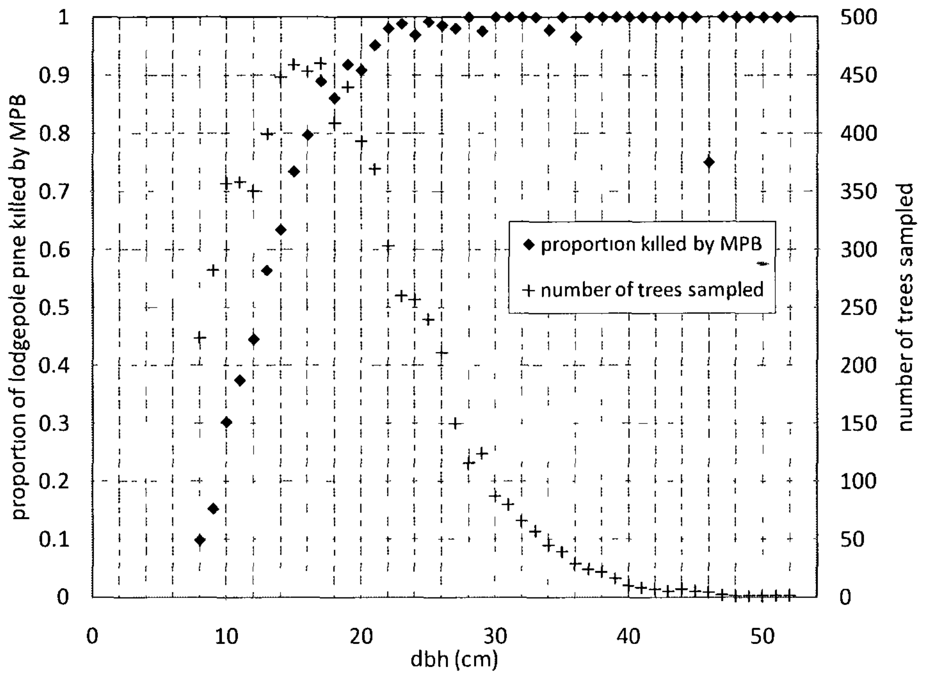


Figure VII.1: Relationship between MPB caused pine tree mortality and dbh for mature stands sampled in the Prince George and Vanderhoof forest districts.

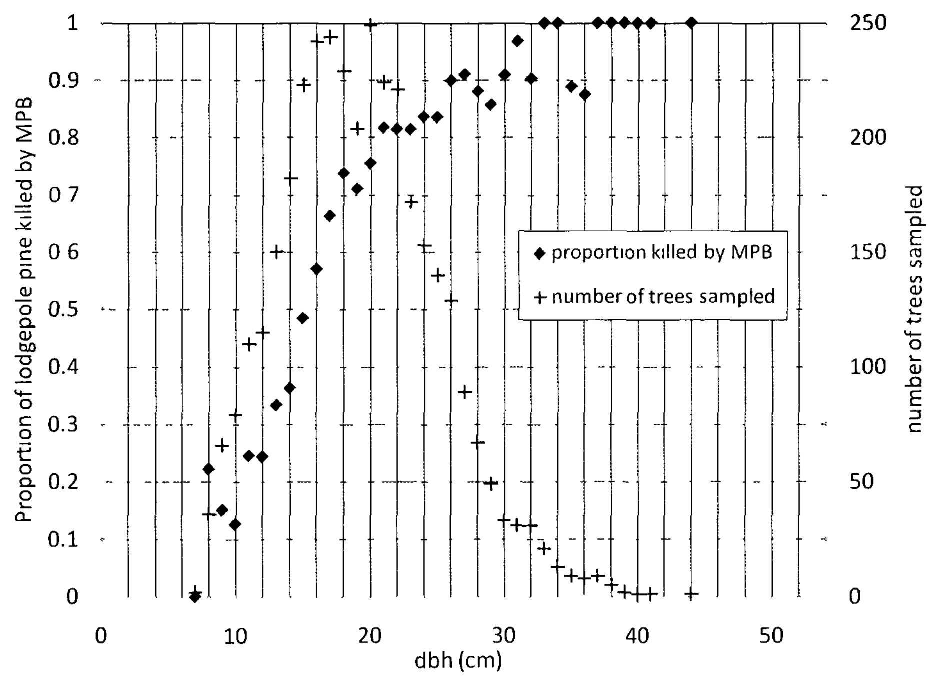


Figure VII.2: Relationship between MPB caused pine tree mortality and dbh for mature stands in the SBS dk BEC subzone in the Nadina forest district.

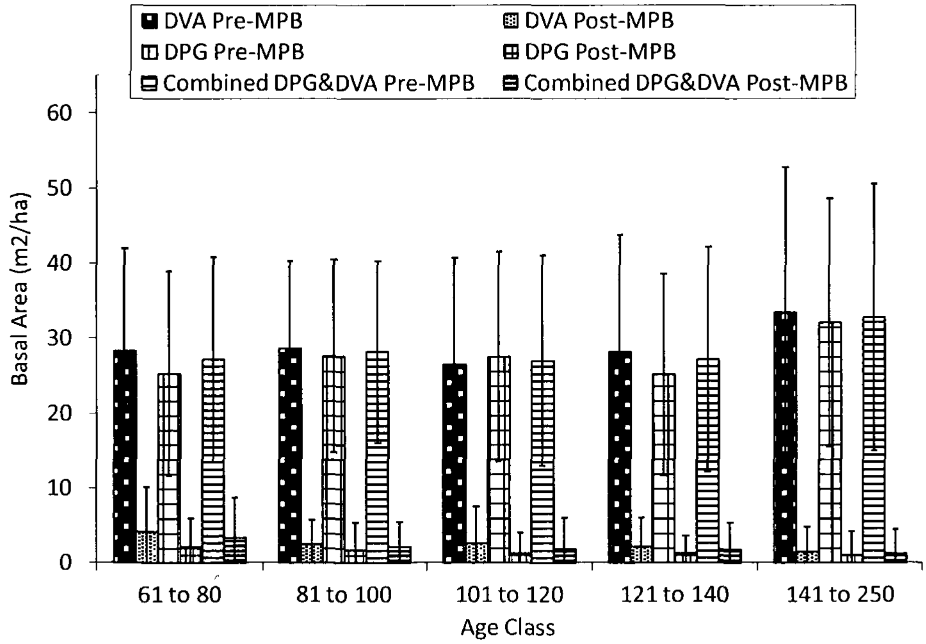


Figure VII.3: Average live pine basal area (m^2/ha) pre and post-MPB attack for trees ≥12.5 cm dbh.

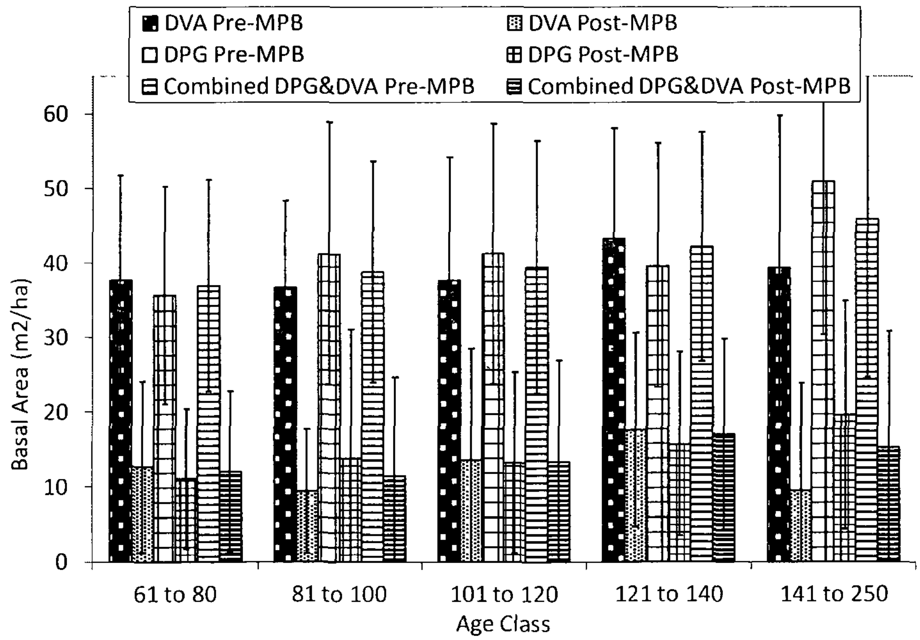


Figure VII.4: Average live all-species basal Area (m^2/ha) pre and post MPB attack for trees ≥12.5 cm dbh.

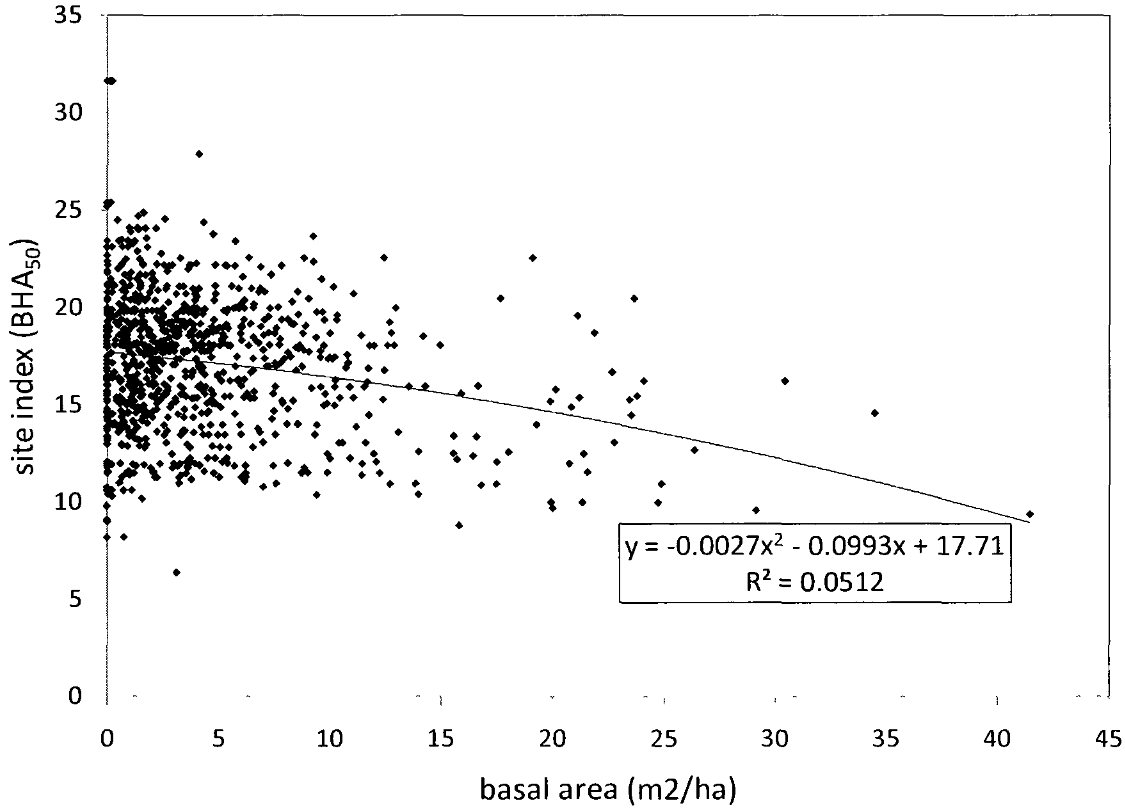


Figure VII.5: Relationship between the amount of post-MPB secondary stand structure basal area (healthy trees ≥ 1.37 m height < 12.5 cm dbh) and calculated site index for all plots in the study area (PG TSA).

APPENDIX VIII: UNADJUSTED VDYP7 VOLUME (m^3/ha) TABLES BASED ON ADVANCED REGENERATION ATTRIBUTES OF SPECIES AND SITE INDEX

	Biogeoclimatic Variant in the Sub-boreal spruce (SBS)						
age	dw2	dw3	dk	mc3	wk1	mk1	vk1
0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
20	0	0	0	0	0	2	0
30	0	0	4	0	4	15	3
40	9	8	19	9	28	51	25
50	36	35	44	33	83	100	77
60	77	77	75	64	151	151	147
70	126	126	106	98	220	198	220
80	179	178	135	133	283	240	289
90	230	228	161	168	339	276	349
100	280	277	184	202	388	306	401
110	326	322	204	235	429	330	444
120	368	362	222	267	463	350	479
130	408	401	237	298	491	365	504
140	443	436	251	329	514	376	522
150	472	462	259	352	528	383	531
160	491	481	266	371	537	386	534
170	503	494	271	383	542	388	533
180	510	501	273	391	545	388	530
190	515	505	275	396	546	388	528
200	516	506	275	398	545	387	525
210	513	503	274	396	542	385	522
220	510	499	272	393	539	383	519
230	507	495	271	390	536	380	516
240	504	492	269	388	533	378	513
250	501	488	267	385	530	376	510

APPENDIX IX:

TIPSY OUTPUTS USED TO DETERMINE EFFECTIVE AGE OF EXISTING ADVANCED REGENERATION BY BEC SUBZONE

Notes to Tables:

Advanced regeneration includes stems from 0 dbh (1.37 m height) to <12.5 cm dbh

For each subzone the equivelent age and other relevant attributes of AR are indicated in a rectangle.

The SBS dk table is used only for "Protect AR" Scenarios.

SBS dw2 TIPSY Age (yr)	Top Ht (m)	Volume (m3/ha) Gross 0 0+	Volume (m3/ha) Total 0 0+	MAI (m3/ha) Total 0 0+	Volume (m3/ha) Merch 12 5+	MAI (m3/ha) Merch 12 5+	Volume (m3/ha) Merch 17 5+	MAI (m3/ha) Merch 17 5+	BA (m2/ha) 0 0+	DBHg (cm) 0 0+	TREES (#/ha) 0 0+	CC (%) All Trees	Volume (m3/ha) Crop Max 250/ha 12 5+	DBHg (cm) Crop Max 250/ha 12 5+	LC (%) Prime 250 trees/ha
0 0	0 0	0	0	0 00	0	0 00	0	0 00	0	0 0	530	0	0	0 0	0
2 0	0 1	0	0	0 00	0	0 00	0	0 00	0	0 0	530	0	0	0 0	0
4 0	0 2	0	0	0 00	0	0 00	0	0 00	0	0 0	529	0	0	0 0	0
6 0	0 5	0	0	0 00	0	0 00	0	0 00	0	0 0	527	0	0	0 0	0
8 0	0 8	0	0	0 00	0	0 00	0	0 00	0	0 0	525	1	0	0 0	0
10 0	1 2	0	0	0 00	0	0 00	0	0 00	0	0 4	523	1	0	0 0	0
12 0	1 6	0	0	0 00	0	0 00	0	0 00	0	0 9	520	2	0	0 0	0
14 0	2 1	0	0	0 00	0	0 00	0	0 00	0	1 3	518	4	0	0 0	0
16 0	2 7	0	0	0 00	0	0 00	0	0 00	0	1 8	515	5	0	15 0	0
18 0	3 2	0	0	0 00	0	0 00	0	0 00	0	2 4	513	7	0	15 0	0
20 0	3 8	1	1	0 05	0	0 00	0	0 00	0	3 1	511	9	0	15 1	0
22 0	4 4	1	1	0 05	0	0 01	0	0 00	1	3 9	508	11	0	15 1	0
24 0	5 1	2	2	0 08	0	0 01	0	0 00	1	4 6	506	14	0	15 1	0
26 0	5 8	3	3	0 12	1	0 03	0	0 00	1	5 4	504	16	1	15 5	0
28 0	6 4	4	4	0 14	1	0 05	0	0 01	2	6 3	502	19	1	15 6	0
30 0	7 1	6	6	0 20	2	0 07	0	0 01	2	7 2	500	22	2	15 6	0
32 0	7 8	8	8	0 25	4	0 11	1	0 04	3	8 1	498	26	4	16 3	0
34 0	8 5	10	10	0 29	5	0 15	2	0 06	3	9 0	496	29	5	16 6	65
36 0	9 1	13	13	0 36	7	0 19	3	0 08	4	9 9	495	33	7	16 8	69
38 0	9 8	16	16	0 42	9	0 25	5	0 13	5	10 8	493	36	9	17 3	73
40 0	10 5	20	20	0 50	12	0 31	7	0 17	5	11 7	492	40	12	17 5	73
42 0	11 1	24	23	0 55	16	0 37	9	0 22	6	12 6	490	43	16	17 7	73
44 0	11 7	28	28	0 64	19	0 44	12	0 27	7	13 4	489	46	19	18 0	72
46 0	12 3	34	33	0 72	25	0 54	16	0 35	8	14 5	486	49	25	18 3	72
48 0	13 0	39	39	0 81	30	0 63	20	0 42	9	15 4	484	53	27	19 0	72
50 0	13 5	45	45	0 90	36	0 71	25	0 50	10	16 3	482	56	31	19 8	72
52 0	14 1	52	52	1 00	43	0 82	32	0 61	11	17 2	480	59	36	20 8	72
54 0	14 7	59	59	1 09	49	0 91	38	0 71	12	18 0	478	61	41	21 7	72
56 0	15 2	66	66	1 18	56	1 00	45	0 80	13	18 8	477	64	45	22 6	72
58 0	15 8	74	73	1 26	64	1 10	53	0 92	14	19 6	475	66	50	23 4	72
60 0	16 3	81	81	1 35	71	1 18	61	1 02	15	20 3	473	68	55	24 0	72
62 0	16 8	89	88	1 42	78	1 26	69	1 12	16	21 0	472	70	59	24 6	71
64 0	17 3	98	97	1 52	87	1 35	78	1 22	17	21 7	471	71	65	25 4	71
66 0	17 8	107	106	1 61	95	1 45	88	1 33	18	22 3	469	73	71	26 2	70
68 0	18 2	116	115	1 69	104	1 53	97	1 43	19	23 0	468	74	78	26 9	70
70 0	18 7	124	124	1 77	113	1 61	106	1 52	20	23 6	467	76	84	27 7	69
72 0	19 1	133	133	1 85	121	1 69	115	1 60	21	24 2	466	77	92	28 4	69
74 0	19 6	142	142	1 92	130	1 75	124	1 68	22	24 7	464	78	97	28 9	68
76 0	20 0	151	151	1 99	138	1 82	133	1 76	23	25 3	463	79	102	29 4	68
78 0	20 4	160	159	2 04	147	1 88	142	1 82	24	25 8	462	80	108	30 0	67
80 0	20 8	169	168	2 10	155	1 94	151	1 89	25	26 3	460	81	114	30 5	66
82 0	21 2	178	177	2 16	164	1 99	160	1 95	26	26 8	459	82	121	31 1	66
84 0	21 5	186	185	2 20	172	2 04	168	2 00	27	27 3	458	83	126	31 6	65

SBS dw3 TIPSY Age (yr)	Top Ht (m)	Volume (m3/ha) Gross 0 0+	Volume (m3/ha) Total 0 0+	MAI (m3/ha) Total 0 0+	Volume (m3/ha) Merch 12 5+	MAI (m3/ha) Merch 12 5+	Volume (m3/ha) Merch 17 5+	MAI (m3/ha) Merch 17 5+	BA (m2/ha) 0 0+	DBHq (cm) 0 0+	TREES (#/ha) 0 0+	CC (%) All Trees	Volume (m3/ha) Crop Max 250/ha 12 5+	DBHq (cm) Crop Max 250/ha 12 5+	LC (%) Prime 250 trees/ha
0 0	0 0	0	0	0 00	0	0 00	0	0 00	0	0 0	630	0	0	0 0	0
2 0	0 1	0	0	0 00	0	0 00	0	0 00	0	0 0	630	0	0	0 0	0
4 0	0 3	0	0	0 00	0	0 00	0	0 00	0	0 0	628	0	0	0 0	0
6 0	0 6	0	0	0 00	0	0 00	0	0 00	0	0 0	626	1	0	0 0	0
8 0	0 9	0	0	0 00	0	0 00	0	0 00	0	0 0	623	1	0	0 0	0
10 0	1 3	0	0	0 00	0	0 00	0	0 00	0	0 5	621	2	0	0 0	0
12 0	1 8	0	0	0 00	0	0 00	0	0 00	0	1 2	618	4	0	0 0	0
14 0	2 3	0	0	0 00	0	0 00	0	0 00	0	1 6	615	6	0	0 0	0
16 0	2 9	1	1	0 06	0	0 00	0	0 00	0	2 3	612	8	0	0 0	0
18 0	3 5	1	1	0 06	0	0 00	0	0 00	0	2 9	610	11	0	0 0	0
20 0	4 1	1	1	0 05	0	0 00	0	0 00	1	3 6	607	14	0	15 0	0
22 0	4 7	2	2	0 09	0	0 01	0	0 00	1	4 6	604	17	0	15 0	0
24 0	5 4	3	3	0 13	0	0 02	0	0 00	1	5 4	601	19	0	15 0	0
26 0	6 1	5	5	0 19	1	0 05	0	0 01	2	6 4	598	23	1	15 3	0
28 0	6 8	7	7	0 25	3	0 10	0	0 02	3	7 4	596	26	3	15 5	0
30 0	7 5	10	9	0 30	4	0 14	1	0 02	3	8 2	593	29	4	15 5	0
32 0	8 1	13	12	0 38	7	0 21	2	0 07	4	9 2	590	33	7	16 2	0
34 0	8 8	16	15	0 44	9	0 27	4	0 12	5	10 1	587	36	9	16 7	0
36 0	9 5	19	18	0 50	11	0 32	6	0 16	6	11 0	585	40	11	17 0	69
38 0	10 1	23	23	0 61	15	0 40	9	0 23	6	11 9	583	43	15	17 6	75
40 0	10 8	28	28	0 70	19	0 48	13	0 32	7	12 8	582	46	19	18 1	76
42 0	11 4	33	32	0 76	23	0 55	16	0 38	8	13 6	581	49	23	18 5	76
44 0	12 0	38	38	0 86	28	0 64	20	0 47	10	14 5	579	53	26	19 3	75
46 0	12 6	46	45	0 98	35	0 76	26	0 56	11	15 4	576	56	31	20 2	75
48 0	13 2	52	52	1 08	41	0 86	31	0 65	12	16 3	573	59	34	21 0	75
50 0	13 7	60	60	1 20	49	0 97	37	0 75	13	17 1	570	62	39	21 9	74
52 0	14 3	68	68	1 31	56	1 08	45	0 87	14	18 0	567	65	44	22 9	74
54 0	14 8	76	76	1 41	64	1 19	53	0 98	16	18 8	564	67	48	23 5	74
56 0	15 3	84	84	1 50	73	1 30	61	1 09	17	19 5	561	70	52	24 1	73
58 0	15 9	93	93	1 60	81	1 40	70	1 21	18	20 3	559	72	57	24 8	73
60 0	16 3	102	101	1 68	89	1 49	80	1 33	19	20 9	557	73	62	25 5	73
62 0	16 8	110	110	1 77	97	1 57	88	1 43	20	21 6	555	75	67	26 2	72
64 0	17 3	120	119	1 86	107	1 67	98	1 54	21	22 2	553	77	74	26 9	72
66 0	17 7	130	129	1 95	116	1 76	108	1 64	22	22 8	551	78	81	27 7	71
68 0	18 1	139	139	2 04	125	1 84	118	1 74	23	23 3	550	79	85	28 2	70
70 0	18 6	149	148	2 11	134	1 92	128	1 83	25	23 9	548	81	90	28 6	70
72 0	19 0	158	158	2 19	144	1 99	137	1 91	26	24 4	546	82	95	29 1	69
74 0	19 4	167	167	2 26	153	2 06	147	1 98	27	24 9	545	82	100	29 6	68
76 0	19 7	177	176	2 32	162	2 13	156	2 06	27	25 4	543	83	106	30 1	68
78 0	20 1	186	185	2 37	171	2 19	166	2 12	28	25 9	542	84	112	30 6	67
80 0	20 5	195	195	2 44	179	2 24	175	2 18	29	26 3	540	85	118	31 2	67
82 0	20 8	204	204	2 49	188	2 29	184	2 24	30	26 7	539	85	124	31 7	66
84 0	21 2	213	212	2 52	196	2 34	192	2 29	31	27 1	538	86	130	32 2	66

SBS mc3		Volume (m3/ha)		MAI (m3/ha)	Volume (m3/ha)	MAI (m3/ha)	Volume (m3/ha)	MAI (m3/ha)	BA (m2/ha)	DBHg (cm)	TREES (#/ha)	CC (%)	Volume (m3/ha)	DBHg (cm)	LC (%)
TIPSY Age (yr)	Top Ht (m)	Gross 0 0+	Total 0 0+	Total 0 0+	Merch 12 5+	Merch 12 5+	Merch 17 5+	Merch 17 5+	0 0+	0 0+	0 0+	All Trees	Crop Max 250/ha 12 5+	Crop Max 250/ha 12 5+	Prime 250 trees/ha
0 0	0 0	0	0	0 00	0	0 00	0	0 00	0	0 0	1290	0	0	0 0	0
2 0	0 1	0	0	0 00	0	0 00	0	0 00	0	0 0	1289	0	0	0 0	0
4 0	0 2	0	0	0 00	0	0 00	0	0 00	0	0 0	1287	1	0	0 0	0
6 0	0 5	0	0	0 00	0	0 00	0	0 00	0	0 0	1282	1	0	0 0	0
8 0	0 8	0	0	0 00	0	0 00	0	0 00	0	0 0	1277	2	0	0 0	0
10 0	1 1	0	0	0 00	0	0 00	0	0 00	0	0 0	1272	3	0	0 0	0
12 0	1 5	0	0	0 00	0	0 00	0	0 00	0	0 7	1266	5	0	0 0	0
14 0	2 0	0	0	0 00	0	0 00	0	0 00	0	1 1	1259	8	0	0 0	0
16 0	2 4	0	0	0 00	0	0 00	0	0 00	0	1 5	1253	11	0	0 0	0
18 0	2 9	1	1	0 06	0	0 00	0	0 00	0	2 0	1247	15	0	15 0	0
20 0	3 4	2	2	0 10	0	0 00	0	0 00	1	2 6	1241	18	0	15 0	0
22 0	4 0	2	2	0 09	0	0 00	0	0 00	1	3 2	1234	22	0	15 0	0
24 0	4 6	4	4	0 17	0	0 01	0	0 00	1	3 9	1228	26	0	15 0	0
26 0	5 1	5	5	0 19	0	0 02	0	0 00	2	4 6	1221	30	0	15 0	0
28 0	5 7	7	7	0 25	1	0 02	0	0 00	3	5 3	1214	34	1	15 0	0
30 0	6 3	9	9	0 30	2	0 06	0	0 01	3	6 0	1206	38	2	15 3	0
32 0	6 9	12	12	0 38	4	0 11	0	0 01	4	6 8	1197	42	4	15 4	0
34 0	7 5	15	15	0 44	5	0 16	1	0 02	5	7 5	1189	46	5	15 4	0
36 0	8 1	19	19	0 53	8	0 21	1	0 04	6	8 2	1182	50	8	15 6	0
38 0	8 7	23	23	0 61	11	0 28	3	0 08	7	8 9	1175	54	11	16 0	65
40 0	9 3	28	27	0 68	14	0 35	5	0 12	8	9 5	1168	58	14	16 3	71
42 0	9 8	33	32	0 76	17	0 42	7	0 16	10	10 2	1162	62	16	16 6	74
44 0	10 4	39	38	0 86	22	0 50	10	0 22	11	10 9	1155	65	18	17 1	74
46 0	10 9	45	44	0 96	27	0 59	13	0 29	12	11 5	1149	68	21	17 8	74
48 0	11 5	52	51	1 06	33	0 69	17	0 36	13	12 2	1143	71	24	18 5	73
50 0	12 0	60	59	1 18	40	0 80	22	0 44	15	12 8	1135	74	27	19 3	73
52 0	12 5	68	67	1 29	48	0 92	27	0 53	16	13 5	1126	77	30	20 1	72
54 0	13 0	77	76	1 41	55	1 03	33	0 62	18	14 2	1118	80	35	21 0	72
56 0	13 5	86	85	1 52	65	1 15	41	0 74	19	14 8	1110	82	39	21 7	71
58 0	13 9	96	95	1 64	74	1 27	50	0 85	21	15 4	1102	84	41	22 2	70
60 0	14 4	105	104	1 73	83	1 39	58	0 97	22	16 0	1093	86	44	22 6	70
62 0	14 8	115	114	1 84	92	1 49	66	1 07	23	16 6	1086	87	46	23 0	69
64 0	15 3	125	124	1 94	102	1 60	76	1 19	25	17 1	1078	89	51	23 6	68
66 0	15 7	135	134	2 03	112	1 70	86	1 31	26	17 6	1071	90	56	24 3	67
68 0	16 1	145	144	2 12	122	1 80	96	1 41	27	18 0	1064	91	60	24 8	66
70 0	16 5	154	154	2 20	132	1 88	106	1 51	28	18 5	1057	92	64	25 4	65
72 0	16 9	165	164	2 28	142	1 97	117	1 62	30	18 9	1050	92	70	26 1	64
74 0	17 3	176	175	2 36	153	2 06	128	1 73	31	19 4	1043	93	75	26 7	63
76 0	17 6	186	185	2 43	163	2 14	139	1 83	32	19 8	1036	94	78	27 0	62
78 0	18 0	197	196	2 51	173	2 22	150	1 92	33	20 2	1029	95	82	27 4	62
80 0	18 3	207	206	2 58	183	2 29	160	2 00	34	20 6	1023	95	85	27 7	61
82 0	18 7	217	216	2 63	193	2 35	171	2 08	35	20 9	1016	95	90	28 1	60
84 0	19 0	227	225	2 68	202	2 40	181	2 15	36	21 2	1010	96	94	28 5	59

SBS mk1

TIPSY Age (yr)	Top Ht (m)	Volume (m3/ha) Gross 0 0+	Volume (m3/ha) Total 0 0+	MAI (m3/ha) Total 0 0+	Volume (m3/ha) Merch 12 5+	MAI (m3/ha) Merch 12 5+	Volume (m3/ha) Merch 17 5+	MAI (m3/ha) Merch 17 5+	BA (m2/ha) 0 0+	DBHq (cm) 0 0+	TREES (#/ha) 0 0+	CC (%) All Trees	Volume (m3/ha) Crop Max 250/ha 12 5+	DBHq (cm) Crop Max 250/ha 12 5+	LC (%) Prime 250 trees/ha
0 0	0 0	0	0	0 00	0	0 00	0	0 00	0	0 0	950	0	0	0 0	0
2 0	0 1	0	0	0 00	0	0 00	0	0 00	0	0 0	949	0	0	0 0	0
4 0	0 2	0	0	0 00	0	0 00	0	0 00	0	0 0	948	0	0	0 0	0
6 0	0 5	0	0	0 00	0	0 00	0	0 00	0	0 0	945	1	0	0 0	0
8 0	0 9	0	0	0 00	0	0 00	0	0 00	0	0 0	941	2	0	0 0	0
10 0	1 2	0	0	0 00	0	0 00	0	0 00	0	0 5	937	3	0	0 0	0
12 0	1 7	0	0	0 00	0	0 00	0	0 00	0	1 1	933	5	0	0 0	0
14 0	2 2	0	0	0 00	0	0 00	0	0 00	0	1 4	928	7	0	0 0	0
16 0	2 7	1	1	0 06	0	0 00	0	0 00	0	2 1	924	10	0	0 0	0
18 0	3 3	1	1	0 06	0	0 00	0	0 00	1	2 7	920	13	0	0 0	0
20 0	4 0	2	2	0 10	0	0 01	0	0 00	1	3 5	915	16	0	15 1	0
22 0	4 6	3	3	0 14	0	0 02	0	0 00	1	4 3	910	20	0	15 1	0
24 0	5 3	5	5	0 21	1	0 03	0	0 00	2	5 0	905	23	1	15 1	0
26 0	6 0	7	7	0 27	2	0 08	0	0 01	3	6 0	900	27	2	15 5	0
28 0	6 8	10	9	0 32	4	0 13	1	0 02	3	6 8	895	31	4	15 5	0
30 0	7 5	12	12	0 40	6	0 19	2	0 05	4	7 7	890	35	6	15 9	0
32 0	8 2	16	16	0 50	8	0 26	3	0 10	5	8 6	886	40	8	16 4	0
34 0	8 9	20	20	0 59	11	0 32	5	0 14	6	9 4	883	45	11	16 7	0
36 0	9 6	26	25	0 69	15	0 41	8	0 22	7	10 3	878	49	15	17 2	71
38 0	10 3	32	31	0 82	20	0 52	11	0 30	9	11 2	874	53	20	17 5	73
40 0	11 0	38	37	0 93	24	0 61	15	0 37	10	12 0	870	57	23	18 1	72
42 0	11 6	45	45	1 07	31	0 73	20	0 47	11	12 9	865	61	26	18 9	72
44 0	12 3	54	54	1 23	39	0 89	26	0 59	13	13 8	859	65	31	19 9	72
46 0	12 9	64	63	1 37	47	1 03	32	0 69	14	14 7	853	69	35	20 9	71
48 0	13 5	74	73	1 52	57	1 19	40	0 83	16	15 6	847	73	41	22 0	71
50 0	14 2	85	84	1 68	68	1 35	50	1 00	18	16 4	842	75	45	22 8	71
52 0	14 7	95	95	1 83	78	1 51	60	1 15	19	17 2	836	78	49	23 3	70
54 0	15 3	107	106	1 96	89	1 65	70	1 30	21	17 9	830	80	54	24 0	70
56 0	15 9	118	118	2 11	101	1 80	82	1 47	22	18 6	824	82	60	24 9	69
58 0	16 4	130	129	2 22	112	1 93	94	1 62	24	19 3	818	84	65	25 6	68
60 0	16 9	141	141	2 35	123	2 06	106	1 76	25	19 9	812	86	71	26 5	68
62 0	17 4	155	154	2 48	136	2 20	119	1 92	27	20 6	806	87	80	27 4	67
64 0	17 9	168	167	2 61	149	2 32	133	2 07	28	21 2	801	88	85	27 8	66
66 0	18 4	180	180	2 73	161	2 44	146	2 21	30	21 8	795	89	89	28 3	65
68 0	18 8	193	192	2 82	173	2 54	159	2 33	31	22 3	791	90	95	28 8	64
70 0	19 3	205	204	2 91	185	2 64	172	2 45	32	22 8	787	91	101	29 4	63
72 0	19 7	218	216	3 00	197	2 74	184	2 56	33	23 3	782	92	108	30 0	62
74 0	20 1	230	228	3 08	209	2 82	196	2 65	34	23 7	778	93	114	30 4	61
76 0	20 5	242	240	3 16	220	2 89	208	2 74	35	24 1	774	93	121	31 0	60
78 0	20 9	253	251	3 22	231	2 96	220	2 82	36	24 5	770	93	128	31 6	59
80 0	21 3	264	262	3 28	242	3 02	231	2 89	37	24 9	765	94	134	32 1	59
82 0	21 6	275	273	3 33	252	3 07	242	2 95	38	25 3	761	94	140	32 7	58
84 0	22 0	286	283	3 37	262	3 12	253	3 01	39	25 7	757	94	146	33 0	57

SBS vk

TIPSY Age (yr)	Top Ht (m)	Volume (m3/ha) Gross 0 0+	Volume (m3/ha) Total 0 0+	MAI (m3/ha) Total 0 0+	Volume (m3/ha) Merch 12 5+	MAI (m3/ha) Merch 12 5+	Volume (m3/ha) Merch 17 5+	MAI (m3/ha) Merch 17 5+	BA (m2/ha) 0 0+	DBHq (cm) 0 0+	TREES (#/ha) 0 0+	CC (%) All Trees	Volume (m3/ha) Crop Max 250/ha 12 5+	DBHq (cm) Crop Max 250/ha 12 5+	LC (%) Prime 250 trees/ha
0 0	0 0	0	0	0 00	0	0 00	0	0 00	0	0 0	5750	0	0	0 0	0
2 0	0 0	0	0	0 00	0	0 00	0	0 00	0	0 0	5745	0	0	0 0	0
4 0	0 1	0	0	0 00	0	0 00	0	0 00	0	0 0	5729	1	0	0 0	0
6 0	0 3	0	0	0 00	0	0 00	0	0 00	0	0 0	5702	1	0	0 0	0
8 0	0 5	0	0	0 00	0	0 00	0	0 00	0	0 0	5664	2	0	0 0	0
10 0	0 8	0	0	0 00	0	0 00	0	0 00	0	0 0	5616	3	0	0 0	0
12 0	1 2	0	0	0 00	0	0 00	0	0 00	0	0 0	5557	5	0	0 0	0
14 0	1 5	0	0	0 00	0	0 00	0	0 00	0	0 0	5506	6	0	0 0	0
16 0	1 9	0	0	0 00	0	0 00	0	0 00	0	0 3	5441	9	0	0 0	0
18 0	2 4	1	1	0 06	0	0 00	0	0 00	0	0 7	5371	14	0	0 0	0
20 0	3 0	1	1	0 05	0	0 00	0	0 00	0	1 1	5294	20	0	0 0	0
22 0	3 6	2	2	0 09	0	0 00	0	0 00	1	1 4	5210	28	0	15 0	0
24 0	4 3	4	4	0 17	0	0 00	0	0 00	2	2 2	5135	38	0	15 0	0
26 0	5 1	7	7	0 27	0	0 00	0	0 00	3	2 9	5059	48	0	15 0	0
28 0	5 8	11	11	0 39	0	0 00	0	0 00	5	3 6	4989	59	0	15 1	0
30 0	6 6	17	17	0 57	0	0 01	0	0 00	7	4 3	4926	68	0	15 1	0
32 0	7 4	25	24	0 75	1	0 03	0	0 00	9	4 9	4868	77	1	15 1	66
34 0	8 2	35	34	1 00	3	0 10	0	0 01	12	5 6	4804	83	3	15 3	66
36 0	8 9	45	44	1 22	6	0 18	1	0 02	14	6 2	4739	88	6	15 3	66
38 0	9 7	58	57	1 50	12	0 32	2	0 05	17	6 8	4652	92	12	15 4	66
40 0	10 5	75	73	1 83	22	0 56	5	0 11	20	7 5	4516	94	16	16 0	65
42 0	11 2	92	90	2 14	34	0 81	8	0 19	23	8 2	4362	96	19	16 6	64
44 0	12 0	112	110	2 50	50	1 13	15	0 34	26	9 0	4176	97	24	17 7	62
46 0	12 7	132	129	2 80	66	1 44	24	0 51	29	9 7	3983	98	29	18 9	60
48 0	13 4	153	149	3 10	85	1 77	34	0 72	32	10 4	3781	99	36	20 3	58
50 0	14 1	173	170	3 40	105	2 10	48	0 97	35	11 1	3592	99	42	21 1	56
52 0	14 8	194	190	3 65	125	2 40	63	1 21	37	11 8	3411	100	46	21 6	54
54 0	15 5	214	210	3 89	145	2 69	79	1 46	39	12 4	3240	100	50	22 2	52
56 0	16 1	235	231	4 13	167	2 98	97	1 74	41	13 1	3080	100	57	23 0	51
58 0	16 8	257	251	4 33	188	3 25	117	2 01	43	13 7	2925	100	64	23 8	50
60 0	17 4	278	272	4 53	211	3 51	138	2 29	45	14 4	2779	100	72	24 8	48
62 0	18 0	299	292	4 71	232	3 74	158	2 55	47	15 0	2644	100	80	25 6	47
64 0	18 5	319	310	4 84	252	3 93	178	2 78	48	15 6	2519	100	89	26 5	46
66 0	19 1	338	327	4 95	270	4 09	197	2 98	49	16 1	2407	100	94	26 8	46
68 0	19 6	356	344	5 06	288	4 24	216	3 17	50	16 7	2299	100	99	27 2	45
70 0	20 2	374	359	5 13	305	4 36	234	3 34	51	17 2	2200	100	105	27 6	44
72 0	20 7	391	372	5 17	321	4 46	252	3 50	52	17 7	2109	100	111	28 0	43
74 0	21 2	407	385	5 20	336	4 54	269	3 64	52	18 1	2024	100	118	28 4	43
76 0	21 6	422	398	5 24	351	4 61	286	3 76	53	18 6	1941	100	123	28 8	42
78 0	22 1	439	411	5 27	365	4 68	303	3 89	54	19 1	1866	100	130	29 3	42
80 0	22 5	456	424	5 30	380	4 75	321	4 01	54	19 6	1801	100	138	29 9	41
82 0	23 0	473	438	5 34	395	4 82	338	4 12	55	20 0	1740	100	147	30 5	41
84 0	23 4	490	450	5 36	409	4 87	355	4 23	55	20 4	1681	100	156	31 0	40

SBS wk1

TIPSY Age (yr)	Top Ht (m)	Volume (m3/ha) Gross 0 0+	Volume (m3/ha) Total 0 0+	MAI (m3/ha) Total 0 0+	Volume (m3/ha) Merch 12 5+	MAI (m3/ha) Merch 12 5+	Volume (m3/ha) Merch 17 5+	MAI (m3/ha) Merch 17 5+	BA (m2/ha) 0 0+	DBHg (cm) 0 0+	TREES (#/ha) 0 0+	CC (%) All Trees	Volume (m3/ha) Crop Max 250/ha 12 5+	DBHg (cm) Crop Max 250/ha 12 5+	LC (%) Prime 250 trees/ha
0 0	0 0	0	0	0 00	0	0 00	0	0 00	0	0 0	1820	0	0	0 0	0
2 0	0 1	0	0	0 00	0	0 00	0	0 00	0	0 0	1819	0	0	0 0	0
4 0	0 2	0	0	0 00	0	0 00	0	0 00	0	0 0	1815	1	0	0 0	0
6 0	0 5	0	0	0 00	0	0 00	0	0 00	0	0 0	1808	2	0	0 0	0
8 0	0 8	0	0	0 00	0	0 00	0	0 00	0	0 0	1801	3	0	0 0	0
10 0	1 2	0	0	0 00	0	0 00	0	0 00	0	0 5	1792	5	0	0 0	0
12 0	1 7	0	0	0 00	0	0 00	0	0 00	0	1 0	1781	8	0	0 0	0
14 0	2 2	1	1	0 07	0	0 00	0	0 00	0	1 4	1771	11	0	15 0	0
16 0	2 8	1	1	0 06	0	0 00	0	0 00	1	2 0	1761	14	0	15 0	0
18 0	3 4	2	2	0 11	0	0 00	0	0 00	1	2 5	1749	19	0	15 1	0
20 0	4 1	4	4	0 20	0	0 01	0	0 00	2	3 3	1737	23	0	15 1	0
22 0	4 9	6	6	0 27	0	0 02	0	0 00	2	4 0	1723	28	0	15 1	0
24 0	5 6	9	9	0 38	2	0 09	0	0 01	3	4 9	1708	33	2	15 3	0
26 0	6 4	12	12	0 46	4	0 15	0	0 01	4	5 7	1693	40	4	15 3	0
28 0	7 2	17	17	0 61	6	0 23	1	0 05	6	6 5	1678	46	6	15 8	0
30 0	8 0	23	23	0 77	10	0 32	3	0 10	7	7 4	1663	53	10	16 2	63
32 0	8 8	29	29	0 91	13	0 40	5	0 16	9	8 2	1650	60	13	16 4	68
34 0	9 6	38	37	1 09	19	0 55	8	0 25	11	9 1	1637	66	19	16 7	69
36 0	10 4	47	47	1 31	25	0 70	12	0 33	13	9 9	1624	71	21	17 3	68
38 0	11 1	57	57	1 50	33	0 86	17	0 43	15	10 7	1609	76	24	18 1	68
40 0	11 9	71	71	1 77	45	1 12	24	0 61	17	11 7	1586	80	29	19 3	68
42 0	12 6	86	85	2 02	57	1 36	32	0 77	20	12 6	1563	85	35	20 5	67
44 0	13 3	101	101	2 30	72	1 63	43	0 98	22	13 5	1539	88	40	21 6	66
46 0	14 0	118	117	2 54	88	1 92	57	1 24	24	14 3	1514	90	45	22 1	66
48 0	14 7	135	133	2 77	104	2 17	70	1 46	27	15 1	1490	92	49	22 7	65
50 0	15 4	152	151	3 02	121	2 42	86	1 72	29	15 9	1466	94	55	23 6	63
52 0	16 0	169	168	3 23	138	2 66	103	1 97	31	16 5	1444	95	62	24 5	62
54 0	16 6	186	185	3 43	155	2 87	119	2 20	33	17 2	1422	96	68	25 4	60
56 0	17 2	205	204	3 64	174	3 10	138	2 46	35	17 8	1399	97	78	26 5	59
58 0	17 8	224	222	3 83	192	3 31	157	2 70	37	18 5	1377	97	83	27 0	57
60 0	18 3	243	241	4 02	210	3 50	175	2 92	39	19 0	1356	98	88	27 5	55
62 0	18 9	261	258	4 16	228	3 67	194	3 13	40	19 6	1333	98	95	28 0	54
64 0	19 4	279	275	4 30	245	3 83	213	3 33	42	20 1	1310	99	103	28 6	53
66 0	19 9	296	292	4 42	261	3 96	231	3 50	43	20 6	1288	99	109	29 1	52
68 0	20 4	312	308	4 53	277	4 08	248	3 65	44	21 1	1267	99	116	29 7	51
70 0	20 9	328	323	4 61	293	4 18	265	3 78	46	21 6	1247	99	124	30 2	50
72 0	21 3	344	338	4 69	307	4 27	280	3 89	47	22 0	1228	99	132	30 8	49
74 0	21 8	359	352	4 76	321	4 34	295	3 99	48	22 4	1209	99	140	31 4	48
76 0	22 2	373	365	4 80	335	4 41	310	4 09	49	22 8	1190	99	148	31 9	47
78 0	22 6	389	380	4 87	350	4 48	326	4 18	50	23 2	1170	99	155	32 4	46
80 0	23 0	404	394	4 93	364	4 55	342	4 27	51	23 7	1150	100	162	32 7	46
82 0	23 4	420	407	4 96	378	4 61	357	4 35	51	24 1	1130	100	167	33 1	45
84 0	23 7	434	421	5 01	391	4 65	371	4 42	52	24 5	1111	100	173	33 4	45

SBS dk

TIPSY Age (yr)	Top Ht (m)	Volume (m3/ha) Gross 0 0+	Volume (m3/ha) Total 0.0+	MAI (m3/ha) Total 0 0+	Volume (m3/ha) Merch 12 5+	MAI (m3/ha) Merch 12 5+	Volume (m3/ha) Merch 17 5+	MAI (m3/ha) Merch 17 5+	BA (m2/ha) 0 0+	DBHg (cm) 0 0+	TREES (#/ha) 0 0+	CC (%) All Trees	Volume (m3/ha) Crop Max 250/ha 12 5+	DBHg (cm) Crop Max 250/ha 12 5+	LC (%) Prime 250 trees/ha
0 0	0 0	0	0	0 00	0	0 00	0	0 00	0	0 0	450	0	0	0 0	0
2 0	0 1	0	0	0 00	0	0 00	0	0 00	0	0 0	450	0	0	0 0	0
4 0	0 3	0	0	0 00	0	0 00	0	0 00	0	0 0	449	0	0	0 0	0
6 0	0 6	0	0	0 00	0	0 00	0	0 00	0	0 0	447	1	0	0 0	0
8 0	1 1	0	0	0 00	0	0 00	0	0 00	0	0 0	444	1	0	0 0	0
10 0	1 4	0	0	0 00	0	0 00	0	0 00	0	0 0	442	2	0	0 0	0
12 0	1 9	0	0	0 00	0	0 00	0	0 00	0	0 9	440	3	0	0 0	0
14 0	2 4	0	0	0 00	0	0 00	0	0 00	0	1 5	438	5	0	0 0	0
16 0	2 9	0	0	0 00	0	0 00	0	0 00	0	2 0	435	7	0	0 0	0
18 0	3 5	1	1	0 06	0	0 00	0	0 00	0	2 6	433	9	0	15 0	0
20 0	4 0	1	1	0 05	0	0 00	0	0 00	0	3 5	431	12	0	15 0	0
22 0	4 6	1	1	0 05	0	0 00	0	0 00	1	4 2	429	14	0	15 0	0
24 0	5 2	2	2	0 08	0	0 00	0	0 00	1	5 0	427	17	0	15 1	0
26 0	5 8	3	3	0 12	0	0 01	0	0 00	1	6 1	424	20	0	15 1	0
28 0	6 5	4	4	0 14	1	0 02	0	0 00	2	7 0	422	22	1	15 1	0
30 0	7 1	5	5	0 17	1	0 04	0	0 01	2	7 9	420	25	1	15 3	0
32 0	7 6	7	7	0 22	3	0 09	0	0 02	3	9 0	418	28	3	15 5	0
34 0	8 2	9	9	0 26	4	0 13	1	0 02	3	9 9	417	30	4	15 6	0
36 0	8 8	11	11	0 31	6	0 16	1	0 03	4	10 7	415	32	6	15 7	0
38 0	9 4	14	14	0 37	8	0 22	3	0 08	4	11 7	413	35	8	16 3	77
40 0	9 9	17	17	0 43	11	0 28	5	0 12	5	12 5	412	37	11	16 7	79
42 0	10 4	19	19	0 45	14	0 32	7	0 16	6	13 3	410	39	14	17 0	82
44 0	11 0	23	22	0 50	16	0 37	9	0 21	6	14 1	409	41	16	17 4	84
46 0	11 5	27	26	0 57	20	0 43	13	0 28	7	14 9	408	43	20	18 0	84
48 0	12 0	31	30	0 63	23	0 49	17	0 35	8	15 7	407	45	23	18 8	83
50 0	12 4	34	34	0 68	27	0 54	20	0 41	9	16 4	406	47	25	19 4	83
52 0	12 9	38	38	0 73	31	0 59	24	0 46	9	17 1	405	49	28	20 1	83
54 0	13 4	43	42	0 78	35	0 65	29	0 53	10	17 9	404	51	32	20 9	83
56 0	13 8	48	47	0 84	40	0 71	33	0 59	11	18 6	403	53	35	21 6	82
58 0	14 2	53	52	0 90	44	0 76	38	0 65	12	19 3	402	55	39	22 3	82
60 0	14 6	57	57	0 95	49	0 81	42	0 71	12	19 9	401	56	43	23 0	81
62 0	15 0	62	61	0 98	53	0 86	47	0 76	13	20 5	400	58	46	23 5	81
64 0	15 4	67	66	1 03	58	0 91	52	0 82	14	21 1	399	59	49	24 0	81
66 0	15 8	72	72	1 09	63	0 96	57	0 87	15	21 6	399	61	52	24 5	80
68 0	16 2	78	77	1 13	68	1 00	63	0 92	15	22 2	398	62	56	25 1	80
70 0	16 5	83	82	1 17	73	1 05	68	0 97	16	22 7	397	63	60	25 6	79
72 0	16 9	88	87	1 21	78	1 08	73	1 02	17	23 2	397	64	63	26 1	79
74 0	17 2	93	92	1 24	83	1 12	79	1 06	17	23 6	396	65	67	26 6	79
76 0	17 5	98	98	1 29	88	1 16	84	1 10	18	24 1	396	66	71	27 1	78
78 0	17 8	104	103	1 32	93	1 19	89	1 15	19	24 5	395	67	75	27 6	78
80 0	18 1	109	108	1 35	98	1 23	95	1 18	19	24 9	395	68	79	28 0	77
82 0	18 4	114	114	1 39	103	1 26	100	1 22	20	25 3	394	69	83	28 5	77
84 0	18 7	119	119	1 42	108	1 29	105	1 25	20	25 7	394	69	87	28 8	76

APPENDIX X: AREA OF BEC SUBZONE IN EACH EFFECTIVE AGE CATEGORY

Forest District	effective age of advanced regeneration	SBS dk	SBS dw2	SBS dw3	SBS mc3	SBS mk1	SBS vk	SBS wk1	Grand Total
Ft St James	1	1,239		10,539		27,536			39,314
	20					49,296			49,296
	22			10,222					10,222
	24	1,197				19,333			20,529
	26			7,731					7,731
	28					12,112			12,112
	29	422		6,271					6,693
	30					18,224			18,224
	32			5,317		5,403			10,720
	33	117							117
	34			3,993		12,412			16,405
	36					3,284			3,284
	37	139		1,760		4,061			5,960
	38					3,117			3,117
	40	88		2,383		5,001			7,471
	42			940		2,461			3,401
	43	16		1,562		1,894			3,471
	44			1,673		1,017			2,690
	46	118		1,463		885			2,466
	47					900			900
	48	6		784					790
	49					487			487
	50	10		3,088		2,892			5,989
dja Total		3,350		57,725		170,313			231,388
Prince George	1		4,486	8,622	462	15,150		1,146	29,866
	17							1,889	1,889
	20					23,312			23,312
	22			8,145	237		180	2,477	11,040
	24		6,468			12,312	504	5,525	24,809
	26			6,122	175		387	3,496	10,180
	27						1,364	3,650	5,015
	28					7,082	585	2,438	10,105
	29		4,448	3,640	46		257		8,391
	30					10,629	247	1,101	11,977
	31							1,082	1,082
	32			4,477	62	3,916		762	9,218
	33		1,225					653	1,878
	34			1,733	3	4,569		168	6,473
	35							251	251
	36		2,118		18	2,330		335	4,801
	37			1,507		2,932		184	4,623
	38				20	2,065			2,085
	39		1,060						1,060
	40			1,794	76	3,514			5,384
	41				13			112	125
	42		799	716		1,324			2,839
	43			636		1,588			2,223
	44		456	938		1,211			2,604
	46		154	455	67	1,184		163	2,023
	47					148			148
	48		213	589	15				817
	49					233			233
	50		2,041	3,031	193	1,551		118	6,934
dpg Total			23,467	42,404	1,388	95,049	3,524	25,549	191,381
Vanderhoof	1	20,879	3,308	13,443	16,034				53,664
	22			14,800	11,531				26,331
	24	14,883	3,667						18,550
	26			11,258	11,237				22,495
	29	7,547	3,464	8,833	5,482				25,326
	32			8,529	2,144				10,673
	33	4,113	1,436						5,549
	34			4,837	916				5,753
	36		1,729		2,796				4,525
	37	3,226		1,643					4,869
	38				4,008				4,008
	39		667						667
	40	1,546		3,625	4,151				9,323
	41				1,367				1,367
	42		647	1,792	1,216				3,656
	43	372		2,110					2,482
	44		233	2,068					2,300
	46	766	139	1,574	4,574				7,053
	48	90	829	945	2,663				4,527
	50	2,287	1,597	4,396	15,345				23,625
dva Total		55,709	17,715	79,852	83,465				236,740
Grand Total		59,059	41,182	179,980	84,853	265,362	3,524	25,549	659,509

APPENDIX XI: SUMMARY OF ADVANCED REGENERATION MODELING ASSUMPTIONS USED IN THE PG TSA SELES TIMBER SUPPLY ANALYSIS.

Attribute	*Base case (PG TSA Alternative Scenario 2)*	*Advanced regeneration (AR) Scenarios*		
		Non-spatial advanced regeneration based on median stand attributes	*Spatial advanced regeneration: prioritization of stands with poor AR for harvest during initial salvage*	*Spatial advanced regeneration: stands with higher AR effective ages are protected*
Residual overstory volume	Original VDYP batch produced yield tables reduced for pine mort.	Original VDYP batch produced yield tables reduced for pine mortality as indicated in BCMPB v5 model.	Original VDYP batch produced yield tables reduced for pine mortality as indicated in BCMPB v5 model.	Original VDYP batch produced yield tables reduced for pine mortality as indicated in BCMPB v5 model.
Understory volume component of unsalvaged pine stands	Based on original pine leading Batch version VDYP7 curves. No change to species composition.	1. VDYP7 compiled to reflect species composition and SI found in field data by BEC subzone. 2. SORTIE ND curves generated based on species and diameter distribution.	VDYP7 recompiled to reflect species composition, and SI found in field data by BEC subzone.	VDYP7 recompiled to reflect species composition, and SI found in field data by BEC subzone.
Availability of volume attributable to understory	Time zero in the model scenarios	After uplift period (year 15)	After uplift period (year 15)	After uplift period (year 15)
Trigger for growth of understory	50% pine mortality	> 1% stand mortality as indicated by BCMPB v5 model	>1% stand mortality as indicated by BCMPB v5 model	>1% stand mortality as indicated by BCMPB v5 model
Regeneration delay to start growth of understory	10 years	No delay – worst case is 0 years, best case is stands are advanced along growth curve to reflect existing BA, (except SBS dk where 89% remains unstocked)	No delay – worst case is 0 years, best case is stands are advanced along growth curve to reflect existing BA (except SBS dk where 89% remains unstocked)	No delay – worst case is 0 years, best case is stands are advanced along growth curve to reflect existing BA (except SBS dk where 89% remains unstocked)

Appendix XII continued

Attribute	Base case (PG TSA Alternative Scenario 2)	*Advanced regeneration (AR) Scenarios*		
		Non-spatial advanced regeneration based on median stand attributes	*Spatial advanced regeneration: prioritization of stands with poor AR for harvest during initial salvage*	*Spatial advanced regeneration: stands with higher AR effective ages are protected*
Age assigned to advanced regeneration	No advanced regeneration only understory that begins to grow 10 years after mortality	All polygons in a subzone are assigned the same effective age based on using median based values for BA, DBHg and density.	A GIS spatial layer of effective ages reflects the distribution of BA found in field samples. Spatial layer created using random assignment.	A GIS spatial layer of effective ages reflects the distribution of BA found in field samples. Spatial layer created using random assignment.
Protection of advanced regeneration	No protection	No protection	Default protection by prioritizing pine stands for harvest based on effective age of advanced regeneration. Stands with no AR or low ages of AR harvested in uplift salvage period.	Stands with effective age greater or equal to 30 years protected from harvest in uplift salvage period.

Appendix XII: Selected SELES STSM Programming Code for Modeling Advanced Regeneration

SELES section heading designation (below)	Function of section
Initialize the StandAgeRegen variable with spatial distribution of ages	Assigns advanced regeneration effective age to rasters
Trigger aging of SSS	Turns on growth of advanced regeneration as soon as stand is attacked by MPB as signalled from BCMPBv5 model
Calculate regen vph	Ensures that during the salvage phase (years 1 to 15) volume from advanced regeneration is not available to be harvested even though it may have begun to accrue volume Nets original advanced regeneration volume tables down to the amount of growing space made available by dead pine component of attacked stand
Spatial Distribution of SSS	Creates spatial layer of distribution of effective age of advanced regeneration Note that this a random spatial distribution based on the distribution of effective ages based on sample data
Priorities	Establishes a list of priorities for harvest at each time step for each raster polygon based on numerical values Priorities are established for species, forest district, effective age of advanced regeneration (SSS) proximity to milling centre (myzone) and volume per hectare
scenario	Initializes model for scenario and inputs spatial layers Names output files Defines shelf life scenario Establishes forecast time period and time steps

Note Information regarding the SELES model and the executable version is available at http //seles info/index php/Main_Page

```
************Initialize the StandAgeRegen variable with spatial distribution of ages***********
STSM_AR
StandAgeRegen[MaxNSRRegenDelay, MaxStandAge] <- SSS // initiate variable with values from SSS spatial distribution layer

*************************Trigger aging of SSS************************************
Succession_kelly
```

```
// Age "secondary" regeneration cohort in cells with some mortality (above min thresh, which is 0 by default)
    // This will start aging a secondary cogen hort as soon as any mortality occurs The secondary
    // cohort comes into existence as soon as PercentKilled > 0
    IF ((100*PercentKilled/PercentKillScale) > RegenPctKillThresh) AND (StandAge > 59)
      StandAgeRegen = MIN(StandAgeRegen + BaseTimestepPrev, MaxStandAge)
    ENDFN
****************Calculate regen vph*************************************************
GrowingStock_kelly
IF CurrYear > 15// assume no volume for 15 years
        AURegen = AUInfo[AU,rUnmanagedAU] // au regenerated is always unmanaged
        decade = CLAMP((StandAgeRegen-AUInfo[AURegen,rRegenDelay])/10,0,MaxDecade)
        l = FLOOR(decade)
        u = CEILING(decade)
        pLower = u - decade
        rVPH = pLower * VolTable[AURegen, l] + (1-pLower) * VolTable[AURegen, u]
        // Apply OAFs before assessing growing stock
        oaf1 = (AUInfo[AURegen,rOAF1] - (SpatialOAFs/SpatialOAFScale))
        rVPH = rVPH * (PercentKilled/PercentKillScale)* CLAMP(oaf1 - (StandAgeRegen * AUInfo[AURegen, rOAF2]/100), 0, 1)
        RegenVPH = CLAMP(ROUND(rVPH*VolScale),0,MaxVolPerHa*VolScale)//harvestrecord field
        TotalVolPerHa = TotalVolPerHa + rVPH//tracking variable
        Vol[MgmtUnit,lRegen] = Vol[MgmtUnit,lRegen] + rVPH * aTHLB//tracking variable
        Area[MgmtUnit,lRegen] = Area[MgmtUnit,lRegen] + (PercentKilled/PercentKillScale) *     aTHLB//tracking variable

***********************Spatial Distribution of SSS****************************************
LSEVENT SSAge
DEFINITIONS
 LAYER bec, PctPine, cceAge, StandAge, itg, Visited
 GLOBAL CONSTANT cceAgeDist[], maxCceAge, maxBec
 LOCAL cceAgeCDF[maxCceAge+1, maxBec+1]
CLUSTER VARIABLE currCceAge
ENDDEF
RETURNTIME
  RETURNTIME = 0
  cceAgeCDF [=] 0
  OVER INDEX SEQUENCE(1,maxBec)
    b = Index
```

```
    t = 0
    OVER INDEX SEQUENCE(0,maxCceAge)
      t = t + cceAgeDist[Index,b]
     cceAgeCDF[Index,b] = t
     DISPLAY RECORD
          t t
       age cceAgeCDF[Index,b]
     ENDFN
    ENDFN
  ENDFN
ENDRT
EVENTLOCATION
  REGION WHOLE MAP
    DECISION (bec > 0) AND (cceAgeCDF[maxCceAge,bec] > 0) AND (StandAge > 60) AND (itg EQ 8)//AND(PctPine > 0)
ENDEL
PROBINIT
  // Exclude stands with deciduous component
  //hasDecid = (itg EQ 8) OR (itg EQ 17) OR (itg EQ 26) OR (itg EQ 31) OR (itg >= 35)
  PROBINIT = 1
 // Pick a random number
  x = UNIFORM(0,cceAgeCDF[maxCceAge,bec])
  // binary search
  mx = maxCceAge
  mn = 0
  curr = ROUND((mx + mn) / 2)
  WHILE (mn < mx)
    curr = ROUND((mx + mn) / 2)
    IF x < cceAgeCDF[curr,bec]
      mx = IF mx EQ curr THEN curr - 1 ELSE curr
    ELSE
      mn = curr
    ENDFN
  ENDFN
  currCceAge = curr
ENDPI
TRANSITIONS
```

```
  TRANSITIONS = !Visited
  cceAge = currCceAge
  Visited = TRUE
ENDTR
SPREADTIME = -1
SPREADLOCATION
  REGION CENTRED(1,1 5)
  DECISION (bec EQ SOURCE bec) AND (StandAge EQ SOURCE StandAge) AND (itg EQ SOURCE itg)
ENDSL

*******************************Priorities*******************************************
MACRO  MoPriorities
// Definitions are optional (but useful for parsing)
DEFINITIONS
  LAYER  MgmtUnit, 4mus, myzone, Districts,SSS
ENDDEF
p1 = (MgmtUnit EQ 1) * (1/myzone) // Decid MU
p2 = (MgmtUnit EQ 2) * (1/myzone) // CWHW MU
p3 = IF (Time < 15) THEN (MgmtUnit EQ 3) * (Districts EQ 2) * (1- (SSS/100)) ELSE (MgmtUnit EQ 3) * (Districts EQ 2) * (1/myzone) // Pine in DPG
p4 = IF (Time < 15) THEN (MgmtUnit EQ 3) * (Districts EQ 3) * (1- (SSS/100)) ELSE (MgmtUnit EQ 3) * (Districts EQ 3) * (1/myzone) // Pine in DPG
p5 = IF (Time < 15) THEN (MgmtUnit EQ 3) * (Districts EQ 1) * (1- (SSS/100)) ELSE (MgmtUnit EQ 3) * (Districts EQ 1) * (1/myzone) // Pine in DPG// Pine in FSJ
p6 = (MgmtUnit EQ 4) * (1/myzone) //BL/SX MU

***************************Priorities*************************************************
```

Interval	Decid	Cw	Pine_DPG	Pine_DVA	Pine_DFSJ	Spruce_Balsam			
0	1	2	3	3	3	4	Mgmt unit		
1	pRelativeAAC	pRelativeAAC	pRelativeAAC	pRelativeAAC	pRelativeAAC	pRelativeAAC	AACType		
2	0	0	0	0	0	0	Rank		
3	rHighestVolFirst	rHighestVolFirst	rHighestVolFirst	rHighestVolFirst	rHighestVolFirst	rHighestVolFirst	Harvest order		
10000	100	100	45	36	100	100	Start of harvest sequence		

```
*********************scenario*******************************************************Scenario Information
/////////////////////////////////////////////////////////_7
// Scenario to simply run a specified harvest flow
```

```
// Useful to generate final output files
/////////////////////////////////////////////////////////

/////////////////////////////////////////////////////////
// The following doesn't normally need to be changed
/////////////////////////////////////////////////////////
$baseDir$ = " "
$outputDir$ = " "
cwd  \STSM // move to STSM folder
Scenario   \STSM\scnBaseLayers_AR scn// Load base layers (Note  location of sub-scenarios is always relative to main scenario)
initialTHLBContribution = $gisData$\thlbcontrib_sss_mk1        // v7 + Morrison buffer
MaxVolxAU = $gisData$\tsa_volume_draft0708maxvol
NDU = $gisData$\ndu
mu5 = $gisData$\mus_leading_fixed
mutsr2 = $gisData$\mus_tsr2
subzone = $gisData$\tsa_BEC_subzones
$MU$ = mus_tsr4_districts
IF (? $SAMPsuffix$)
  $SAMPsuffix$ = 1
END
/////////////////////////////////////////////////////////
// PART 1  The following are specific to the scenario
// - where to put output, and modified input layers/files
/////////////////////////////////////////////////////////
// 1a  Specify scenario name (where to put output) and whether 1% solution is used
$AACsuffix$ = 1
$scnPrefix$ = tsr4_barry_spatial_hvol_myzone_districts
$scnDir$ = 12_5_6M_AR_base_june1_protect_mk130_june8_1
//$scnDir$ = 12_5_6M_AR_jan2_sortie_newdk
IF (? $scnDir$)
  $scnDir$ = 10_625M
END
$use1PctSolution$ = FALSE // 1% solution  setting this to TRUE will add '_1Pct  as suffix to scenario name, load 1% MgmtUnit layer and reduce harvest target
$use5PctSolution$ = FALSE // 1% solution  setting this to TRUE will add '_1Pct' as suffix to scenario name, load 1% MgmtUnit layer and reduce harvest target
$use10PctSolution$ = FALSE // 1% solution  setting this to TRUE will add '_1Pct' as suffix to scenario name, load 1% MgmtUnit layer and reduce harvest target
// 1b  Change (re load) any layers specific to this scenario
```

```
if ($use1PctSolution$)
  MgmtUnit = $gisData$\$MU$_1pct$SAMPsuffix$ // 1% solution  Load 1% of mgmt unit (override normal MgmtUnit)
else
  if ($use5PctSolution$)
 MgmtUnit = $gisData$\$MU$_5pct$SAMPsuffix$ // 1% solution  Load 1% of mgmt unit (override normal MgmtUnit)
  else
    if ($use10PctSolution$)
      MgmtUnit = $gisData$\$MU$_10pct$SAMPsuffix$ // 1% solution  Load 1% of mgmt unit (override normal MgmtUnit)
    else
      MgmtUnit = $gisData$\$MU$ // otherwise load partitioned MgmtUnit
    end
  end
end

// 1c  Change any external script variables specific to this scenario
//$AACFile$ = AAC_PGTSR_12p53m6mSx_AR4_sortie
//$AACFile$ = AAC_PGTSR_12p53m6mSx_AR3
//$AACFile$ = AAC_10M_4
//$AACFile$ = AAC_10M_4_sortie
//$AACFile$ = AAC_PGTSR_250yrs_TSR4mus_districts_barry12p53m6mSx
$AACFile$ = AAC_PGTSR_12p53m6mSx_protect
IF (? $AACFile$)
  $AACFile$ = AAC_PGTSR_250yrs_TSR4mus_districts_barry
END
// Reset the NRL file to apply to 5 mus
$NRLFile$ = NRL_4mu
//$PriorityAACFile$ = PriorityAACSalvage // Load salvage/green priorities (2)
//$PrioritiesFile$ = prioritiesSalvage
$PriorityAACFile$ = PriorityAACPartition_hvol_4mu_districts // Load salvage/green priorities (2)
//$PriorityAACFile$ = PriorityAACPartition_hvol_4mu_districts_AR
//$PrioritiesFile$ = prioritiesPartition_myzone_4mu_Districts_AR
$PrioritiesFile$ = prioritiesPartition_myzone_4mu_Districts

$ShelfLifeOption$ = 1 // this will redirect to the desired shelf life series
if ($use1PctSolution$)
  $scnDir$ = $scnDir$_1Pct$SAMPsuffix$ // 1% solution  add "_1Pct" as suffix to scenario name
```

```
end
if ($use5PctSolution$)
  $scnDir$ = $scnDir$_5Pct$SAMPsuffix$ // 1% solution  add "_1Pct" as suffix to scenario name
end
if ($use10PctSolution$)
  $scnDir$ = $scnDir$_10Pct$SAMPsuffix$ // 1% solution  add "_1Pct" as suffix to scenario name
end

////////////////////////////////////////////////////////
// The following doesn't normally need to be changed
////////////////////////////////////////////////////////

//$BCMPBTimeSeriesDirRip$ = " \ \ \gisData\MPBTimeSeries\cell" // relative to where output will be put
//$BCMPBTimeSeriesDirVPH$ = ' \ \ \gisData\MerchVolTimeSeries\ShelfLifeOption$ShelfLifeOption$\cell' // relative to where output will be put
$BCMPBTimeSeriesDirRip$ = " \ \ \pg_model_location\PERMANENT\cell" // relative to where output will be put
$BCMPBTimeSeriesDirVPH$ = " \ \ \pg_model_location\PERMANENT\MerchVolTimeSeries\ShelfLifeOption$ShelfLifeOption$\cell" // relative to where
output will be put
//$transferFile$ = Transfers_sss
//First Redirect AUInfo table then call SELES
$AUInfoFile$ = AUinfo_advanced_regen2
//$VolumeFile$ = Volumes_ar_sortie_jan2
$CoverConstraintsFile$ = constraints2
//$VolumeFile$ = Volumes_advanced_regen2_jan2
$VolumeFile$ = Volumes_advanced_regen_may14
$HeightFile$ = Heights_advanced_regen
//RegenPctKillThresh = 0
STSM_AR sel // Load model
Scenario   \STSM\paramsBase_AR scn
//Scenario   \STSM\paramsBase scn
Scenario   \STSM\paramsSpatial scn // Load default parameters to make aspatial
// Reset time horizon to 250 years

$TimeHorizon$ = 90

////////////////////////////////////////////////////////
// PART 2  The following are specific to the scenario
```

```
//////////////////////////////////////////////////////

// 2a  Modify any parameters specific to this scenario
if ($use1PctSolution$)
  AACMult = 0 01  // 1% solution  reduce harvest target (default for AACMult is 1)
end
if ($use5PctSolution$)
  AACMult = 0 05  // 1% solution  reduce harvest target (default for AACMult is 1)
end
if ($use10PctSolution$)
  AACMult = 0 10  // 1% solution  reduce harvest target (default for AACMult is 1)
end

AssessPeriodEndStatus = TRUE // Assess post-harvest growing stock/limiting constraints (default  FALSE)


// Set up timestep to be annual for 20 years, then decadal
$StartTimestep$ = 1  // 1 year step for 20 years, then 10 years
$SwitchYear$ = 30 // negative means no switch
$EndTimestep$ = 10
$initialYear$ = 2008

// Save logging output (NextReportingInterval2), but not other dynanamic layers (controlled by NextReportingInterval)
NextReportingInterval = 1  // stand age etc -- a negative means dont save spatial layer
NextReportingInterval2 = 1  //logged layer
$stopReporting2$ = $SwitchYear$
schedule($stopReporting2$)
  NextReportingInterval2 = 10
  NextReportingInterval = 10
  $stopReporting2$ = 1
end

//////////////////////////////////////////////////////
// The following doesn't normally need to be changed
//////////////////////////////////////////////////////
```

```
// Change to an appropriate output folder (will be created)
cwd $baseDir$
cwd $outputDir$
cwd $scnDir$
cwd oScn
Minimize Static
Tile

// create output directories
mkdir cell
mkdir cellhd

SimPriority Low Priority // sets engine to low priority

// Load scenario to find pipe severity inputs
Scenario    \STSM\scn_BCMPB scn

// leave a comment at the end for the moment
```

APPENDIX XIII: SECTION 43.1 AND 43.3 OF THE FOREST PLANNING AND PRACTICES REGULATION: SECONDARY STRUCTURE RETENTION IN MOUNTAIN PINE BEETLE AFFECTED STANDS

B.C. Reg. 14/2004 Deposited January 23, 2004

O.C. 17/2004 effective January 31, 2004

Excerpts from:

Forest and Range Practices Act

FOREST PLANNING AND PRACTICES REGULATION

[includes amendments up to B.C. Reg. 4/2010, January 14, 2010

Section 43.1 and 43.2: Secondary structure retention in mountain pine beetle affected stands

"adequate stocking density" means a stand of trees comprised of

(a) at least 700 trees per ha that are

(i) at least 1.6 m apart from each other, and

(ii) 6 m or greater in height, or

(b) at least 900 trees per ha that are

(i) at least 1.6 m apart from each other, and

(ii) 4 m or greater in height;

"suitable secondary structure" means the saplings, poles, sub-canopy and canopy trees within a stand of trees that are

(a) likely to survive an attack from mountain pine beetle,

(b) a species of tree

(i) specified in a forest stewardship plan applicable to the area, or

(ii) if there is no forest stewardship plan applicable to the area, specified as a preferred or acceptable species in the publication of the Ministry of Forests and Range, Reference Guide for Forest Development Plan Stocking Standards, as amended from time to time,

for the purposes of establishing a free growing stand on the site series, and

(c) of sufficiently good form, health and vigor to provide merchantable trees for future harvesting;

"targeted pine leading stand" means a stand of trees that has all of the following attributes:

(a) is depicted on a government-endorsed forest cover map that indicates lodgepole pine is the leading tree species;

(b) is at least 5 ha in size with an adequate stocking density of suitable secondary structure;

(c) is located in

(i) a timber supply area or tree farm licence area designated by the chief forester in an order made under section 43.2 (1) (a), or

(ii) an area within

(A) the 100 Mile House timber supply area, the Kamloops timber supply area, the Lakes timber supply area, the Merritt timber supply area, the Prince George timber supply area, the Quesnel timber supply area, the Williams Lake timber supply area or the Okanagan timber supply area, or

(B) Tree Farm Licence 18, 35, 42, 48, 49, 52 or 53 unless the timber supply area or tree farm licence area is designated by the chief forester in an order made under section 43.2

(1) (b) as an area which may not contain a targeted pine leading stand.

[am. B.C. Regs. 546/2004, App. s. 11; 580/2004, s. 1; 62/2005, s. 1; 182/2008, s. 1; 240/2009, ss. (a) and (b); 4/2010, s. 3.]

Secondary structure retention in mountain pine beetle affected stands

43.1 (1) A holder of a cutting permit, a forestry licence to cut that does not provide for cutting permits or a timber sale licence must not carry out timber harvesting in a targeted pine leading stand, unless

(a) it is necessary to fell or modify a tree that is a safety hazard and there is no other practicable option for addressing the safety hazard,

(b) the harvesting is necessary to construct a road in the targeted pine leading stand and there is no other practicable option for locating the road, or

(c) at the conclusion of timber harvesting, the holder retains an adequate stocking density of suitable secondary structure.

(2) Despite subsection (1), a holder of a cutting permit, a forestry licence to cut that does not provide for cutting permits or a timber sale licence may harvest timber in a targeted pine leading stand without retaining an adequate stocking density of suitable secondary structure if

(a) the timber in the stand is subject to a significant risk of blowdown,

(b) at the time of harvesting, at least 30% of the pine trees in the stand contain live mountain pine beetles,

(c) harvesting the timber is necessary to protect a community, or other area agreed to by the minister prior to harvesting, from wildfire, or

(d) harvesting the timber is necessary to facilitate collection of tree seed and the resulting opening does not exceed 1 ha.

(3) Without limiting the stocking standards applicable under section 29 (1) or (2) of the Act or section 46 of this regulation, if a person referred to in subsection (1) (c) carries out harvesting in a targeted pine leading stand that creates an obligation to establish a free growing stand, each tree of suitable secondary structure retained in the stand is considered to be a tree of a preferred species for the purpose of establishing a free growing stand on the area where the adequate stocking density of suitable secondary structure was retained.

(4) This section does not apply to

(a) an occupant licence to cut or a master licence to cut that provides for cutting permits,

(b) a forestry licence to cut entered into by a timber sales manager,

(c) a road permit,

(d) a community forest agreement,

(e) an area that is subject to

(i) a cutting permit that has been issued,

(ii) a timber sale licence that has been advertised or entered into, or

(iii) a forestry licence to cut that does not provide for cutting permits which has been entered into by the regional manager or district manager,

before this section comes into force,

(f) an area that is subject to a cutting permit, a forestry licence to cut that does not provide for cutting permits or a timber sale licence if the timber cruising or field layout for the cutting permit, forestry licence to cut or timber sale licence has been completed before this section comes into force,

(g) a cutblock, if the cutblock has been specified in a forest stewardship plan as an area to which section 196 (1) (a) of the Act applies, or

(h) an area depicted on a government-endorsed forest cover map which indicates that lodgepole pine is the leading tree species if a timber cruise of the timber on the area, or other process agreed to by the minister prior to harvesting, shows that lodgepole pine is not the leading tree species.

[en. B.C. Reg. 182/2008, s. 4.]

Chief forester may designate timber supply areas or tree farm licence areas

43.2 (1) The chief forester may make an order designating a timber supply area or tree farm licence area

(a) as an area which may contain a targeted pine leading stand for the purposes of paragraph (c) (i) of the definition of "targeted pine leading stand", or

(b) as an area which may not contain a targeted pine leading stand for the purposes of paragraph (c) (ii) of the definition of "targeted pine leading stand",

if satisfied that the designation is appropriate having regard to the allowable annual cut determination for the area.

(2) An order made under subsection (1) (a)

(a) must be contained in the allowable annual cut determination for the area that

(i) is most recent, and

(ii) includes an increase to the allowable annual cut for mountain pine beetle, and

(b) takes effect 4 months after the date the order is made.

(3) When an order designating an area is made under subsection (1) (a), section 43.1 (1) and (2) do not apply to

(a) an area within the designated area that is subject to

(i) a cutting permit that has been issued,

(ii) a timber sale licence that has been advertised or entered into, or

(iii) a forestry licence to cut that does not provide for cutting permits which has been entered into by the regional manager or district manager,

before the order takes effect under subsection (2) (b), or

(b) an area within the designated area that is subject to a cutting permit, a forestry licence to cut that does not provide for cutting permits or a timber sale licence if the timber cruising or field layout for the cutting permit, forestry licence to cut or timber sale licence has been completed before the order takes effect under subsection (2) (b).

[en. B.C. Reg. 182/2008, s. 4.]