Sundance Forest Industries Ltd.

Forest Management Plan 2007

Timber Supply Analysis Documentation (revised)

April 20, 2009

EXECUTIVE SUMMARY

Sundance Forest Industries Ltd. entered into a forest management agreement with the Government of Alberta in 1997. As a requirement of the forest management agreement they must create a forest management plan at least every 10 years. This forest management plan, which covers the period from 2007 to 2016, is a comprehensive process including a landbase classification, yield curve development, and a timber supply analysis. A timber supply analysis examines the effects of tradeoffs between timber supply and all of the other values being managed for.

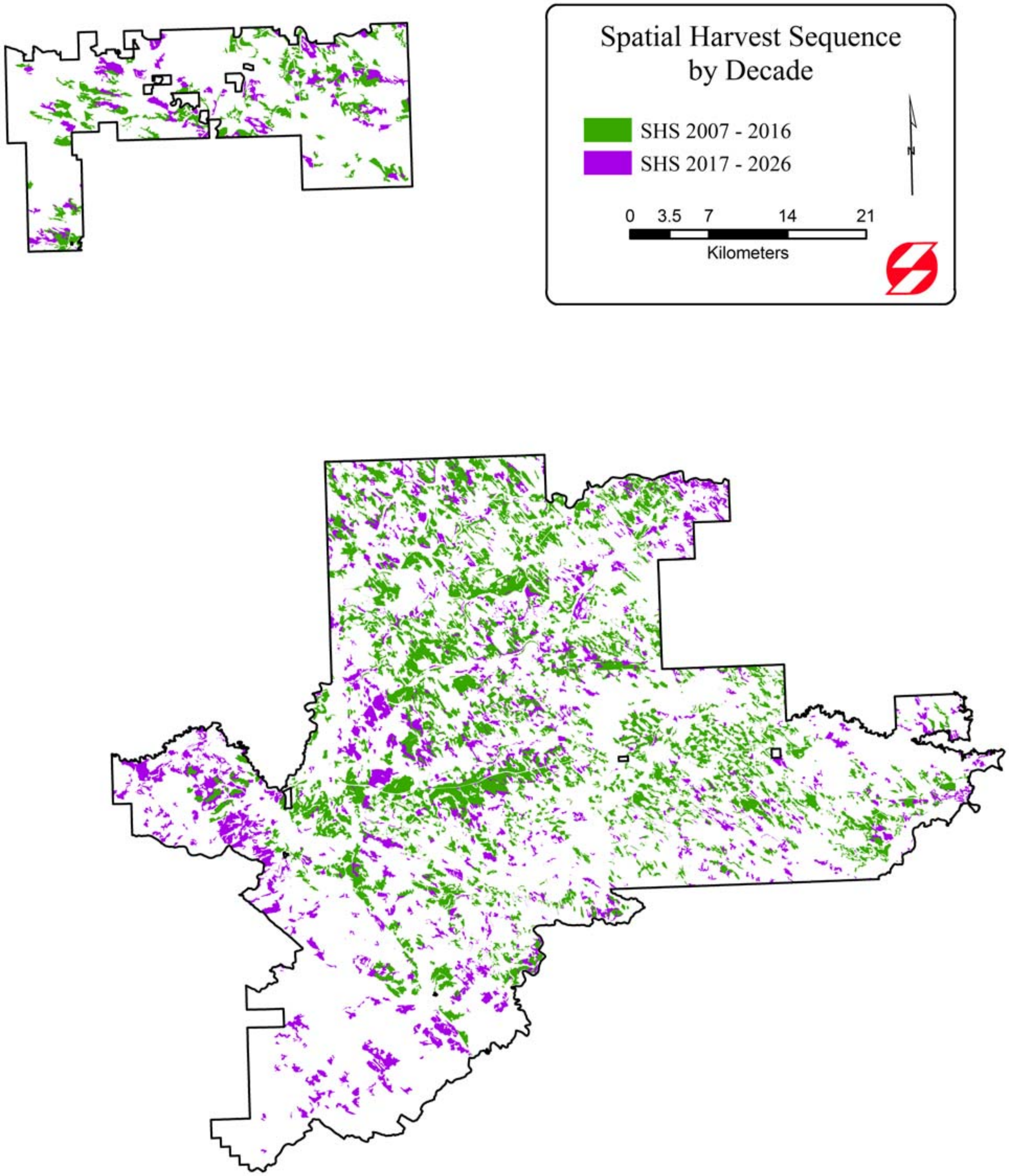
Sundance Forest Industries Ltd.'s landbase is dominated by mature lodgepole pine. Currently there is an epidemic of mountain pine beetle in British Columbia, which has spread into Alberta and is expected to thrive and impact Sundance Forest Industries Ltd. Due to the potential losses from an outbreak of mountain pine beetle, Sundance Forest Industries Ltd., proposing a preferred management scenario which will reduce the ecological and economic impact associated with a potential mountain pine beetle epidemic in their forest management agreement area. This will be accomplished by increasing the short term harvest level through a surge cut, which will directly target susceptible lodgepole pine stands that have a high breeding potential and are of high economic value.

The preferred forest management scenario is the final product of the timber supply analysis described in this document. The preferred forest management scenario contains a number of assumptions and inputs, which are described in this document. These assumptions and inputs cover a wide range of topics including minimum harvest ages, succession rules, access schedules, and seral stages. The preferred forest management scenario is the result of balancing a large number of indicators in the model to achieve a biologically, socially, and economically viable spatial harvest sequence. Sundance Forest Industries Ltd. will follow this spatial harvest sequence for at least the next 10 years, while adapting to MPB threats as the arise. The conifer harvest levels in this preferred forest management scenario are higher in the first 10 year period while dropping in subsequent periods. The harvest level is achieved from the preferred forest management scenario can be seen in Table 1, while the spatial pattern of this scenario can be seen in Map 1.

Table 1. Harvest levels from the preferred forest management scenario.

	Harvest Level (m^3/yr)	
Year	**Conifer (15/11)**	**Deciduous (15/10)**
2007-2016	841,666	60,041
2017-2026	418,763	60,029
2027-2206	420,776	54,739

Prior to the creation of the preferred forest management scenario a large number of sensitivity analyses were completed. These sensitivity analyses explored issues including harvest flow constraints, volume commitments, mountain pine beetle susceptible stand harvest targeting, and spatial harvest constraints. These sensitivities were completed during plan development and are documented in a manner which allows the decision process to be followed.



Map 1. Map of the SHS from the Sundance PFMS by decade

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1. Introduction

Sundance Forest Industries Ltd., (herein referred to as Sundance) entered into a forest management agreement (FMA) with the Government of Alberta in 1997 (Government of Alberta, 1997). As a condition of their FMA agreement the company had to complete a Detailed Forest Management Plan and a new plan every 10 years. Sundance completed this Detailed Forest Management Plan in 1999 (Sundance (1), 1999 and Sundance (2), 1999), including an operational harvest sequence; an update was also completed in 2002 (The Forestry Corp., 2002). This document describes the timber supply analysis (TSA) that was completed for the 2007 Forest Management Plan (FMP). This planning process was completed under the Alberta Forest Management Planning Standard (Version 4.1) (ASRD, 2006).

The TSA is a small portion of the FMP. Though it required a number of other components of the FMP to be completed prior to its finalization, specifically the landbase classification and yield curve development. The development of the landbase and yield curves coincided with the beginning of the TSA so an understanding of the effect of landbase and yield curve decisions could be understood in terms of their effect on the TSA. The TSA used the final classified landbase and the final yield curves to determine a preferred forest management scenario (PFMS). To determine a PFMS it was necessary to complete numerous sensitivity analyses to understand the dynamics of the forest.

The landbase classification (The Forestry Corp. (1), 2007) and yield curve development (The Forestry Corp (2), 2007) along with the TSA were completed by The Forestry Corp. with direction from Sundance and other stakeholders. The landbase and yield curves were developed with nine yield strata; and an effective date of 2005.

The TSA was a complex process that involved the understanding of the tradeoffs that were associated with the different values and their indicators on the forested landbase, balanced to best meet the objectives of the forest managers and stakeholders. The TSA used two different models to explore the tradeoffs and values on the forest. Woodstock, which is an aspatial planning tool using linear programming was used to explore aspatial issues and Patchworks which is a spatial planning tool was used for spatial issues and the PFMS.

The end result of the TSA was a PFMS, of which the first spatially explicit 20 years is referred to as the spatial harvest sequence (SHS). The PFMS balances the management objectives, which range from harvest level to old growth.

The largest issue in the TSA was the threat of a mountain pine beetle (MPB) infestation on the Sundance FMA. MPB breed and develop under the bark of mature pine trees, killing the host tree when enough beetles attack the same host tree. MPB is in a epidemic population in British Columbia (BC), and is expected to kill 80% of the pine trees by 2013. This MPB population has already spread into Alberta to a level that has never occurred in the past. The population is also expected to expand in Alberta. Sundance's FMA is dominated by mature pine on the landbase, which is of high susceptibility to MPB attack. If an epidemic population of MPB were to attack the Sundance FMA there would not be adequate harvest possible from the FMA to sustain the current mill. Therefore this TSA addresses, to the best of the ability a TSA can, the MPB risk that exists on the Sundance FMA.

1.1 Document Structure

This is document is laid out to allow easy reference to information throughout the next 10 years when this plan is implemented. It is broken down into 7 sections: an introduction, a brief landbase summary, a brief yield curve summary, a discussion of inputs and assumptions, a detailed description of the PFMS, an explanation of the issues analyzed, and a conclusion. The introduction includes the preceding as well as a discussion of the historical AAC's from the FMA. The landbase and yield curve summary sections show an overview of the landbase and yield curves included in the TSA. The inputs and assumptions section shows the final inputs into the PFMS, including minimum harvest ages, transitions, and access schedules. The PFMS section shows in detail the targets, and results from the TSA as well as implementation targets. The issues section lays out the issues that were dealt with throughout the TSA, this section is meant to have individual stand-alone information for reference regarding the issues examined. The conclusion summarizes the information within this document.

1.2 Historical TSA

Prior to the creation of the FMA, there were a number of quota certificates and Miscellaneous Timber Use commitments within 4 different provincial Forest Management Units. Sundance's FMA agreement was created in 1997 and an interim harvest level was calculated for the FMA area. In 2002, a Timber Supply Update was prepared and approved (The Forestry Corp, 2002), resulting in new annual and quadrant cuts for all operators. Three years later, part of the Community Timber Program allocation was converted to a quota certificate. The history of allocations on the Sundance FMA area since 1992 is shown in Table 1-1 and Table 1-2 in this section.

Table 1-1. Historical Allocations for FMU R13 as established on January 14, 2002.

Company Name	Disposition Number	Coniferous AAC		Deciduous AAC		Effective Date
		Basis for Cut	m^3/year	Basis for Cut	m^3/year	
Tall Pine Timber	E5-CTQ03	0.16% of FMU AAC	687	n/a	0	1-May-02
Precision Forest Industries	E1-CTQ06	0.46% of FMU AAC	1,976	n/a	0	1-May-02
Medicine Lodge Timber Products	E1-CTQ15	1.92% of FMU AAC	8,246	n/a	0	1-May-02
E1 Community Timber Program	E1 CTP	2.26% of FMU AAC	9,220	11.85% of FMU AAC	5,762	1-May-02
E5 Community Timber Program	E5 CTP	Fixed Volume	7,062	n/a	0	1-May-02
Sundance Forest Industries	FMA 9700032	Balance of FMU	402,266	Balance of FMU AAC	42,859	14-Jan-02

Table 1-2. Historical Allocations for FMU R13 as established on May 1, 2005.

Company Name	Disposition Number	Coniferous AAC		Deciduous AAC		Effective Date
		Basis for Cut	m^3/year	Basis for Cut	m^3/year	
Tall Pine Timber	CTQR130003	0.16% of FMU AAC	687	n/a	0	1-May-02
Precision Forest Industries	CTQR130001	0.46% of FMU AAC	1,976	n/a	0	1-May-02
Medicine Lodge Timber Products	CTQR130002	1.92% of FMU AAC	8,246	n/a	0	1-May-02
E1 Community Timber Program	R13 CTP	1.21% of FMU AAC	5,204	11.85% of FMU AAC	5,762	1-May-05
Edson Community Harvesting Org.	CTQR130004	0.94% of FMU AAC	4,016			1-May-05
Edson Community Harvesting Org.	CTQR130004	Fixed Volume	7,062	n/a	0	1-May-05
Sundance Forest Industries	FMA 9700032	Balance of FMU AAC	402,266	Balance of FMU AAC	42,859	14-Jan-02

Utilization standards were consistent for all operators on the FMA area and are shown in Table 1-3.

Table 1-3. Utilization used to determine harvest levels in PFMS.

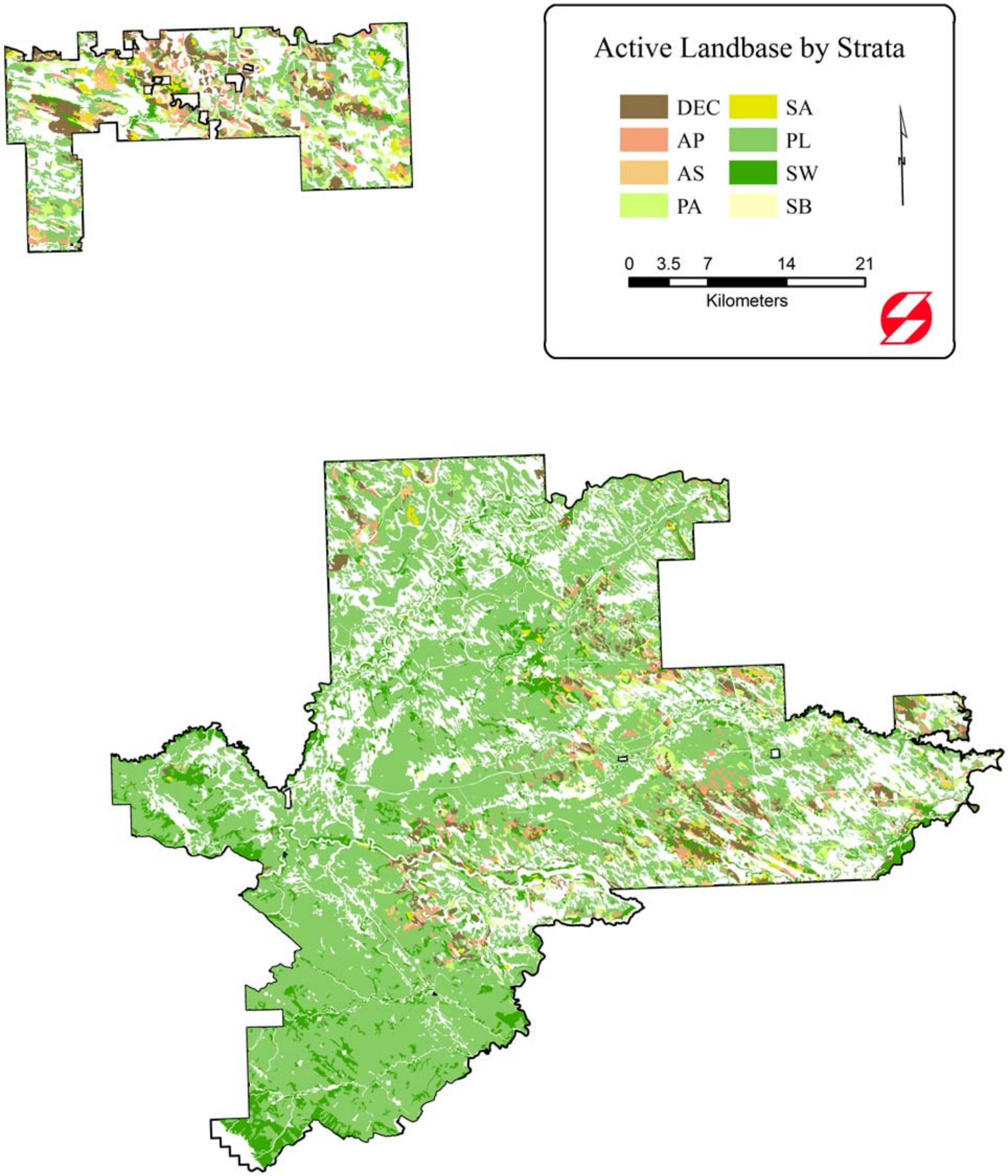
Disposition Number	Coniferous				Deciduous			
	Top D.I.B. (cm)	Butt D.O.B (cm)	Minimum Length (m)	Stump Height (cm)	Top D.I.B. (cm)	Butt D.O.B (cm)	Minimum Length (m)	Stump Height (cm)
CTQR130003	11	15	3.84	15	n/a	n/a	n/a	15
CTQR130001	11	15	3.84	15	n/a	n/a	n/a	15
CTQR130002	11	15	3.84	15	n/a	n/a	n/a	15
R13 CTP	11	15	3.84	15	10	15	2.49	15
CTQR130004	11	15	3.84	15	n/a	n/a	n/a	15
FMA 9700032	11	15	3.84	15	10	15	2.49	15

2. TSA Landbase Summary

Four landbase files were generated during the Sundance TSA process. These four landbase files are described below;

1. R13_LB3_CLS contains all of the line work required in the planning standard;
2. R13_LB3CLSAVI contains the same polygons as R13_LB3_CLS but includes the full AVI string;
3. R13_LB3_TSA includes an area representation instead of line work for seismic, roads, and other layers that are not required for TSA decision making;
4. R13_LB3_MODEL uses the same line work as R13_LB3_TSA but only contains fields necessary for TSA modeling.

Sundance's landbase is a combined coniferous and deciduous landbase. The landbase was classified using nine species and the effective date of 2005. The classified landbase contained too much line work to allow the operational decisions required in spatial TSA models therefore the TSA landbase included an area representation of all layers but did not specifically include line work for seismic, roads, and other layers that were not required for TSA decision making. This created polygon sizes more suitable for operational decisions. This process caused no real change to areas, which can be seen in the Landbase Classification document (The Forestry Corp (1), 2007).



Map 2-1. Map of the managed landbase by species strata.

Area by yield strata can be seen in Table 2-1; it can be seen that the majority of the managed landbase is made up of pine with a mixture of other species. The spatial distribution of these strata can be seen in Map 2-1.

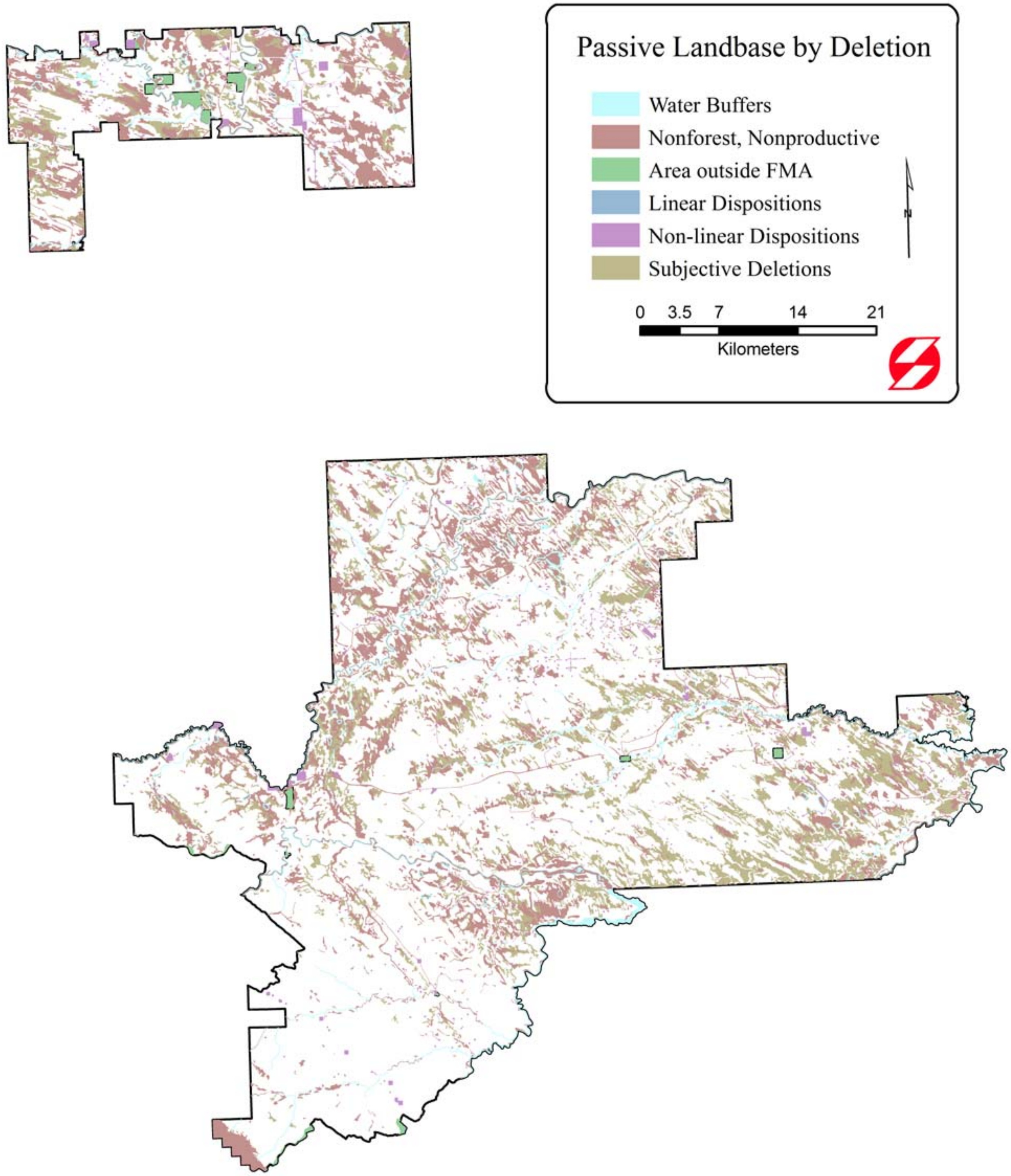
Table 2-1. Area by yield strata on the managed landbase from the TSA landbase.

Description	F_YC	Area(ha)	% Managed Landbase	% Gross Landbase
Deciduous	DEC	9,960	6%	4%
Aspen Pine mixedwood	AP	6,237	4%	2%
Aspen Spruce mixedwood	AS	3,000	2%	1%
Pine Aspen mixedwood	PA	8,034	5%	3%
Spruce Aspen mixedwood	SA	1,989	1%	1%
Pine	PL	125,568	72%	47%
Black spruce	SB	2,489	1%	1%
White spruce	SW	17,378	10%	7%
Managed landbase	**Total**	**174,656**	**100%**	65%

There were numerous deletion categories that caused landbase areas to be removed from the managed landbase. The hierarchical deletion categories, including area and percent of the gross and unmanaged landbase can be seen in Table 2-2. The spatial allocation of these deletions can be seen in Map 2-2.

Table 2-2. Hierarchical deletions from the 2007 Sundance TSA landbase.

Description	F_DEL	Area(ha)	% Unmanaged Landbase	% Gross Landbase
Area outside FMA	XDFA	2,028	2%	1%
Linear features and utility corridors	LINEAR	2,100	2%	1%
Roads	ROADS	3,496	4%	1%
Seismic	SEIS	4,104	4%	2%
Government reservations	GOVRES	664	1%	0%
Mineral and surface leases	LEASE	2,095	2%	1%
Areas burnt since AVI	FIRE	121	0%	0%
Nonforest area	NF	9,675	10%	4%
Nonproductive areas	TPR	27,403	30%	10%
Water buffers	GRBUF	6,758	7%	3%
Larch stands	LT	3,616	4%	1%
Non-commercial black spruce	NCSB	21,133	23%	8%
'A' density black spruce	SB_ADENS	4,389	5%	2%
Horizontal stand deletion in managed landbase		4,578	5%	2%
Unmanaged Landbase	**Total**	**92,160**	**100%**	**35%**



Map 2-2. Map of the landbase deletions on the Sundance landbase.

3. Growth and Yield Summary

The primary growth and yield components of the Sundance 2007 FMP relate to the development of yield curves, which were inputs to the TSA.

3.1 Utilization

Gross merchantable volume estimates were used for yield curve development. Use of the term *gross* indicates that there has been no deduction for *cull*.

The merchantable length of each live tree with a minimum stump diameter of 15.0 cm was calculated based on the height of the tree, a 15.0 cm stump height, and a minimum top diameter (by species type) and log length as defined in Table 3-1. Individual tree volumes were summed to obtain coniferous and deciduous volumes for each plot.

Table 3-1. Minimum utilization standards by species type.

Utilization Characteristic	Conifer Species	Deciduous Species
Stump height	15 cm	15 cm
Minimum log length	3.84 m	2.49 m
Minimum stump diameter outside bark	15 cm	15 cm
Minimum top diameter inside bark	11 cm	10 cm

3.2 Yield Curves

Yield curves are required for use in the TSA that accompanies FMP development. Empirically-fit yield curves were developed for the Sundance 2007 FMP (Figure 3-1 and Figure 3-2) using TSP and PSP plot data. More detailed growth and yield- related FMP information, including methods for determining the yield curves, cull deductions, development of piece size curves (trees/m^3), and calculation of regeneration lag can be found in the Yield Curve Documentation Document (The Forestry Corp. (2), 2007).

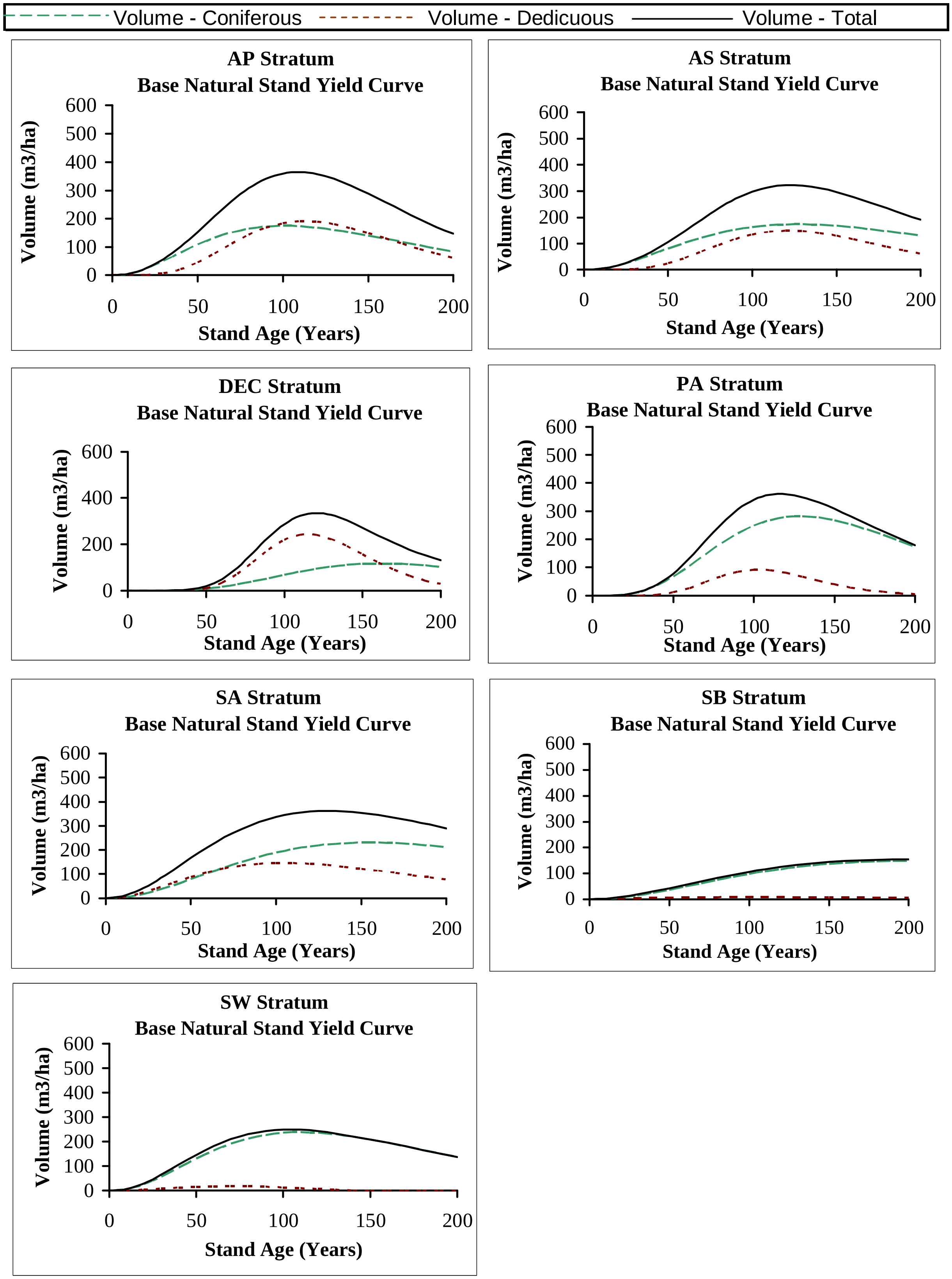


Figure 3-1. Base natural stand yield curves.

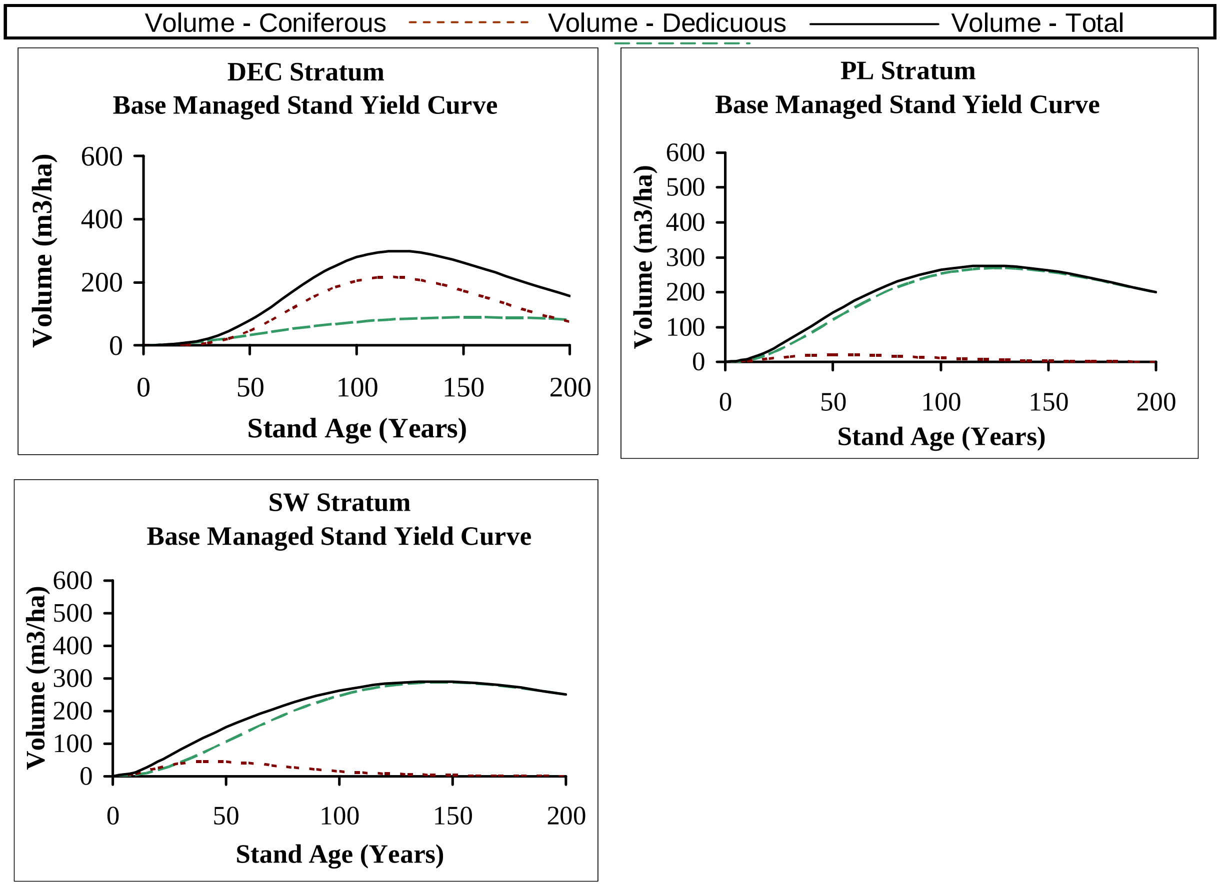


Figure 3-2. Base managed stand yield curves.

Although the managed stand yield curves for the deciduous and white spruce strata have lower maximum volumes that their respective natural curves, the managed curves were used in the timber supply analysis. There was no other reason, other than a lower maximum volume, for not using them and the end result would be a more conservative (i.e. lower) estimate of allowable cuts that could easily be increased in the next plan if supported by additional data. As shown in Table 3-2, the LRSYA is not negatively affected.

Table 3-2. LRSYA for Natural and Managed Curves.

Yield Stratum	Managed Landbase (ha)	Natural Stand Maximum MAI (m^3/ha/y)	Natural Stand LRSY m^3/y	Managed Stand Maximum MAI (m^3/ha/y)	Managed Stand LRSY m^3/y
DEC	9,971	2.935	29,266	2.804	27,960
AP	6,243	3.843	23,991	3.843	23,991
AS	3,026	3.007	9,098	3.007	9,098
PA	7,985	3.410	27,229	3.410	27,229
SA	1,991	3.625	7,218	3.625	7,218
PL	128,331	2.762	354,450	2.946	378,062
SW[1]	17,461	2.997	52,331	2.740	47,844
Total	175,008		503,583		521,402

3.3 Cull

The new Alberta Forest Management Planning Standard (SRD 2006) requires that cull be applied as a percent reduction to yield curves, rather than as a reduction to the harvest level in TSA. A 0.84% coniferous cull was determined using Sundance scale data. A 7% deciduous cull, used by Weyerhaeuser in their last FMP, will be used for deciduous cull in Sundance 2007 FMP.

A 7% reduction was applied to the deciduous component of each yield curve, and a 0.84% reduction was applied to the coniferous component of each yield curve. Cull was applied to yield curves during timber supply modeling. (The Forestry Corp. (2), 2007).

4. Assumptions and Inputs

4.1 Overview

Forecasting timber supply is a complex process that requires many inputs and assumptions. The purpose of this section is to explicitly show the final inputs and assumptions used in the forecasting for the Sundance FMP. In many cases, there were sensitivity analyses completed to compare different sets of assumptions. The results of these analyses allowed managers and stakeholders to make decisions on which set of assumptions or inputs to use in the FMP, many of these can be seen in Section 6. This section shows only the finals sets used in the analysis. In many cases, the assumptions and inputs represent simplifications of natural systems to allow them to be implemented in a TSA model.

This section describes the modeling tools used in forecasting, the key objectives of the analysis, the desired future forest and the inputs and outputs of the many scenarios that were analyzed.

4.2 Modeling tools

Two timber supply modeling tools were used for this TSA: Woodstock for non-spatial analysis and Patchworks for spatial analysis. The Patchworks interface allows the conversion of Woodstock models into Patchworks format, as a result common datasets were utilized to ensure continuity and meaningful comparison of results.

Woodstock was used for strategic, non-spatial analysis to test and compare different management assumption. Patchworks dealt with the spatial issues involved with creating management strategies. Where possible, sensitivity analyses were completed using Woodstock for two reasons. Firstly, Woodstock uses linear optimization which, when feasible, provides the maximum possible solution whereas Patchworks uses a heuristic approach, which does not always provide the maximum possible objective function. Secondly, Woodstock is fast at providing optimal solutions compared with Patchworks. For these reasons, whenever there were no spatial requirements for sensitivities, Woodstock was used. The recommended harvest level and the SHS were set using one scenario, which was developed in Patchworks.

4.2.1 Woodstock

Woodstock is a strategic forest estate-modeling tool developed and serviced by Remsoft (Remsoft, 2006) (version 2006.8). It was used for strategic analysis of timber supply and comparisons of alternative strategies and formulations. This strategic analysis provided insight for the resolution of specific issues including growing stock, minimum harvest age and harvest flow.

Woodstock is completely non-spatial; therefore every unique type is rolled up into forest classes (TSA themes by age class). The model can then apply treatments to all or a portion of that unique forest class. Post-treatment transitions can be one to many relationships defined as percentages. The optimizer selects the optimal combination of treatments throughout the entire planning horizon to solve the objective function.

Woodstock can be formulated as either:

- Basic optimization where there was one modeling objective with rigid constraints; or
- Goal programming where the modeling objective was to minimize deviations from a goal.

Goal programming required the identification of a weighting, which is the penalty for deviating from the goal, to allow the model to rank the goals. Typically, a high weighting results in a small deviation from the goal.

For this TSA, only one Woodstock formulation was used basic optimization, where the modeling objective was to maximize harvest volume subject to constraints such as even flow harvest volume and minimum ending growing stock.

Woodstock uses a mathematical technique called linear programming to quickly determine the absolute answer to the management assumptions.

A structured, progressive approach was used in the development and analysis of Woodstock scenarios. Increasing levels of constraints were applied in successive scenarios to meet forest management objectives and to answer specific management questions and issues. The end result of the Woodstock stage was scenarios that met all of the non-spatial key objectives.

Woodstock runs and reports in 5-year periods in this analysis.

Linear Programming

Linear programming is a commonly used mathematical tool used in forest management because of it’s speed and accuracy in finding the ‘optimal’ solution with regards to a single objective and several constraints. Davis et al. (2001) describes linear programming as: “Problems that are linear with respect to the relationships between the decision variables can be solved by a technique called linear programming. By linear, we mean the operators are restricted to plus or minus."

4.2.2 Patchworks

Patchworks is relatively new to forest management planning in Alberta. It is a spatially-explicit wood supply modeling tool developed and serviced by Spatial Planning Systems[1]. Patchworks is designed to provide the user with operational-scale decision-making capacity within a strategic analytical environment. Trade-off analysis of alternative operational decisions are quickly determined and visually displayed.

Patchworks operates at the polygon level. In Patchworks terminology, polygons are the smallest element, which in this case, are the subdivided AVI stands in the classified landbase. The treatments applied to each polygon are an *all or nothing* decision for the model. There is only one post-treatment transition for each polygon. When Patchworks operates, one or more polygons adjacent to each other that meet specific criteria can be combined to form "patches". The classified landbase is made up of many small polygons to allow for more options in creating patches.

The tool is fully spatial through time and the impact on an adjacent polygon 200 years into the future is considered in the first year of the simulation. Patchworks decision space can be thought of as a matrix consisting of each polygon and each potential outcome for every time slice in the planning horizon.

Patchworks is a heuristic model that attempts to achieve close to an optimal solution for the defined goals or targets (similar to the goal-programming in Woodstock). Its modeling objective is to minimize deviation from the modeling targets. The term *goal* will be used in this document to define the modeling targets used in both Patchworks and Woodstock models, to distinguish them from other types of targets. Patchworks uses a stochastic solving technique called simulated annealing defined in more detail below. Unlike Woodstock, spatial relationships (*i.e.* patch size distributions) can be applied in the objective function.

In this analysis, a variety of goals were defined such as harvest levels, minimum growing stock levels, minimum seral stage areas, maximum block size and range of regeneration patch sizes by period.

Goals were represented by different features (*e.g.* cubic meters or hectares) and weighting factors, which ranked the importance and contribution of each feature towards the modeling objective. Patchworks allows planners to explore the interactions between attributes such as physical wood supply, harvesting economics and other values.

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[1] Spatial Planning Systems. 134 Frontenac Cres., Box 908, Deep River, ON K0J 1P0

Patchworks solves in annual periods, however, it was set up to model and report in 40 five year increments to match Woodstock for this analysis. The model begins in 2007 and plans till 2206.

Patchworks scenarios were developed from Woodstock, to ensure identical assumptions, including landbase, yield curves, treatments and responses.

Simulated Annealing

A description of simulated annealing from Davis et al. (2001) is;

> An algorithm that simulates the cooling of materials in a heat bath – a process known as annealing. Essentially, (the) algorithm simulates the change in energy of a metal during the cooling process, and models the rate of change until it converges to a steady "frozen" state. Searching the feasible regions of a planning problem with the objective of converging on an optimal solution (a steady state) is the goal of simulated annealing. The technique moves from one "good" solution to a neighboring solution, generally by randomly changing a single piece of the solution, perhaps the harvest prescription for a management unit.

The textbook further describes the process in which a random starting point is chosen (feasible or infeasible) and then as new choices are made, the model decides if the new treatment selection is better than the current treatment selection. If the new selection is better, then it replaces and becomes the current solution. This process is repeated many times over until no new choices provide a better solution set than what is currently being used. Furthermore, Lockwood and Moore (1993) state that "a simulated annealing procedure mimics this slow cooling process by gradually rearranging the elements of a system from a disordered state to an ordered, or nearly optimal state."

The comparison to linear programming is difficult, but at least one study has examined the differences between the different modeling techniques. Boston and Bettinger (1999) compared simulated annealing with Monte Carlo Integer programming and with Tabu search heuristics, and then compared all three with linear programming solutions to four different problems. They stated that "Simulated annealing found the highest solution value for three of the four planning problems, and was less than 1% from the highest objective function value in the fourth problem."

4.3 Natural disturbance

Prior to human activity natural disturbance caused the majority of changes in the forest structure and age. Natural disturbance includes all natural factors that affect a forest ecosystem such as fire and insect outbreaks. Historically in Alberta, fire has had the largest effect on forest dynamics. It has been suggested that through time, fire suppression activities have increased the age class and structure of the forest, by reducing the area burned on the landbase (Cumming, S.G., 2005). There have also been different insect populations that have affected the forest dynamics in Alberta. These insect populations include forest tent caterpillar (*Malacosoma disstria)*, spruce budworm (*choristoneura funiferana*), and mountain pine beetle (*Dendroctonus ponderosae*).

Alberta's Green Zone has largely been allocated to forestry companies for the purpose of timber production. Though other industries use same landbase, such as oil and gas and ranchers, they do not rely on the mature timber. They may view the timber as a hindrance. Since natural disturbances, on a large scale, typically affect the mature timber, they mainly impact the forest companies. As natural disturbances, fires and insects, and other forest uses, harvesting and oil and gas, are all working on the landbase it is important to mitigate the affect of natural disturbance, to prevent over harvesting of the resource. Historically, companies have been able to salvage the areas burned, which is one means of mitigating the affect of forest fires.

As the amount of mature and overmature forest on the landbase is reduced through natural disturbance or forest harvesting it is arguable that there will be a larger effect of natural disturbance on forest companies in the future. Though there could also be a decreased amount of area affected by natural disturbance, especially by pests, when the mature and over-mature forest area is reduced.

4.4 Mountain Pine Beetle

There were two MPB ranking systems used in the Sundance TSA. The first was the SRD ranking system which had three component 'Pine rating', compartment risk, and climate factor. The second ranking was the Sundance rating of pine, which used pine percent, and height to assign the rating. These systems are shown below along with how they were used in the Sundance TSA.

The 'Pine Rating' of the stands was calculated using the ASRD Pine Rating model. We used all of the default input parameters with the effective date of 2007.

The 'Compartment Risk' was completed by Alberta Sustainable Resource Development for Sundance's FMP. They ranked the following compartments as moderate:

- 21
- 22
- 23
- 24
- 6
- 7
- 8

The rest of the Compartments they ranked as low risk.

The final component of the MPB rating was the 'Climate Factor'. 'Climate Factor' is a measure of the effect that climate will have on beetle development, or the probability that they will undergo one year lifecycles (ASRD (2), 2006).

These three components were combined as shown in Table 4-1 to calculate the SRD MPB ranking. A map of the SRD rating by managed and unmanaged can be seen in Map 4-1.The Climate Factor and Compartment Risk comprise the main effect of the MPB rating; a climate factor of >= 0.8 and a high compartment would result in a Rank 1 stand, even if there were only

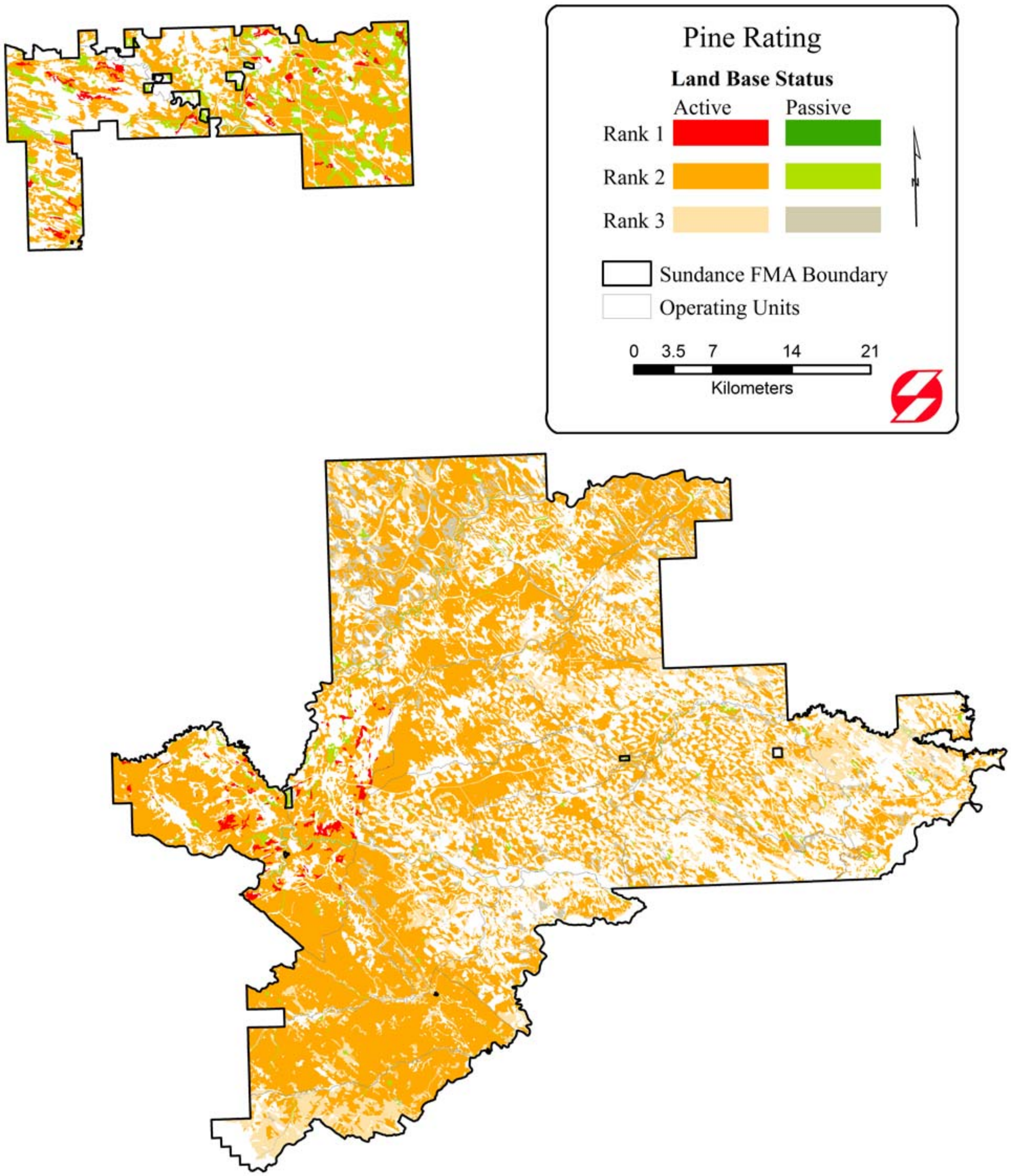
10% pine in the stand. Alternatively, if the Compartment rank were Low and the Climate Factor were <= 0.5, the highest the rank would be is 2 even if the SSI were 100 (highest SSI possible).

Table 4-1. Pine stand ranking.

Climate Factor (per stand)	Compartment Risk	Pine Rating			
Very Suitable 1.0	High	1	1	1	1
	Moderate	2	1	1	1
	Low	2	2	1	1
Highly Suitable 0.8	High	1	1	1	1
	Moderate	2	2	1	1
	Low	2	2	2	1
Moderately Suitable 0.5	High	2	1	1	1
	Moderate	2	2	2	1
	Low	3	2	2	2
Low Suitability 0.2	High	2	1	1	1
	Moderate	3	2	2	2
	Low	3	2	2	2
Very Low Suitability 0.1	High	3	2	2	2
	Moderate	3	3	2	2
	Low	3	3	3	3
Pine Rating		0 to 30	31 to 50	51 to 80	81 to 100

The Sundance rating of pine was pine stands with greater than 90 percent pine and a height greater than 20 meters tall.

The Sundance rating of pine was used to control the TSA model, while the SRD ranking was used to assess SHSs but not to actively control the model. Both rankings were calculated for the 2007 landbase and high ranked stands had a low rank assigned post harvest, but no stands were able to increase in rank during the modeling. The SRD ranking classified such a large amount of area that it was not feasible to use to actively control the model. The Sundance ranking was generally a subset of the SRD ranking which targeted high economic value stands.



Map 4-1. SRD MPB rating on the managed and unmanaged landbase.

4.5 Productivity losses accounted

There are a number of different mechanisms to account for productivity losses on the landbase. The first is the AAC recalculation trigger, when the harvest level or managed landbase is reduced by more than 2.5% from the current area, Sundance would have to recalculate their harvest level based on the new reduced landbase. The second mechanism that exists is a result of the historical method of dealing with fire. When a fire burns on the landbase it was typically been removed from the managed landbase in the next TSA; until the area is inventoried or surveyed to show regeneration. Though these areas are out of the managed landbase they are very likely to regenerate to forested stands. As most of the forest types in Alberta are adapted to frequent fires, and in some cases reliant on fire for regeneration, it may be assumed that as fires are burning on the landbase area and is 'removed from the landbase' due to fire will be returning to the landbase. Therefore, fire has inherently been accounted into the harvest level calculations through both a recalculation trigger and post fire area removal.

4.6 Yield curves

4.6.1 Volume

The final volume yield curves used in the TSA are described in Section 3 of this document. These curves were slightly modified from their original form for use in the TSA as the cull factor was applied to the yield curve based on Section 3.3.

4.6.2 Regeneration Lag

The regeneration lags were calculated during the blocks classification process and were applied to the yield curves. The final regeneration lags were 2 years for deciduous cover group blocks and 3 years for the other cover groups (Table 4-2). In this TSA process, the regeneration lag was included by shifting the yield curves in the future by the length of the regeneration lag. Detailed calculations can be seen in the Growth and Yield document (The Forestry Corp. (2), 2007).

Table 4-2. Regeneration lags by FMU and broad cover group.

Broad Cover Group	Non-rounded Regeneration Lag (years)	Rounded Regeneration Lag (years)
C, CD, DC	2.95	3
D	1.76	2

4.7 Structural retention

The Alberta government requires that companies include structure retention into there harvesting activities. Sundance will include 1.5% retention in their harvesting. The structural retention volume will be accounted for from the harvest level on a block by block basis and is chargeable to the AAC. No reductions due to this percentage will be shown in this document.

4.8 Seral stages

The seral stages used in the Sundance FMP were based on the SRD provincial seral stages. Though the Sundance FMA spans multiple natural sub-regions, only the Lower Foothills sub-region seral stage curves were used. Additionally, there are only 9 strata in the Sundance FMP, fewer than the number of provincial strata. Due to this, there were some Sundance strata that had multiple provincial strata associated. In these cases, the provincial strata that represented the majority of the Sundance strata area was selected. Specifically, the D-Aw leading strata was used for all of the DEC strata and C-Pl leading strata was used for the PL strata. In cases where the minimum harvest age was lower than the minimum age for the Young to Mature transition between seral stage, the age of the young to mature transition was lowered to the minimum harvest age of the strata. Finally, the maximum age of the late old growth seral stage was set to the lifespan of the strata. The resulting seral stage definitions can be seen in Table 4-3.

Table 4-3. Seral stages definitions used in the Sundance TSA.

	Regenerating		Young		Mature		Early Old Growth		Late Old Growth	
Strata	Min (yrs)	Max (yrs)	Min (yrs)	Max (yrs)	Min (yrs)	Max (yrs)	Min (yrs)	Max (yrs)	Min (yrs)	Max* (yrs)
DEC	0	20	21	70	71	130	131	160	161	245
AP	0	25	26	80	81	140	141	180	180	400
AS	0	30	31	90	91	150	151	190	191	400
PA	0	25	26	80	81	140	141	180	181	400
SA	0	30	31	90	91	150	151	190	191	400
LT	0	40	41	100	101	200	201	250	251	400
PL	0	30	31	80	81	160	161	210	211	295
SB	0	40	41	100	101	200	201	250	251	295
Sw	0	30	31	90	91	180	181	230	231	295

* Based on Oct 4, 2006 Succesion rules lifespan

4.9 Lifespan and succession

The final succession rule set were based on the 1997 Sundance FMP (Table 4-4). They were simplified due to the lower number of species strata in the 2007 FMP versus the previous DFMP.

Table 4-4. Succession rules used in the PFMS.

Pre-Succession Strata			Post-Succession Strata	
Broad Cover Group	Yield Strata	Age (years)	Yield Strata	Age (years)
D	DEC	245	DEC	0
DC	AP	400	AP	0
	AS	400	DEC	0
CD	PA	400	PA	0
	SA	400	SA	0
CD	LT	400	LT	0
	PL	295	PL	0
	SB	295	SB	0
	SW	295	SW	0
NF	X	400	X	0

4.10 Planning horizon

For this TSA the planning horizon was 200 years. In this report all of the results show the 200 years of the planning horizon from 2007 to 2206. These are timber years, as are all years reported in this document, therefore 2007 is from May 1st, 2007 to April 30, 2008.

4.11 Treatment

The minimum clearcut harvest ages used in this FMP can be seen in Table 4-5. Managed stand minimum clearcut harvest ages were five years less than the natural stand minimum harvest ages. Minimum harvest ages were based on piece size and the mill's capacity to utilize the timber produced. It is expected that the wider initial stand spacing of managed stands will result in a reduction in the time required to achieve minimum operability conditions. When determining rotation period, the regeneration lag time of 2 years for deciduous and 3 years for conifer must be added to the minimum harvest ages. For example, the pine rotation period is 79 years.

Selecting minimum harvest ages that are less than the peak MAI for a stratum gives the model more flexibility in meeting patch size and interior forest objectives. Polygons with merchantable timber adjacent to polygons at peak MAI may be combined to create larger openings, thereby reducing fragmentation. In attempting to maximize coniferous timber production, the model preferentially selects polygons at peak MAI. However, other non-timber objectives, which may reduce the timber-producing capacity of the landbase, must also be incorporated.

Table 4-5. Sundance TSA minimum harvest ages for clearcutting.

Broad Cover Group	Yield Strata	Age (years)
Natural		
D	DEC	61
DC	AP	81
	AS	101
CD	PA	71
	SA	101
C	PL	81
	SB	111
	SW	101
Regenerating		
D	DEC	56
DC	AP	76
	AS	96
CD	PA	66
	SA	96
C	PL	76
	SB	106
	SW	96

4.12 Transitions

This TSA had different responses based on the pre-treatment strata of a stand. Table 4-6 shows the pre-treatment stand information, the available treatment regimes, and the post-treatment stand information for the clearcut action.

Table 4-6. Response to treatment matrix used in the Sundance TSA.

Pre-Harest Strata						Post-Harvest Strata			
Broad Cover Group	Yield Strata	Crown Closure	TPR	Disturbance Origin	Harvest Type	Yield Strata	Crown Closure Class	Disturbance Origin	Age
D	DEC	AB,CD	G,M,F	Nat, Regen	Clearcut	DEC	CD	Regen	0
DC	AP	AB,CD	G,M,F	Nat, Regen	Clearcut	AP	CD	Regen	0
	AS	AB,CD	G,M,F	Nat, Regen	Clearcut	AS	CD	Regen	0
CD	PA	AB,CD	G,M,F	Nat, Regen	Clearcut	PA	CD	Regen	0
	SA	AB,CD	G,M,F	Nat, Regen	Clearcut	SA	CD	Regen	0
CD	LT	AB,CD	G,M,F	Nat, Regen	Clearcut	LT	CD	Regen	0
	PL	AB,CD	G,M,F	Nat, Regen	Clearcut	PL	CD	Regen	0
	SB	AB,CD	G,M,F	Nat, Regen	Clearcut	PL	CD	Regen	0
	SW	AB,CD	G,M,F	Nat, Regen	Clearcut	SW	CD	Regen	0

4.13 Understory management

There are very few understory stands in Sundance's FMA. The management of these multi-story stands will be decided at the operational level; unique understory treatments were not modelled into this TSA.

4.14 Patches (Opening and Old)

Patches are an important issue in forestry, especially given the ever increasing fragmentation of the forest. For many biological reasons, there has been recent push to minimizing fragmentation. There are two mechanisms to allow a reduction in forest fragmentation. First, in young patches, it has been seen that by moving to larger patches, that historical disturbance patches can be mimicked to some degree, thereby, we can reduce fragmentation. As harvest is aggregated, there is less need for extensive road networks that negatively effect forest fragmentation. Creating these larger patches than were historical harvested is a first step in creating less fragmented habitat.

The second issue is aggregating the old forest on the landbase. The historical disturbance patterns show that there would be large disturbed areas and large undisturbed areas. Therefore, as we try to mimic the historical disturbance patterns, it is also important to aggregate the old patches on the landbase. Patches are a biological entity and are measured on the gross landbase. However, when targets are set only the managed landbase, they can be manipulated to achieve the patch targets.

Patches were only dealt with within Patchworks as Woodstock is not capable of true spatial analysis; whereas Patchworks is largely designed around Patching. Patches were created by determining which adjacent stands met certain criteria and the summing the area of these adjacent stands. Neighbouring stands within 15 m were considered adjacent.

Figure 4-1 shows seven patches of equal size, but very different shapes. Although the modeling tools interpreted each patch as being equal, a person typically does not visually interpret them as such. The dark blue shape is typically how a patch is visualized (one solid area with the smallest perimeter to area ratio). However, the patch might be long and narrow (red), comprised of two smaller areas either connected through a narrow strip (olive green) or physically separate but within the adjacency tolerance (pink), a checkerboard pattern where many small areas touch at the corners (dark green), or completely surround another stand (light blue). In this analysis, patches were made of forest stands, which typically have irregular shapes (orange).

Caution should be used when interpreting patch results because although there may be patches that exceed the goal, the patch shape plays an important role in the functioning of the patch towards biodiversity.

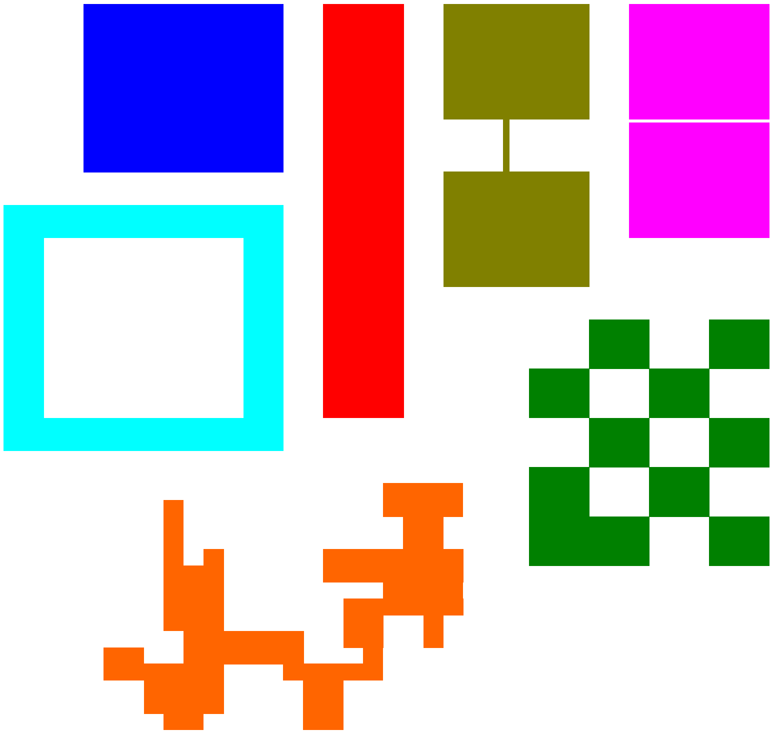


Figure 4-1. Examples of patch shapes

4.14.1 Opening

The Opening patch goal in this model was developed based on the work of David Andison in the foothills of Alberta and were based on work for the Millar Western DFMP. There were a total of 5 Opening patch goals placed on the model. Table 4-7 shows the modelling objective in terms of Opening Patches desired on the forest.

Table 4-7. Opening patch goals placed on the TSA.

		Modelling Target	
Patch Size	**Objective***	**Minimum**	**Maximum**
0 - 2 ha	0%	0%	0%
2 - 100 ha	76%	76%	76%
100 - 1000 ha	19%	19%	19%
1000 + ha	5%	5%	5%

* Percent of area

Deciduous stands contribute to opening patches for 10 years and other broad cover groups contributed to Opening Patches for 20 years.

4.14.2 Old

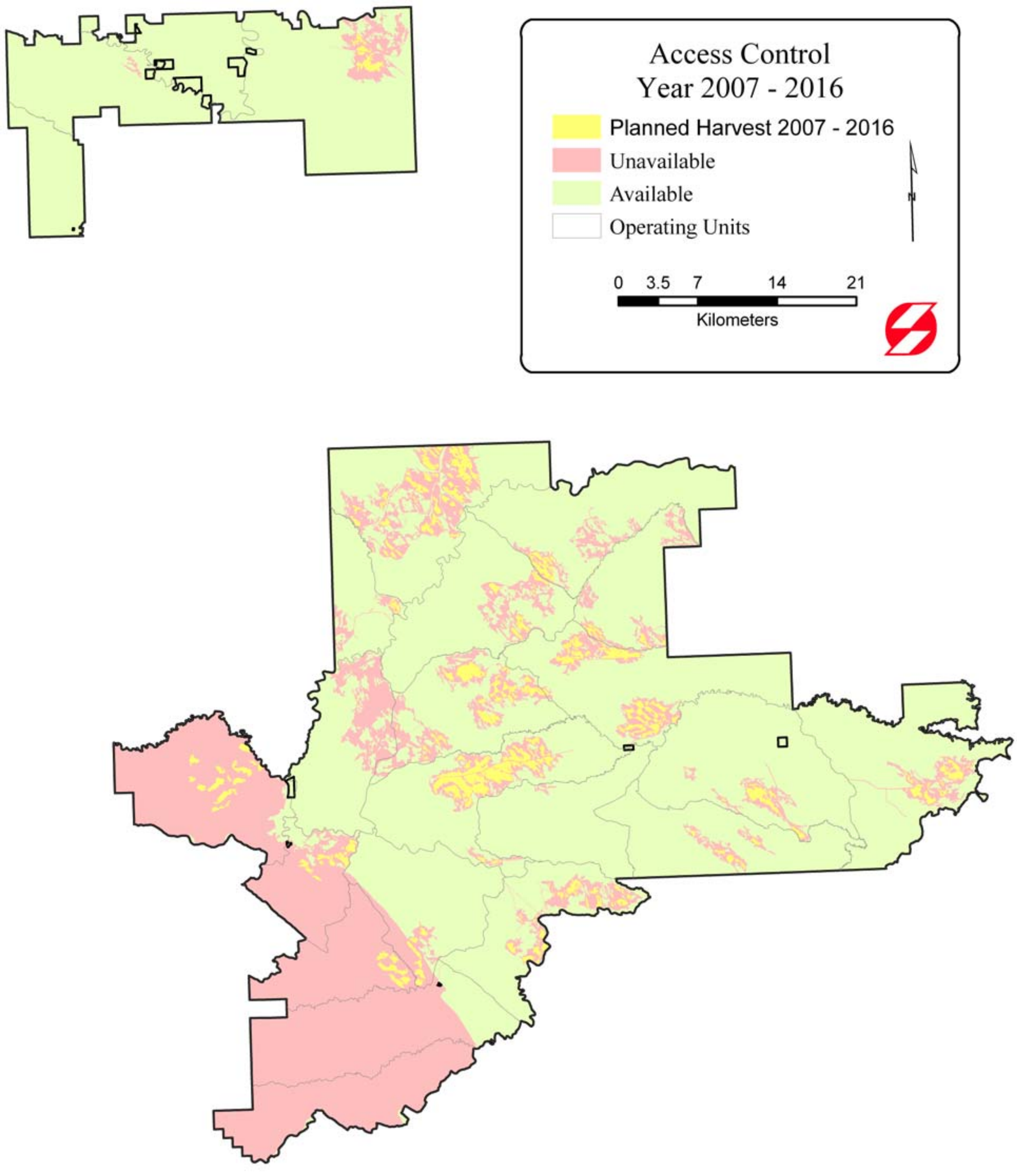
There was an old patch goal, which was meant to aggregate the patches on the forest. The goal was that 100% of the old area on the forest was aggregated into patches greater than 120 ha in size. These patches could be made up on managed or unmanaged old areas. The 120ha size was decided upon to be a proxy for the 100ha interior old patch referred to in the Planning Standard (version 4.1). The proxy was used to permit integration of old patch goals in the forecasting and tradeoffs within the PFMS.

4.15 Green-up

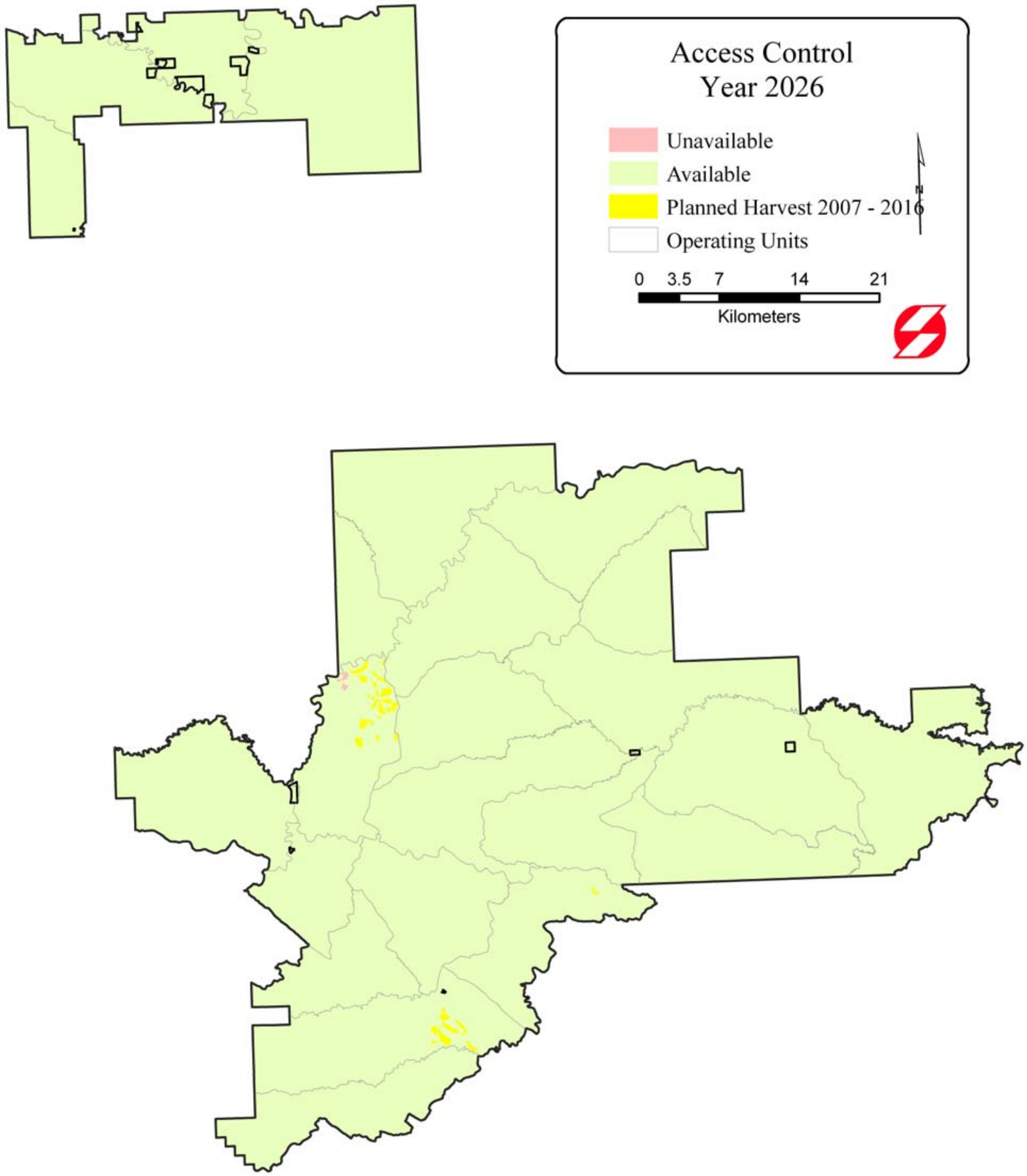
The use of patch size and interior forest objectives in this analysis replaced the traditional green-up constraints used previously in timber supply modeling. In order to meet patch size targets, it was necessary to intentionally schedule second pass harvests adjacent to first pass cuts while the openings were less than 20 years old to create future interior forest. To maintain the range of patch sizes, the model leaves adjacent areas unscheduled for at least 20 years thereby creating a mix of ages over time. Although a green-up constraint is not specifically applied, adjacency considerations are implicit in the model and the spatial harvest sequence.

4.16 Access schedule

Patchworks uses access control units to control the distribution of harvest during periods of interest. It was decided to only control the compartment sequence for 20 years, after which time the model was able to select harvest from any operable areas of the FMU. Twenty years of the harvest sequence SHS were constrained due to a lack of knowledge about factor that will inevitably change the desired harvest patterns in the future. The 2007-2016 and 2017-2026 year access control schedules can be seen in Map 4-2 and Map 4-3 respectively. The access control units were based on a number of factors, including compartments, the area west of the forestry trunk road, planned blocks, the area surrounding planned blocks, and fire after the effective date of the landbase. The area west of the forestry trunk road was isolated from harvesting, except in planned blocks due to access limitations and therefore no harvesting was allowed in this area in the first 10 years.. Additionally, areas within 15m of planned blocks were deferred in the first period. This was to ensure planned block shapes were maintained in the first period avoid unnecessary work in modifying blocks with boundaries already laid out. Additionally planned blocks were not allowed to be modified in the model. There was a fire that burned after the effective date of the landbase, which was not incorporated into the landbase. Harvesting was not allowed in this area for the first 20 years, to ensure it was not included in the SHS. This area will be removed from the landbase, if necessary, in the next TSA.



Map 4-2. Access control included in the PFMS from 2007-2016.



Map 4-3. Access control included in the PFMS from 2017-2026.

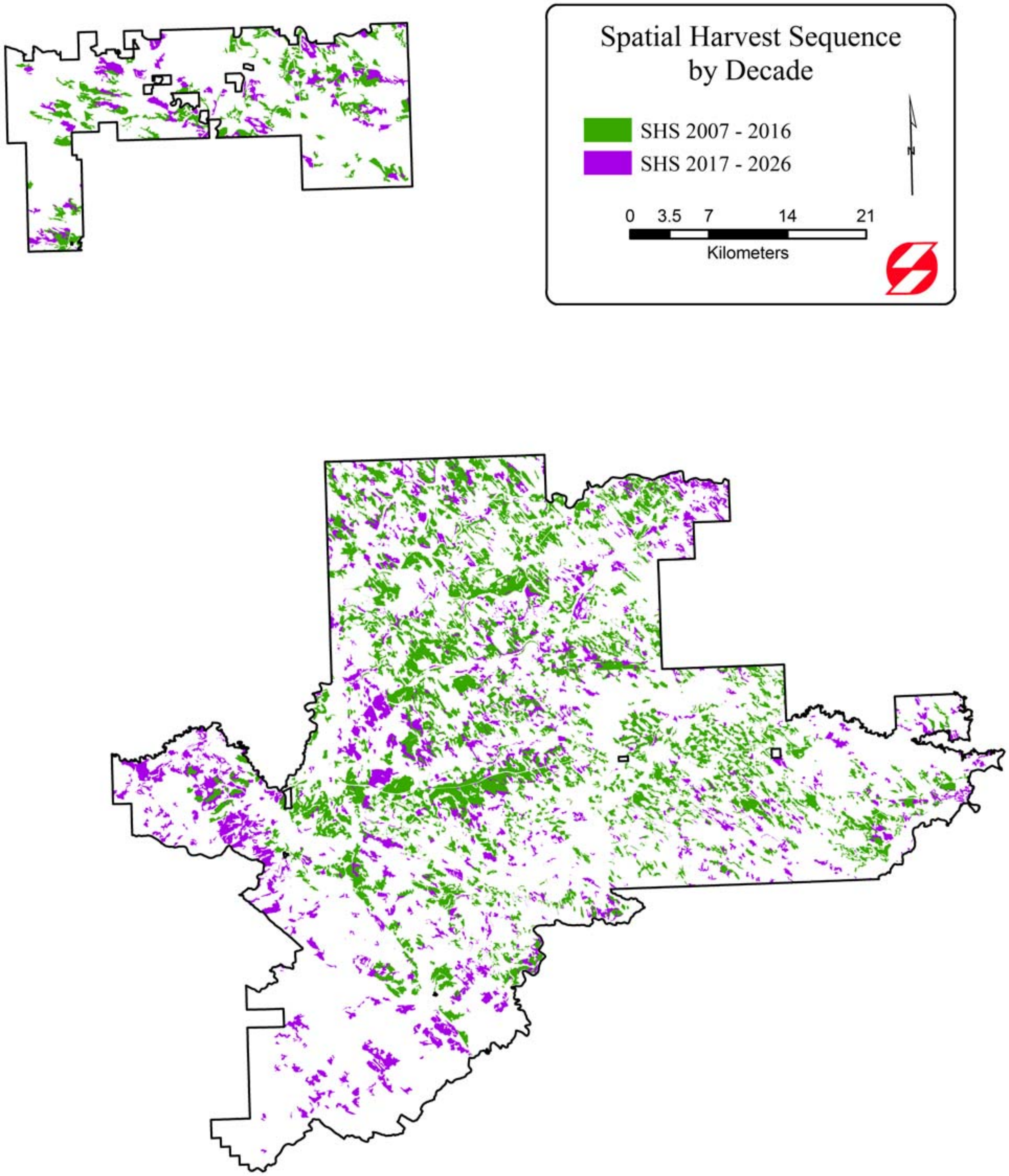
5. PFMS

The PFMS was the result of combining the decisions from the issues and trade-offs that were examined (section 6), the inputs and assumptions (section 4), and operational considerations. The end result of this process is a biologically, socially, and economically reasonable management scenario which Sundance wishes to implement. The PFMS is a 200 year spatially explicit plan, with the first 20 years representing the SHS.

Many different indicators were tracked in the Sundance TSA. This section will present the results from the PFMS in detail. The results are broken down by category. Initially, all of the action-based outputs will be presented. Subsequently, the inventory outputs will be presented and discussed. The patch targets, both opening and old, will then be presented. Finally, the road targets will be discussed. In many cases, the results will be discussed from 2 levels - the planning horizon level results and the 10 and 20 year implementation results. The 20 year SHS can be seen in Map 5-1.

Throughout this section, the targets implemented in Patchworks are shown and explained. In many cases, targets worked together to create the desired PFMS. At the end of this section, the interactions observed between these will be explained.

The tables in this section which contain volumes by strata represent the volume for the area of the stratum not the individual species volumes. For example, the PL stratum is composed of pine, white spruce and black spruce trees.



Map 5-1. Map of the SHS by decade from the Sundance PFMS.

5.1 Harvest Volume

The harvest volumes varied throughout the planning horizon (Table 5-1). Harvest volumes reported in this document are averages of the appropriate 5-year periods The first 10 years of the planning horizon included a 100% coniferous surge cut. This surge cut was included to reduce the amount of suitable MPB habitat that was on the landbase. It will also decrease the losses that would be associated with a possible large-scale MPB infestation.

The PFMS coniferous harvest level was 841,666m^3/yr from 2007-2016. The coniferous harvest level from 2017-2026 was 418,763m^3/yr and was 420,776m^3/yr for the remainder of the planning horizon. As Patchworks does not use linear programming, it allows slight variations in target values, therefore there was some change in the even flow harvest level throughout the planning horizon; there was a 1.09% difference from the maximum to minimum of the periodic coniferous harvest levels between 2017 and 2206. The deciduous harvest level from 2007-2016 was 60,041m^3/yr, while the 2017-2026 harvest level was 60,029m^3/yr. The average deciduous harvest level for the remainder of the planning horizon was 54,739m^3/yr.

Table 5-1. Harvest volume by period in the planning horizon from the Sundance PFMS.

	Harvest Level (m^3/yr)	
Year	**Conifer**	**Deciduous**
2007-2016	841,666	60,041
2017-2026	418,763	60,029
2027-2206	420,776	54,739

5.1.1 Coniferous Harvest

As previously discussed, a coniferous surge cut is included in the PFMS for 10 years. The coniferous harvest level target graph can be seen in Figure 5-1, indicating that the coniferous harvest target was achieved for all periods. Figure 5-2 shows the coniferous volume harvested by yield strata from the landbase. The first 2 decades of harvest volume by strata can also be seen in Table 5-2. The majority of the harvest throughout the planning horizon is from the pine strata. The first decade also has a higher proportion of pine harvested than the remainder of the planning horizon. The surge cut is included in the PFMS to reduce the MPB threat. Harvesting non pine yield strata does not reduce the MPB threat but is necessary to make operationally feasible harvest patterns.

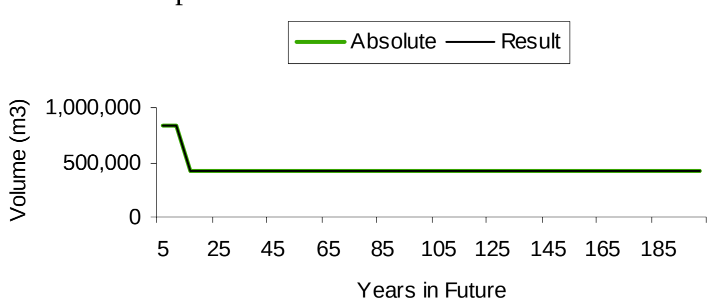


Figure 5-1. Coniferous harvest target from Sundance PFMS.

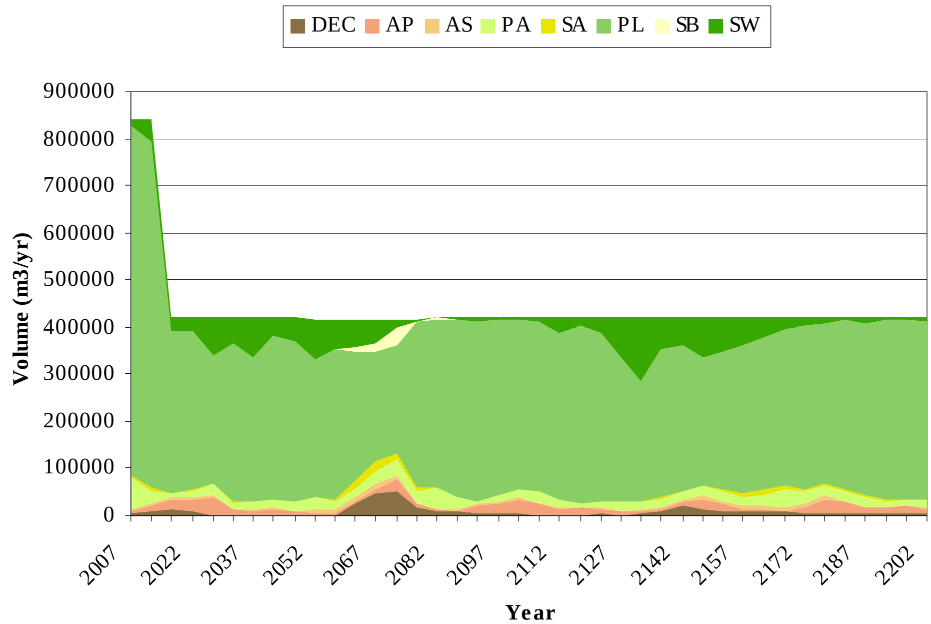


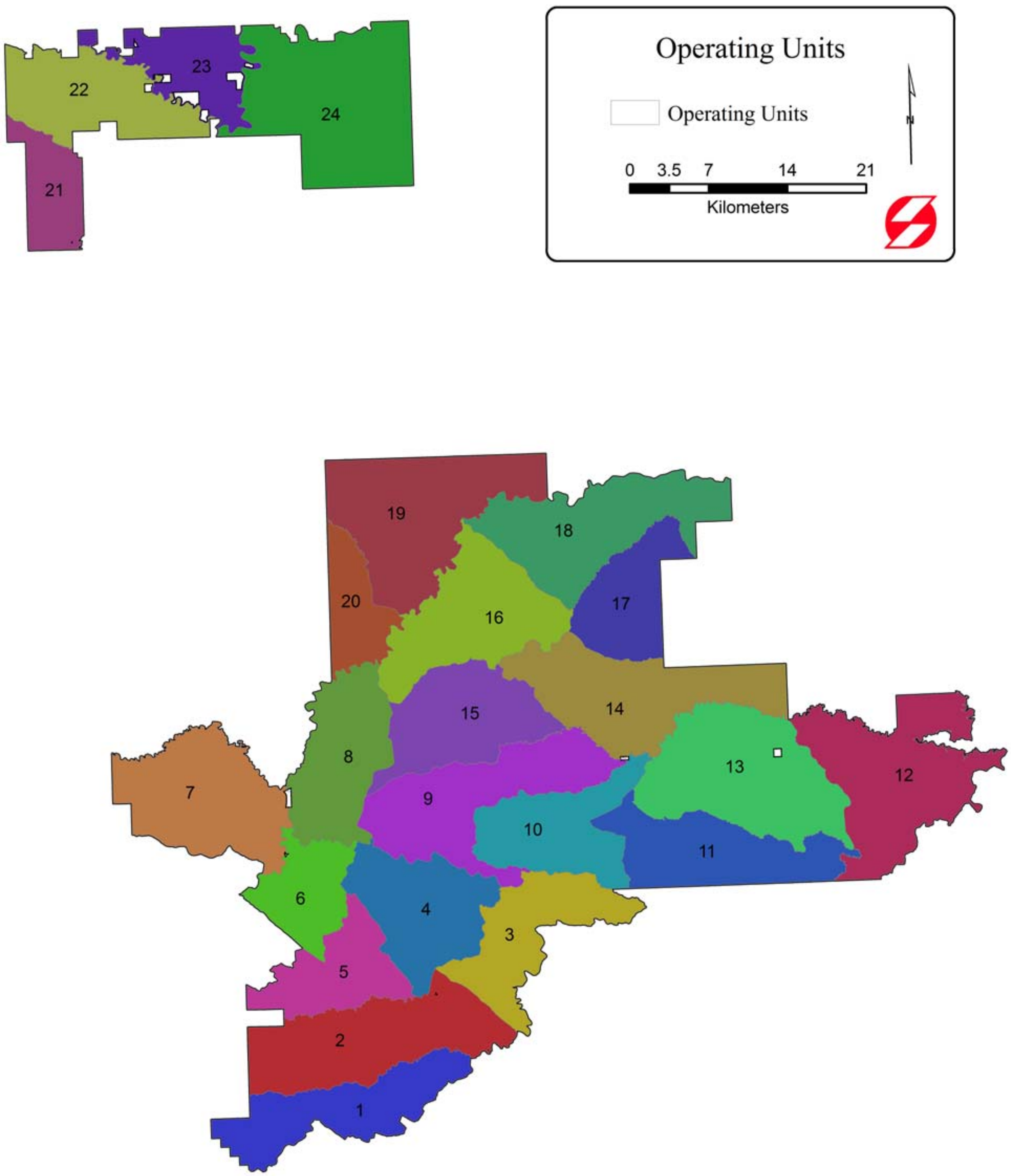
Figure 5-2. Coniferous harvest volume by strata from Sundance PFMS.

Table 5-2. Volume harvested by strata for first 2 decades from the Sundance PFMS.

	2007-2016 Harvest (m^3/yr)		2017-2026 Harvest (m^3/yr)	
Strata	**Coniferous**	**Deciduous**	**Coniferous**	**Deciduous**
DEC	6,184	13,192	10,598	21,603
AP	8,401	8,656	23,485	24,476
AS	4,644	3,666	5,019	3,961
PA	47,523	13,506	9,726	2,159
SA	5,196	3,112	2,250	1,447
PL	739,018	17,464	339,660	6,223
SB	313	11	155	5
SW	30,388	432	27,870	156
TOTAL	841,666	60,041	418,763	60,029

5.1.2 Quota Coniferous Harvest

There are coniferous licences in compartments 22, 23, and 24 of the Sundance FMA. These compartments are located in the north portion, (Erith Operating Area) of the Sundance FMA (Map 5-2). The coniferous volume targets and results from compartment 22, 23 and 24 can be seen in Figure 5-3, Figure 5-4, and Figure 5-5 respectively. The first 10 years of each of these targets had a 100% surge to correlate to the coniferous surge seen in the previous section. It can be seen in each of these target graphs that all of the targets were meet for the first 20 years of the planning horizon that the targets were active. The average harvest in the first two decades from these compartments, along with the desired levels is presented in Table 5-3. All of these compartments have large fluctuations in harvest throughout the planning horizon. These commitments were not forced for the length of the planning horizon because of the lack of volume to maintain the harvest into perpetuity from these units.



Map 5-2. Map of the Sundance compartments used in the Sundance TSA.

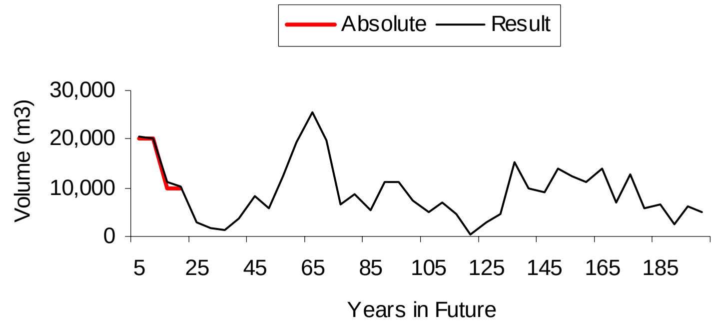


Figure 5-3. Coniferous harvest volume from compartment 22 from Sundance PFMS.

Figure 5-4. Coniferous harvest volume from compartment 23 from Sundance PFMS.

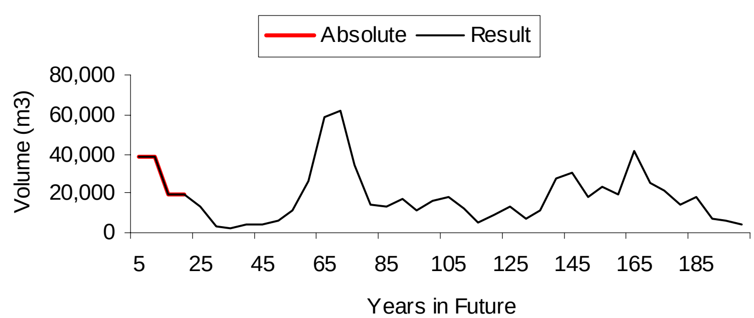


Figure 5-5. Coniferous harvest volume from compartment 24 from Sundance PFMS.

Table 5-3. Average harvest in Erith compartments with other harvest quotas from the Sundance PFMS.

	2007-2016 Coniferous Harvest (m^3/yr)		2017-2026 Coniferous Harvest (m^3/yr)	
Compartment	Achieved	Target	Achieved	Target
22	21,501	20,000	10,666	10,000
23	4,994	4,800	2,730	2,400
24	39,210	38,000	19,098	19,000

5.1.3 Deciduous Harvest

The deciduous harvest target on the Patchworks model is only active for the first 20 years of the planning horizon (Figure 5-6). The reason that the deciduous harvest was not maintained at an even flow level was because there was inadequate volume to maintain this harvest at the required level into perpetuity. Sundance only requires 43,500m^3/yr to meet their commitments to Weyerhaeuser. An additional volume is required for the Community Timber Program. The target was set above the required 49,320m^3/yr at 60,000m^3/yr for the first 20 years. It was seen early on in the spatial modeling that it was necessary to allow more than the required deciduous to allow for the surge cuts extra incidental volume and the mixedwood and deciduous stands that made better operational block shapes, and subsequently old patches. Therefore, the shorter constraint will allow this issue to be dealt with in the future while maintaining this commitment.

Figure 5-7 shows the deciduous harvest by strata throughout the planning horizon and Table 5-1 shows the average annual harvest for the first 2 decades. It can be seen that the deciduous harvest comes from both deciduous, mixedwood, and coniferous yield strata. In the first 10 years there is a large amount of the deciduous volume that is from incidental coniferous harvest.

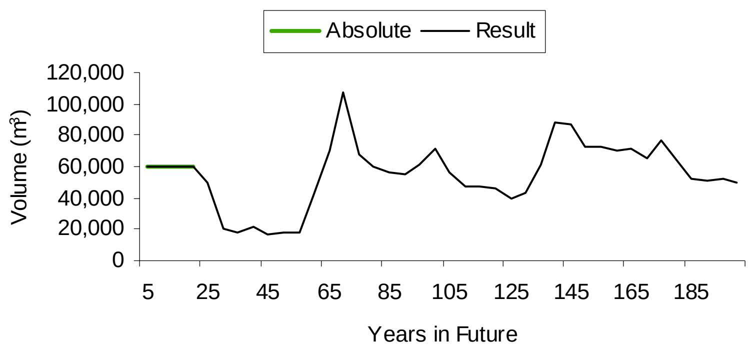


Figure 5-6. Deciduous harvest target from Sundance PFMS.

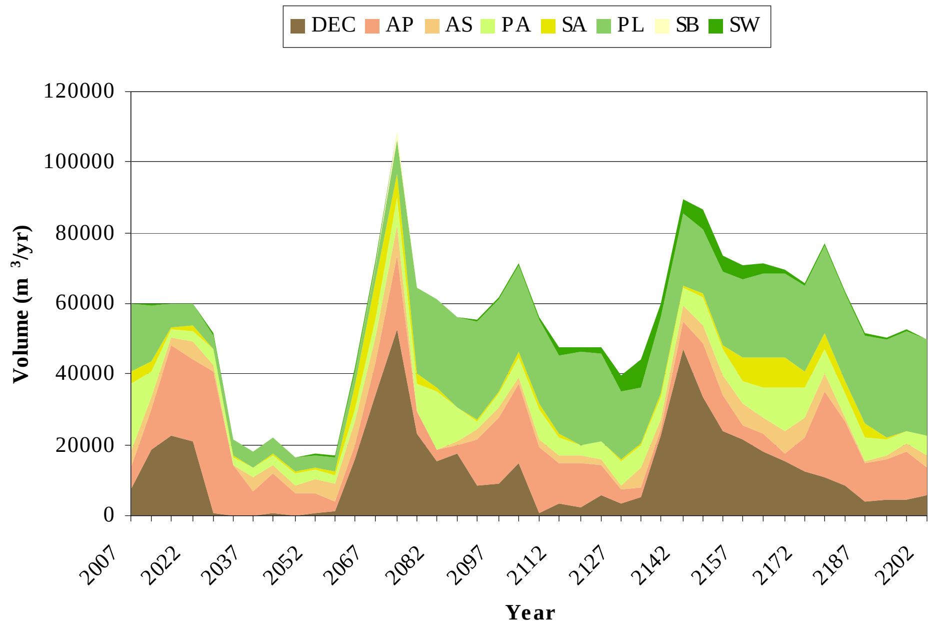


Figure 5-7. Deciduous harvest volume by strata from Sundance PFMS.

5.2 Area Harvested

The area harvested varied throughout the planning horizon. This section will show the area harvested from a number of different perspectives such as harvest area by strata, age class, and treatment.

5.2.1 Yield Strata

The area harvested by strata has similar trends to the volume harvested by strata. It can be seen that corresponding to the coniferous surge cut there is a larger amount of area harvested from 2007 to 2016 than in the remainder of the planning horizon (Figure 5-8). Also, there is a slight increase in the area harvested, post surge, throughout the remainder of the planning horizon. This increase is associated with harvest moving from existing mature stands to second rotation stands of younger ages.

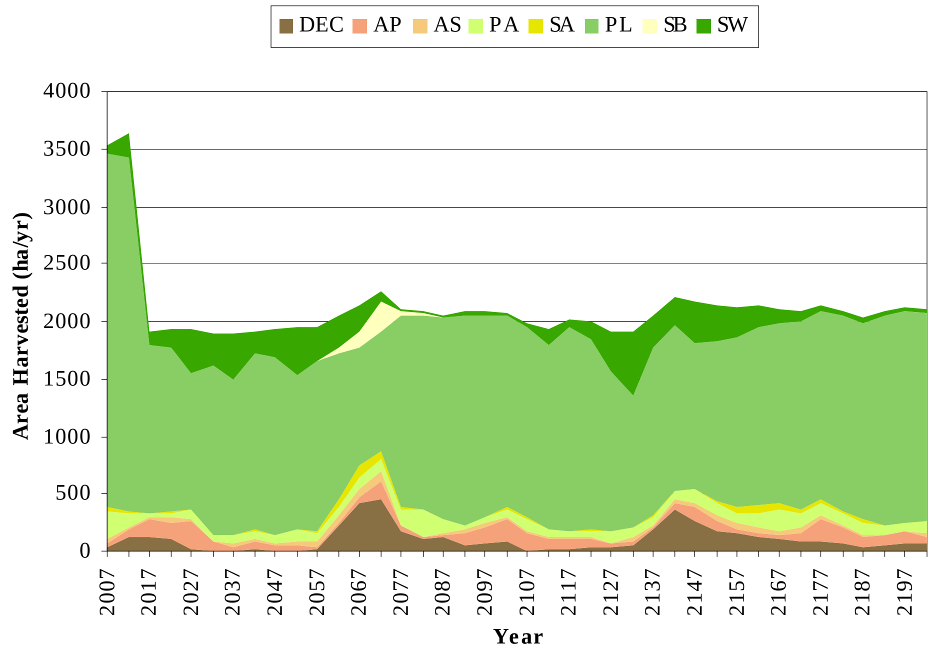
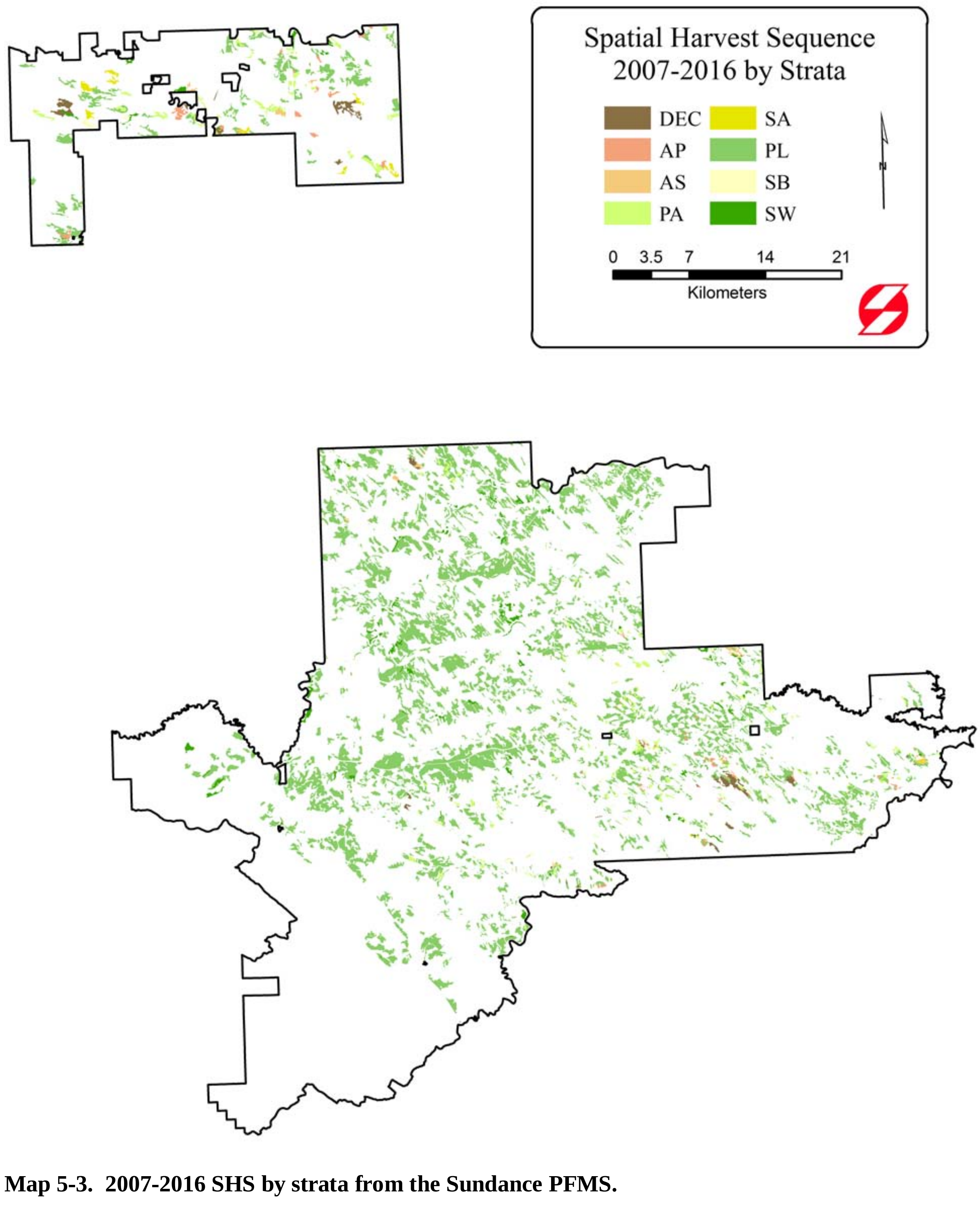
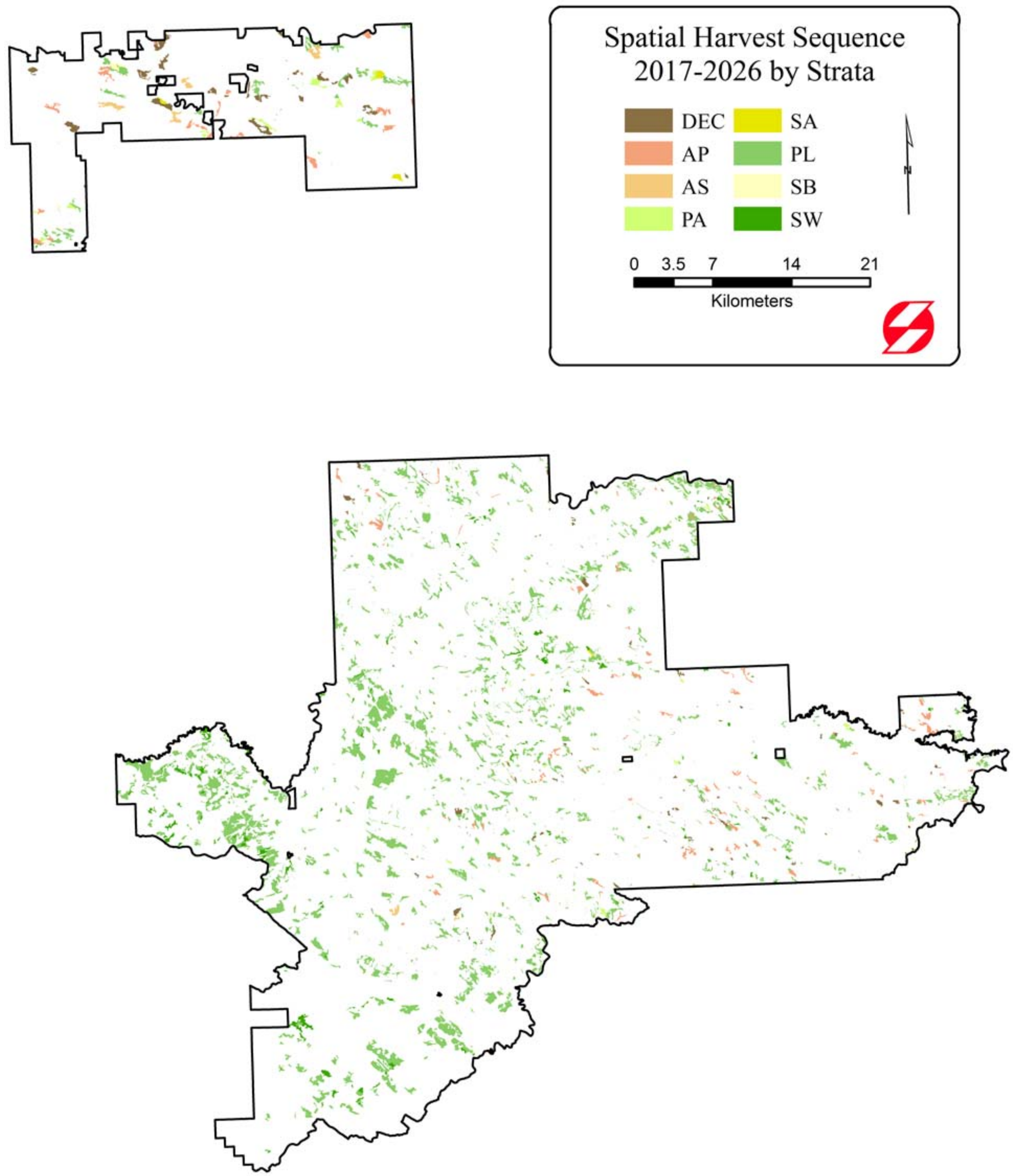


Figure 5-8. Area harvested by yield strata from Sundance PFMS.

The area harvested by strata, and regenerated by strata can be seen in table format in Section 5.2.3. Additionally the first decade and second decade of the SHS can be seen in the Map 5-3 and Map 5-4 respectively.



Map 5-3. 2007-2016 SHS by strata from the Sundance PFMS.



Map 5-4. 2017-2026 SHS by strata from the Sundance PFMS.

5.2.2 Age Class

The age class distribution of area harvested changes though the planning horizon (Figure 5-9). For the first 60 years, approximately, of the planning horizon the age class distribution of harvest increases. Subsequently, the age class distribution decreases, as the second rotation of timber is being harvested. The age class distribution then stabilizes for the remainder of the planning horizon.

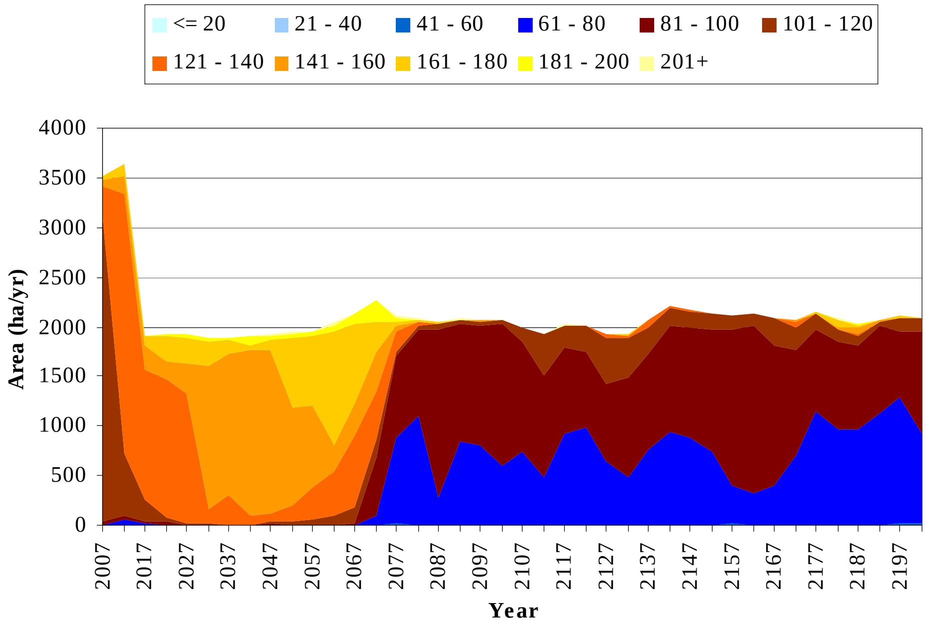


Figure 5-9. Area harvested by age class from Sundance PFMS.

5.2.3 Action/Intensity/Reforestation

Sundance currently only undertakes one basic harvest and regeneration regime, basic clearcut action. Meaning that for each stand harvested there will be only one resulting transition in the TSA model. Subsequent to the clearcutting, all stands are regenerated to their pre harvest strata other than black spruce, which are regenerated to lodgepole pine (Table 5-4 and Table 5-5).

Table 5-4. Annual area harvested and regenerated by strata in the first decade of the planning horizon from the Sundance PFMS.

	Regenerating Strata							
Harvest Strata	**DEC**	**AP**	**AS**	**PA**	**SA**	**PL**	**SB**	**SW**
DEC	76							
AP		50						
AS			27					
PA				183				
SA					24			
PL						3,080		
SB						2		
SW								140

Table 5-5. Annual area harvested and regenerated by strata in the second decade of the planning horizon from the Sundance PFMS.

	Regenerating Strata							
Harvest Strata	**DEC**	**AP**	**AS**	**PA**	**SA**	**PL**	**SB**	**SW**
DEC	114							
AP		148						
AS			29					
PA				37				
SA					11			
PL						1,445		
SB						1		
SW								138

5.3 Piece Size

Harvest volume is one component of operational considerations when assessing a PFMS. Mills are often designed to optimally run on a certain size distribution of wood. Therefore piece size is an important criterion to consider. The coniferous piece size (stems per cubic metre) is generally stable through the first third of the planning horizon. There is a slight overall decrease in piece size before reaching a relatively stable state through the later half of the planning horizon (Figure 5-10). Generally, the current harvest profile will be maintained until the second rotation stands are being harvested. The same trends are observed for the deciduous harvest profile (Figure 5-11).

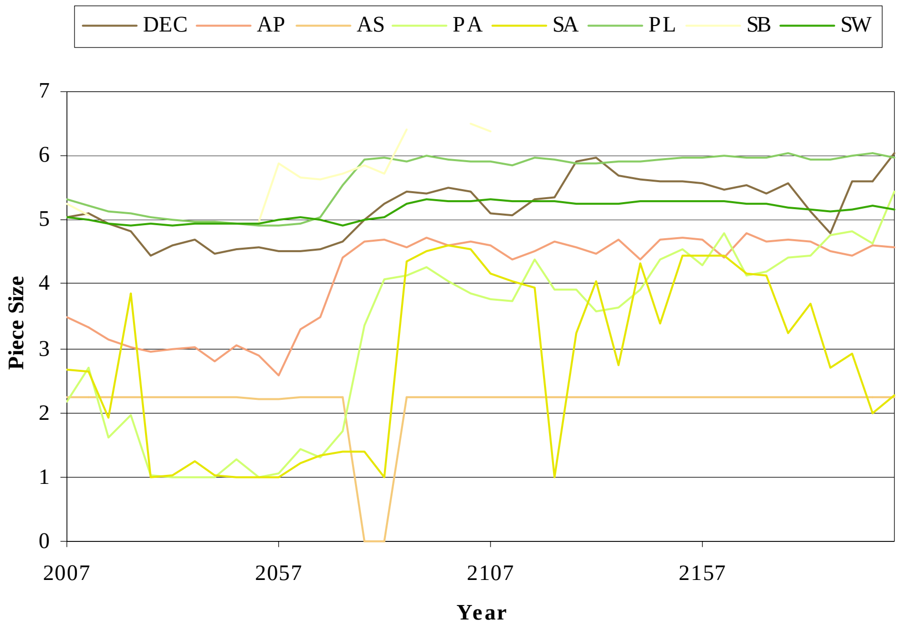


Figure 5-10. Coniferous piece size harvested from the Sundance PFMS.

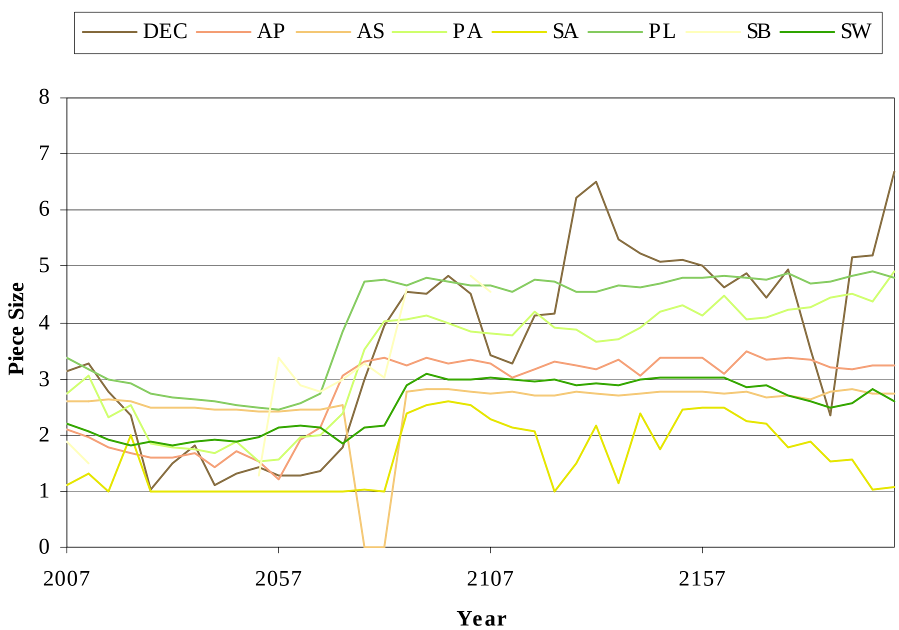


Figure 5-11. Deciduous piece size harvested from the Sundance PFMS.

5.4 Growing Stock

Growing stock represents the volume on the landbase. This document deals with three different representations of growing stock, firstly forested growing stock, known as total growing stock. This includes all volume on the landbase within forested stands that have managed components.

The forested growing stock is calculated by using the managed landbase curves, meaning that the volume may be overestimated in some stands. As well larch stands are subjectively deleted so these are not representation on the managed landbase, meaning no yield curves are created for the species; and therefore they are excluded from the growing stock calculations.

A second representation is the managed growing stock represents the volume in forested stands that are in the managed landbase. The final representation is operable growing stock representing the volume that is on the managed landbase and within stands greater than the minimum harvest age, all volume currently available for harvest. All of these representations are also broken down into coniferous and deciduous components.

There is an initial decrease over the first 60 years in coniferous growing stock of all types, after which the volume generally levels out for the remainder of the planning horizon. The forested and managed deciduous growing stock stays fairly constant throughout the planning horizon, though the operable growing stock decreases over the first 60 years then stabilizes over the planning horizon (Figure 5-12).

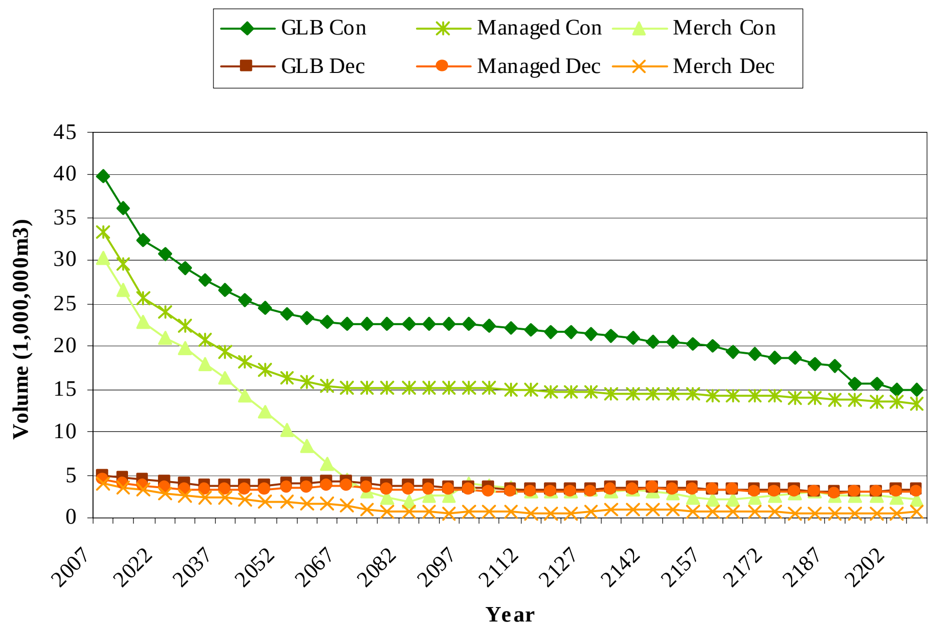


Figure 5-12. Growing stock by type on the landbase from the Sundance PFMS.

5.4.1 Coniferous Growing Stock

There is a target on the operable growing stock from the forest. The planning standard specifies that the growing stock must be stable, or non-declining over the final 50 years of the planning horizon. Patchworks is not the optimal tool for creating such a constraint, so a similar Woodstock level was used to assign a minimum growing stock level for the length of the planning horizon (Figure 5-13). The model met this target, though there were a few short periods were it was slightly below this level, these were prior to the final 50 years of the planning horizon.

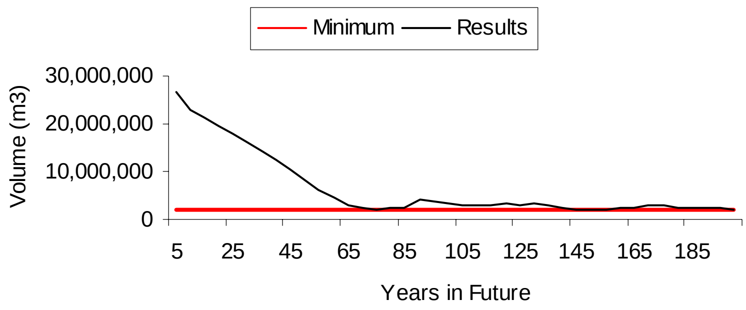


Figure 5-13. Target of merchantable coniferous growing stock on the landbase by yield strata.

There is a decrease in forested coniferous growing stock throughout the planning horizon, with the majority of the decrease in the first 60 years (Figure 5-14). The decreases in growing stock occur for a number of reasons. On the managed landbase, harvest is responsible for the majority of the decreases. Additionally, on the managed and forested landbase, there is succession occurring, which artificially 'kills' the stands returning them to a young age with very little volume, reducing the growing stock. Additionally, all of the volume yield curves used decrease after a given age. Therefore, as the age class of the forest increases early in the planning horizon while the model is showing decreases in standing volume of stands. This decrease in volume as stands age is a requirement of yield curves approved by Alberta Sustainable Resource Development.

In Figure 5-14 the majority of the coniferous volume is from pine stands with a significant portion from black and white spruce stand types. The representation of these non-pine species in growing stock decreases through time.

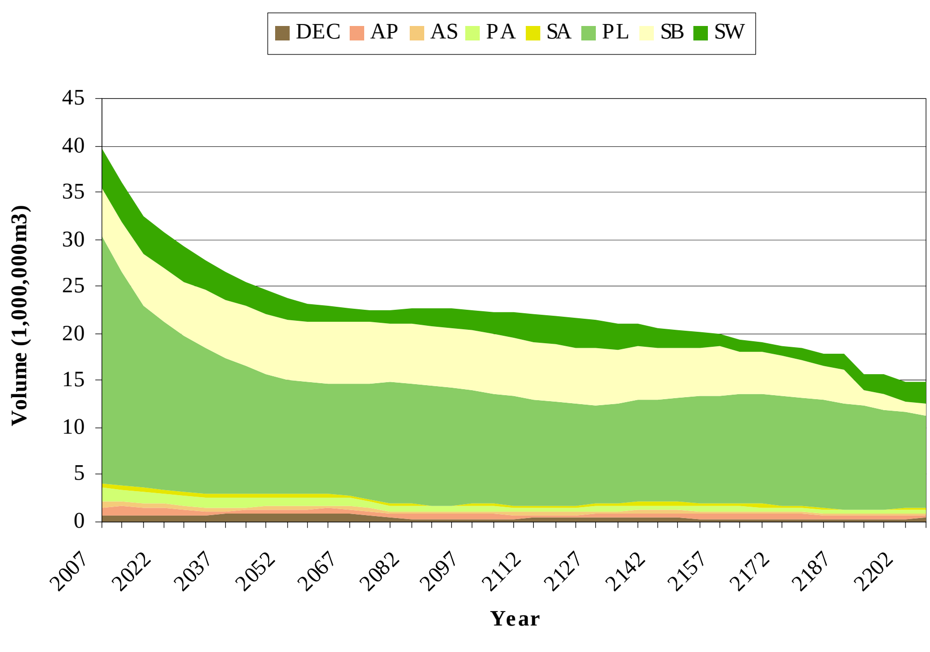


Figure 5-14. Coniferous growing stock on the gross landbase by yield strata.

On the managed landbase, the majority of the volume comes from the pine strata (Figure 5-15). There is a smaller component of the other strata on the forested landbase, this is largely related to landbase deletions. Many of the black spruce stands were subjectively deleted from the landbase. Additionally, deleting watercourse buffers had a greater impact on white spruce area than any other species. On the Sundance landbase, white spruce seems to be related to watercourse buffers.

Through time, the managed growing stock follows similar trends to the forested growing stock. The black spruce volume decreases through time on the managed landbase. When this black spruce area is harvested it is regenerated to pine, reducing the area, and volume of black spruce on the managed landbase.

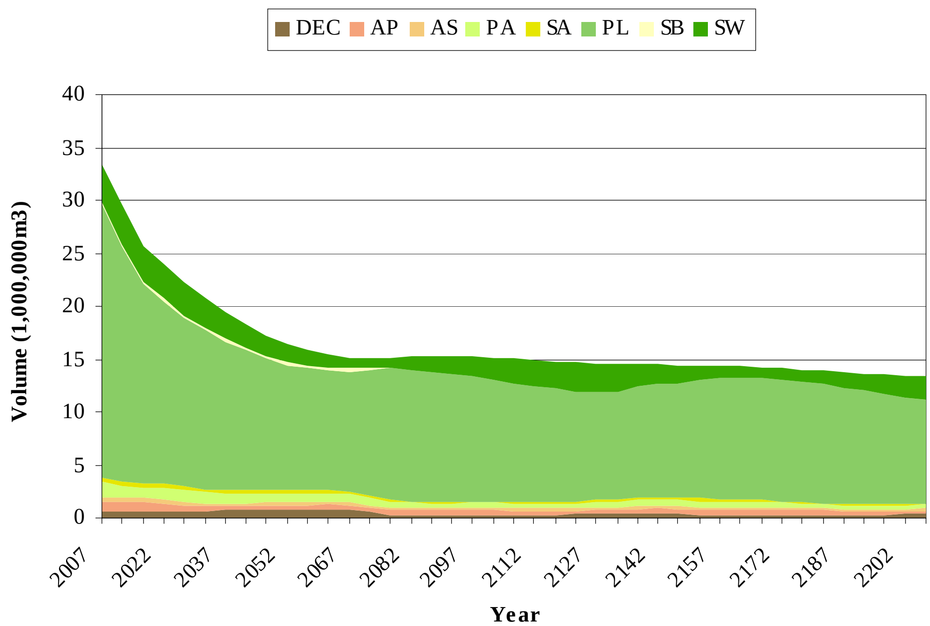


Figure 5-15. Coniferous growing stock on the managed landbase by yield strata.

The operable growing stock on the landbase follows similar trends as the managed, though the levels are lower, as operable growing stock is a subset of managed growing stock (Figure 5-16).

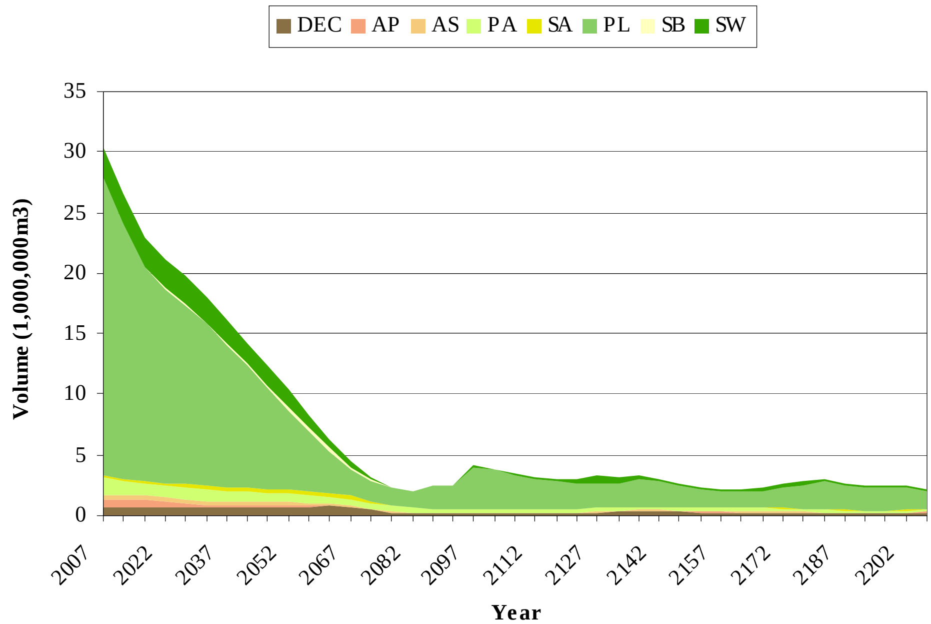


Figure 5-16. Merchantable coniferous growing stock on the landbase by yield strata.

5.4.2 Deciduous Growing Stock

There is a target on the operable deciduous growing stock from the forest. The Alberta Forest Management Planning Standard specifies that the growing stock must be stable, or non-declining over the final 50 years of the planning horizon. Patchworks is not the optimal tool for creating such a constraint, so a similar Woodstock level was used to assign a minimum growing stock level for the length of the planning horizon (Figure 5-17). The model met this target in all periods.

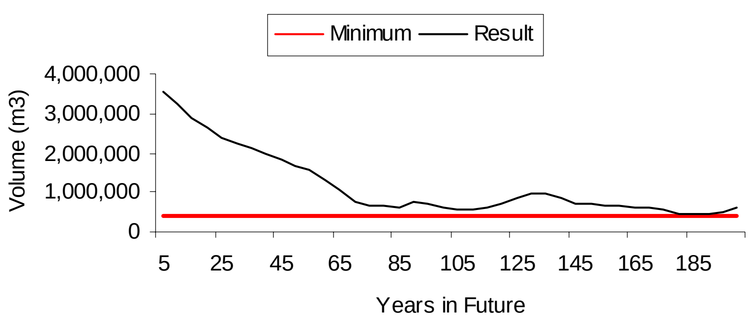


Figure 5-17. Target of merchantable deciduous growing stock on the landbase by yield strata.

The forested deciduous growing stock on the forested landbase is significantly different from the coniferous growing stock. The growing stock is not dominated by any yield strata at the beginning of the planning horizon, but is spread across many (Figure 5-18). Through the planning horizon the representation of deciduous volume from pine stands increases. The total forested deciduous growing stock slightly decreases through the planning horizon.

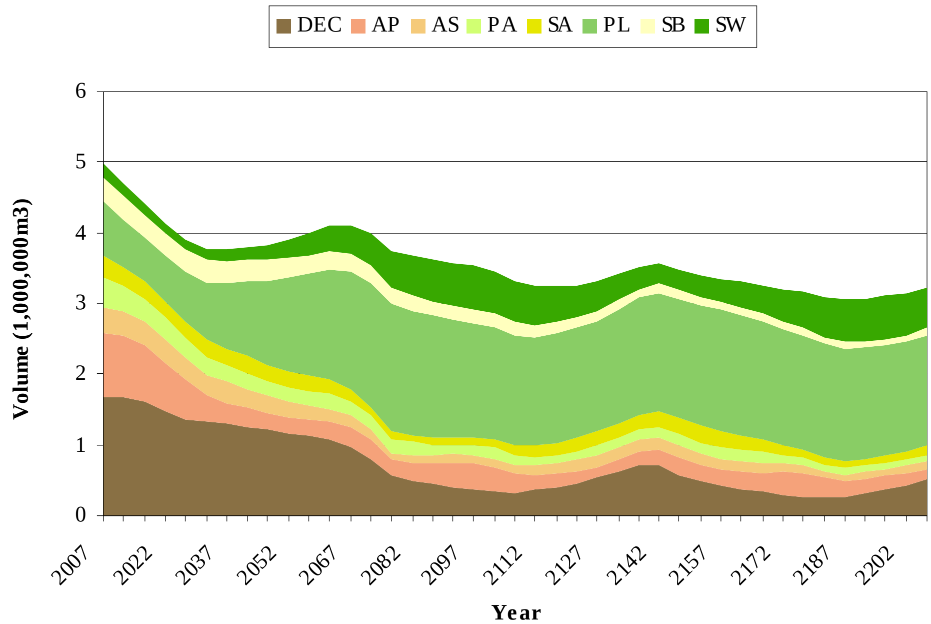


Figure 5-18. Deciduous growing stock on the gross landbase by yield strata.

The managed deciduous growing stock follows very similar trends as the forested deciduous growing stock (Figure 5-19). Though similar to the managed coniferous growing stock the representation of the black spruce strata is decreased through time, for the same reasons.

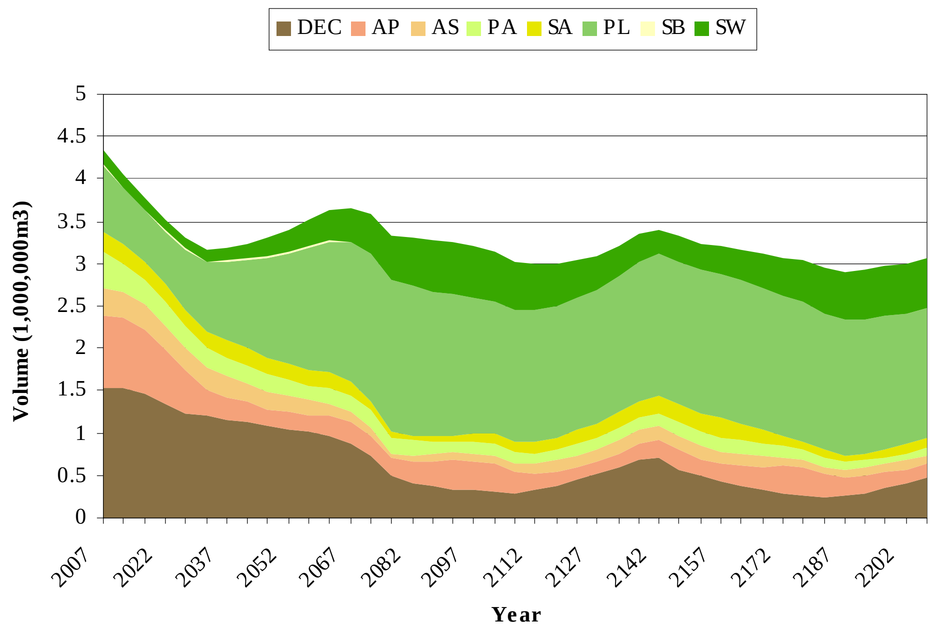


Figure 5-19. Deciduous growing stock on the managed landbase by yield strata.

The operable deciduous growing stock has different trends from the managed and forested deciduous growing stock (Figure 5-20). The representation of yield strata changes to the majority of the growing stock being from deciduous stands and mixedwood stands. The merchantable deciduous growing stock decreases quickly then stabilizes.

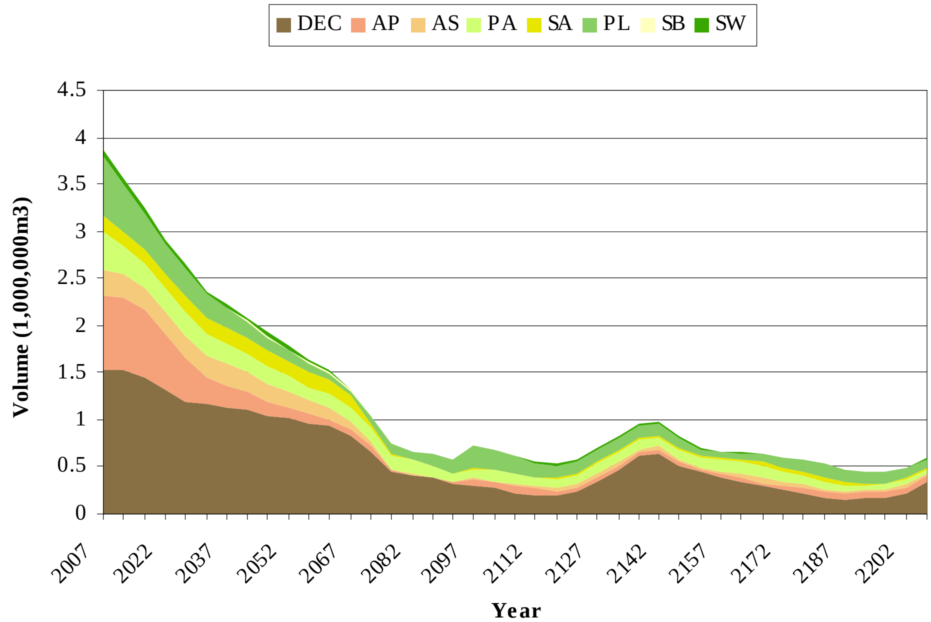


Figure 5-20. Merchantable deciduous growing stock on the landbase by yield strata.

5.5 Area

Harvest volume, area, and growing stock are all indicators of interest in all FMP's as they are all derived from the landbase areas. This section will describe the landbase through time.

5.5.1 MPB

MPB has been a large component of this FMP. MPB poses a threat to all pine trees in Alberta and possibly across the entire boreal forest. Therefore, the reduction of biological, social and economic risks from MPB are important. The largest effect Sundance can have on MPB is by reducing the habitat for, and losses from MPB.

SRD Rank

SRD has a ranking system that classifies stands by their ability to produce viable populations of MPB's in one year. The system takes into account three components, climate factor, compartment risk, and stand susceptibility index. Figure 5-21 shows the SRD ranking of these stands through time. There is very little Rank 1 area on the landbase, but the area that does exist is harvested rapidly. Also, there is a constant reduction in rank 2 and 3 area for the first 60 years, with the largest decrease associated with the surge cut in the first 10 years. There is a very large amount of area in rank 1 and 2 stands at the beginning of the planning horizon. One of the issues with this classification is that once a rank reduced, it does not have the ability to increase through time.

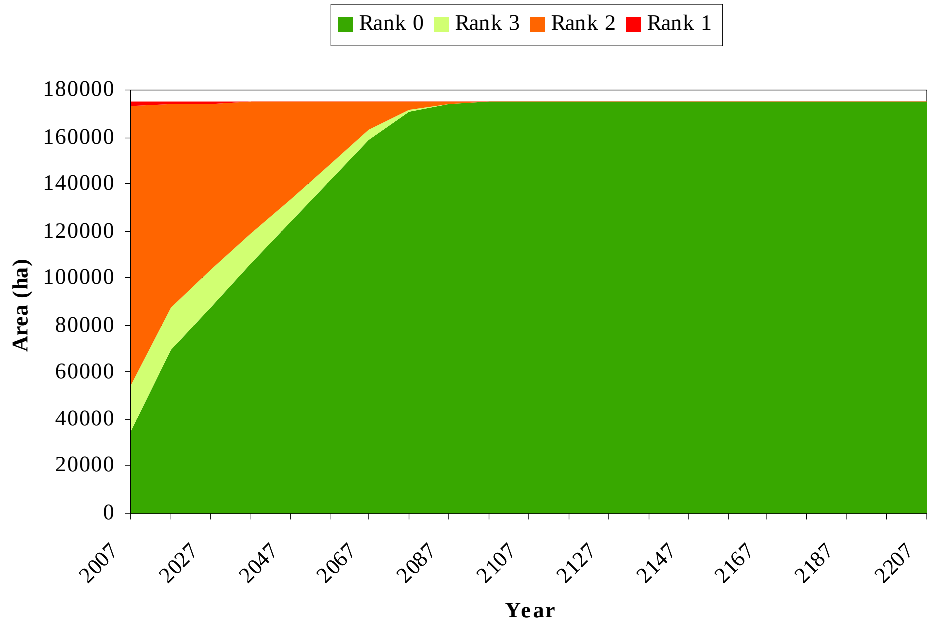


Figure 5-21. Area of SRD ranked pine on the managed landbase from Sundance PFMS.

Sundance Rank

There is a target placed on the removal of all Sundance rated pine within 20 years (Figure 5-22). This target is meant to reduce the MPB risk on the forest. This target is achieved and all of the Sundance rated pine is rapidly removed from the forested landbase.

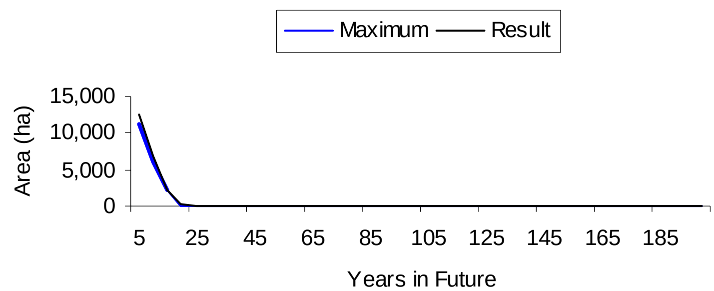


Figure 5-22. Target area of Sundance ranked pine on the landbase from Sundance PFMS.

Due to the very large amount of area that is ranked under the SRD ranking, Sundance used their own ranking, which is largely a subset of the government ranking, but prioritizes stands with high biological and economical risk. These stands are largely removed within the first 20 years of the planning horizon (Figure 5-23).

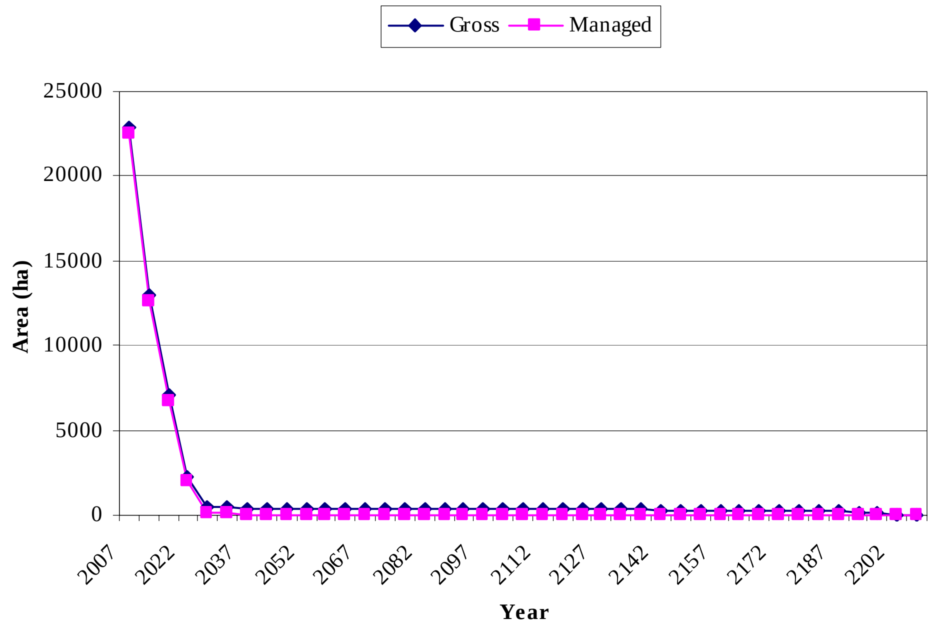


Figure 5-23. Area of Sundance ranked pine on the landbase from Sundance PFMS.

5.5.2 Strata

The forested landbase area by strata stays constant through time (Figure 5-24). The majority of the landbase is pine. The only change is associated with the black spruce area on the managed landbase that is harvested and regenerated to pine.

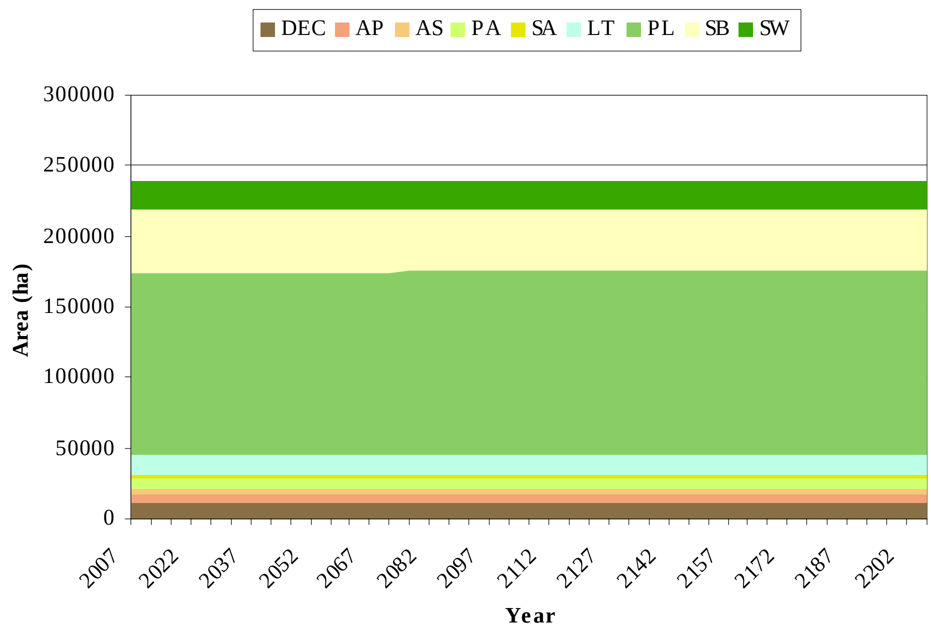


Figure 5-24. Area by yield strata on the gross landbase from the Sundance PFMS.

The managed landbase by yield strata is similar to the forested landbase but there is a lower proportion of black spruce as previously discussed (Figure 5-25)

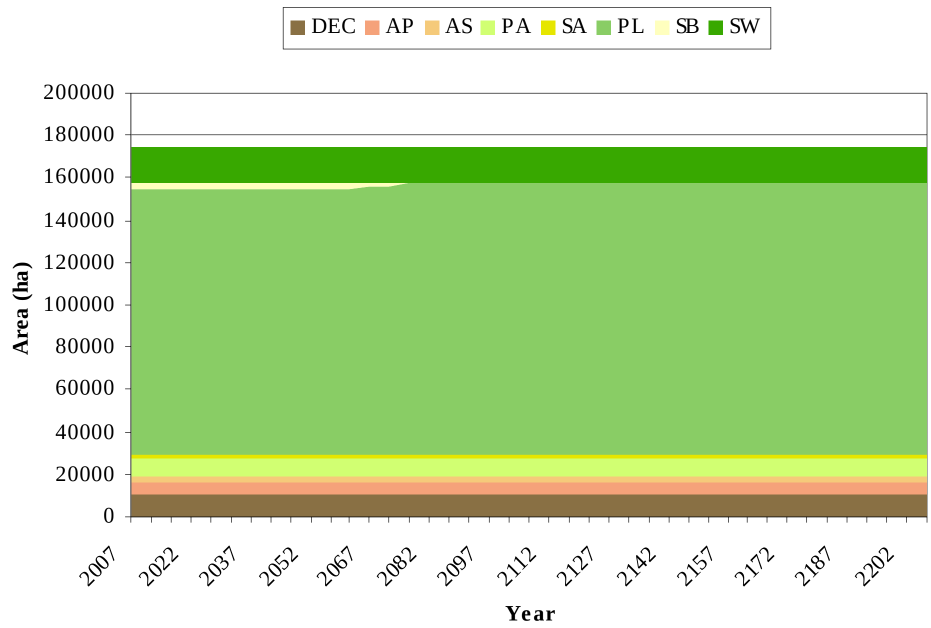


Figure 5-25. Area by yield strata on the managed landbase from the Sundance PFMS.

5.5.3 Origin

At the beginning of the planning horizon, stands on the Sundance FMA are predominantly natural, or fire origin (Figure 5-26). Later in the planning horizon, this changes to become largely managed stands, or stand with harvest and regeneration occurring through time. On the managed landbase, the trend is similar, though a larger portion of the landbase becomes managed more rapidly, and to a larger extent through time (Figure 5-27)

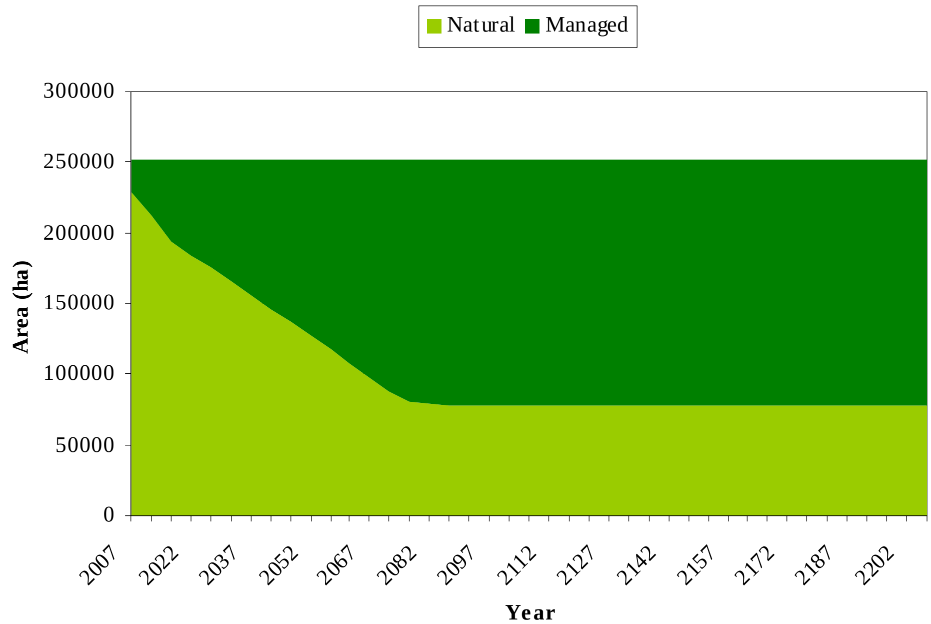


Figure 5-26. Area by origin on the gross landbase from the Sundance PFMS.

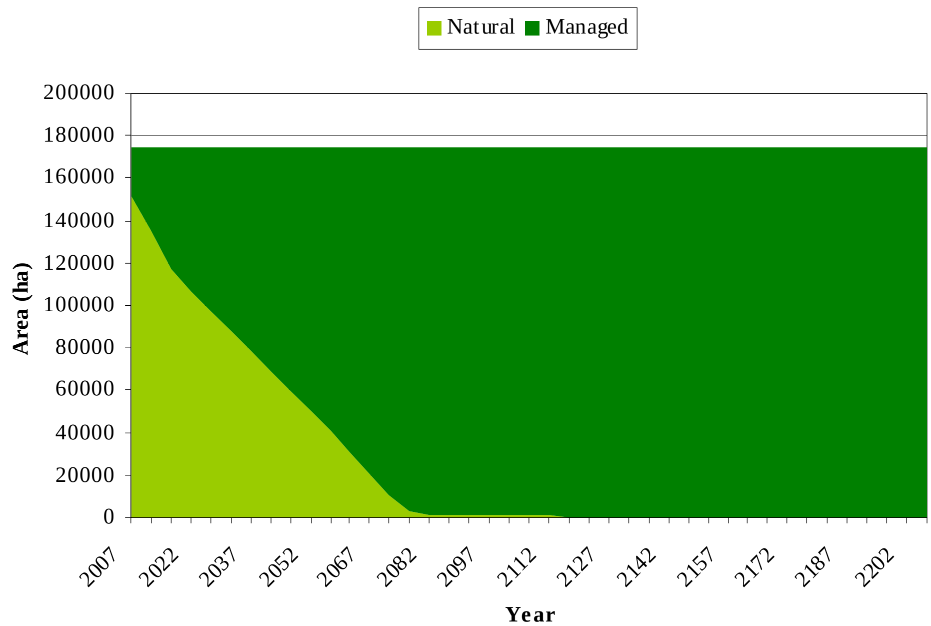


Figure 5-27. Area by origin on the managed landbase from the Sundance PFMS.

5.5.4 Age Class

The age class distribution of the forest changes throughout the planning horizon, though the trends on the gross and managed landbase differ (Figure 5-28 and Figure 5-29). The managed landbase has an initial increase in the amount of young on the landbase; through time this changes to a more regulated forest state than the current mature-dominated age class structure. The gross landbase is the combination of the managed landbase, which moved to a younger age class structure and the remainder of the forested landbase, which moved to an older age class structure through time. This is because no actions were eligible to happen on the non managed forested landbase.

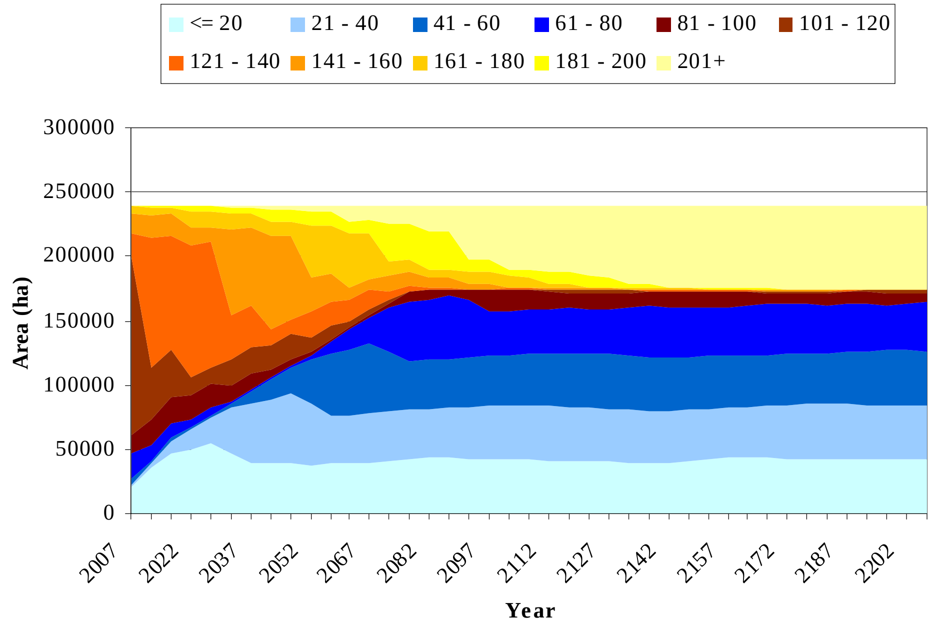


Figure 5-28. Area by age class on the gross landbase from the Sundance PFMS.

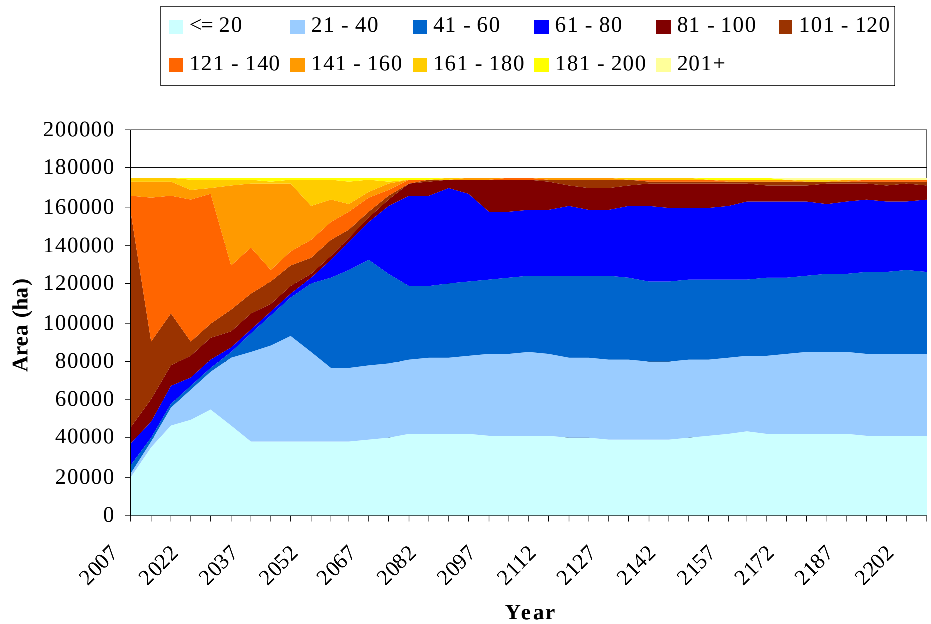


Figure 5-29. Area by age class on the managed landbase from the Sundance PFMS.

5.5.5 Seral Stage

The seral stage distribution on the gross and managed landbase follow similar trends as the age class distributions, Figure 5-30 and Figure 5-31 respectively. The amount of regenerating area on the gross landbase increases then generally stabilizes; the same general trend is followed by the young seral stage. The area of mature on the gross landbase decreases throughout the planning horizon, with a stabilization in the area towards the end of the planning horizon. The area of early old growth increases from the beginning to middle of the planning horizon and then decreases towards the end of the planning horizon. The area of late old growth increases throughout the planning horizon with a slight decrease towards the end of the planning horizon.

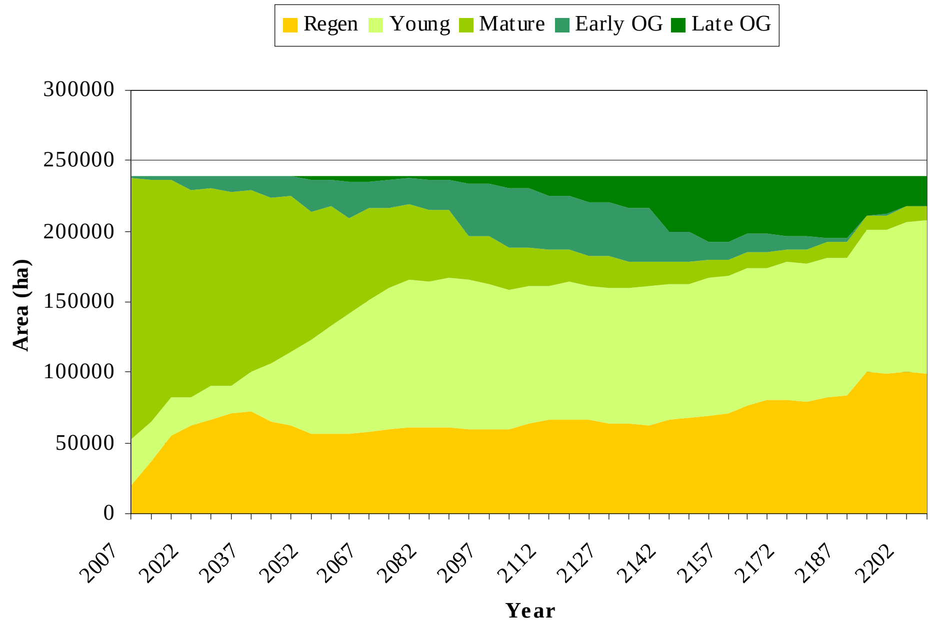


Figure 5-30. Area by seral stage on the gross landbase from the Sundance PFMS.

The managed landbase seral stage distribution differs from the gross landbase. Both the regeneration and young seral stages increase early in the planning horizon then stabilize. The area of mature decreases early in the planning horizon then stabilizes. The area of early and late old growth increases in the first ½ of the planning horizon then decreases for the remainder of the planning horizon.

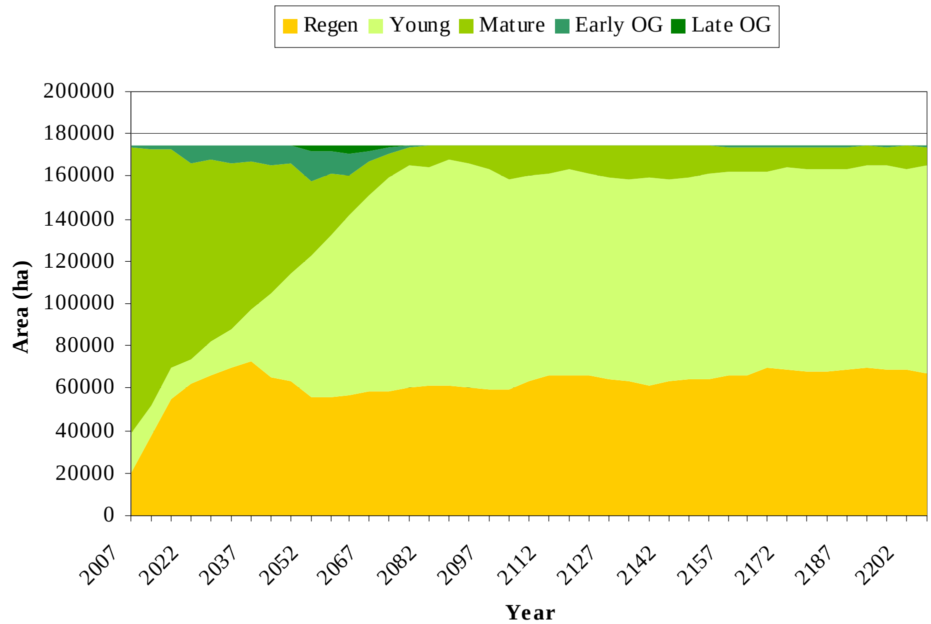


Figure 5-31. Area by seral stage on the managed landbase from the Sundance PFMS.

Old refers to the combination of early and late old growth seral stages. On the gross landbase the area increase throughout the first ¾ of the way through the planning horizon, then decreases towards the end of the planning horizon (Figure 5-32). The majority of this old comes from black spruce and larch.

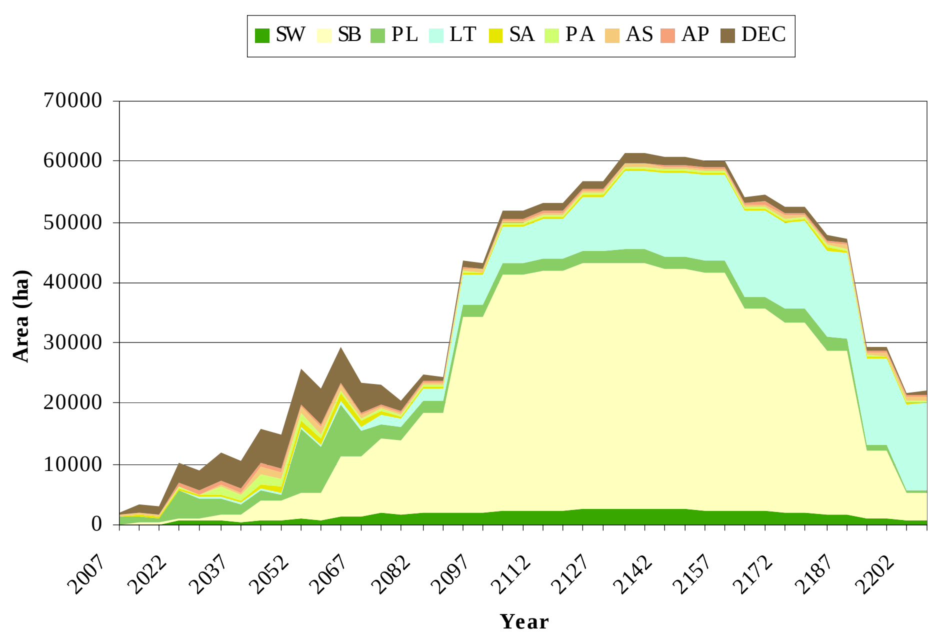


Figure 5-32. Old growth area on the gross landbase from the Sundance PFMS.

There is a target placed on the managed landbase to maintain 2% old growth area (Figure 5-33). This target was not met throughout the planning horizon. There were a number of issues related to this trend through time. The old classification system requires very old stands to be on the forest, largely older than are on the forest today, or may be achievable for stands. Secondly, with the MPB issues currently in the forest and directives such as the Alberta pine strategy (reference) it was decided that though old would be targeted, it would not be the overriding objective.

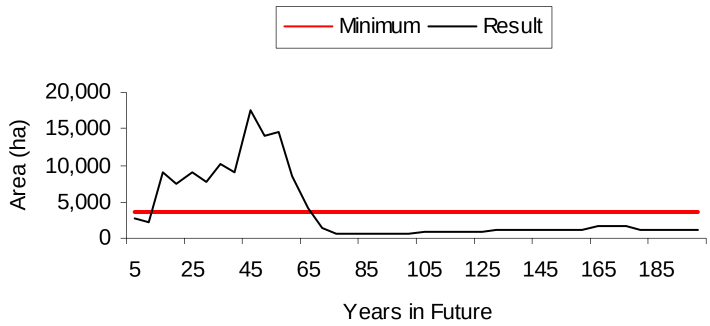


Figure 5-33. Target old growth area on the managed landbase from the Sundance PFMS.

The managed landbase old growth area is made up of a variety of species strata at the beginning of the planning horizon (Figure 5-34). Towards the end of the planning horizon, the old growth representation of deciduous increases.

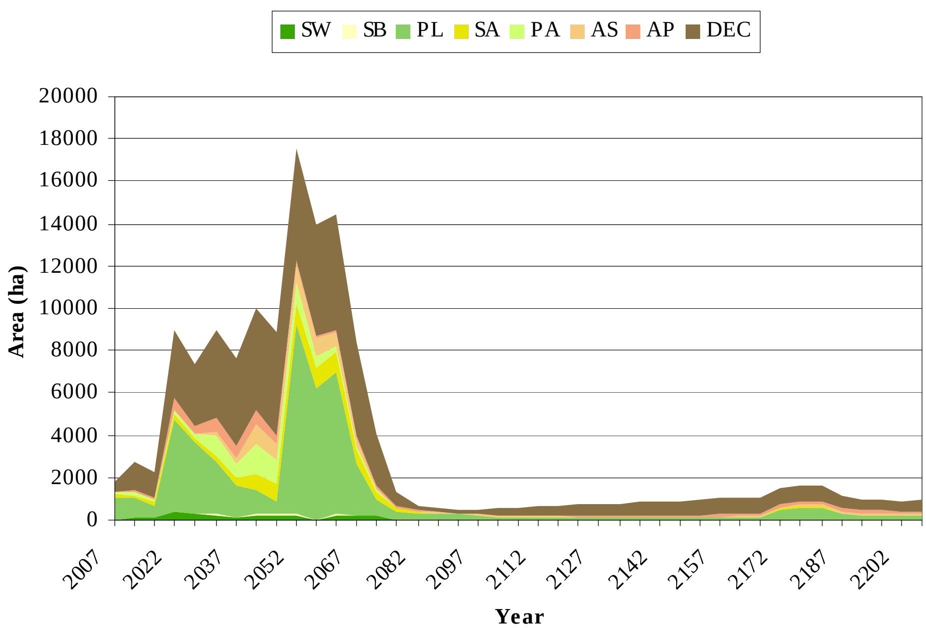


Figure 5-34. Old growth area on the managed landbase from the Sundance PFMS.

5.6 Opening Patches

There were four targets placed on the PFMS relating to opening patches. The targets are meant to create an opening patch distribution similar to a natural range of distribution that is also operationally feasible. The first target is to reduce the percent of patches under the minimum opening size of 2 ha to 0% (Figure 5-35). This is achieved in all periods. The second target is to ensure that 76% of the opening patches are between 2 and 100 ha (Figure 5-36). This objective is underachieved in all periods. The third target is to have 19% of opening patches in the 100 to 1000 ha size range (Figure 5-37). This target is overachieved in all periods. The fourth target is to ensure that 5 % of opening patches are over 100 ha (Figure 5-38). This target is more or less achieved in all periods; it fluctuated over and under the target but is generally correct.

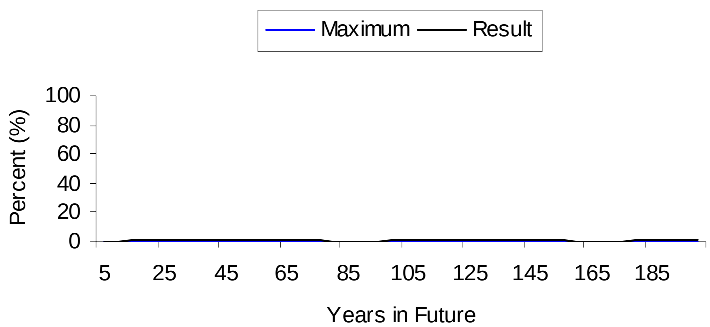


Figure 5-35. 0 – 2 ha Opening patch target on the gross landbase from the Sundance PFMS.

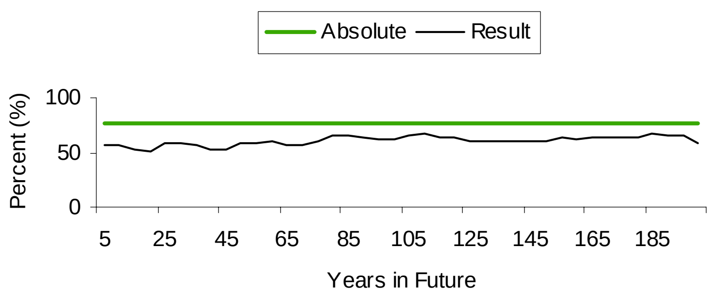


Figure 5-36. 2 - 100 ha Opening patch target on the gross landbase from the Sundance PFMS.

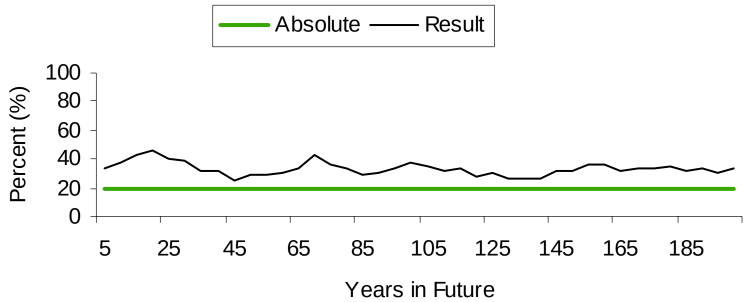


Figure 5-37. 100 – 1000 ha Opening patch target on the gross landbase from the Sundance PFMS.

Figure 5-38. 1000 ha + Opening patch target on the gross landbase from the Sundance PFMS.

Overall, there were more 100 to 1,000 ha patches on the landbase, though as previously discussed, Patchworks generally represent patches larger that what would be seen by people (Figure 4-1).

5.7 Old Patches

There is a Patchworks target on the PFMS to have 60% of the old forest area in patches greater than 120 ha (Figure 5-41). Initially, the target is not met, but later in the planning horizon it is.

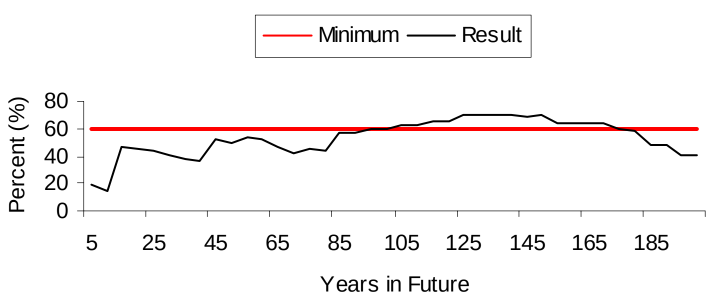


Figure 5-39. Target of interior old growth area on the landbase from the Sundance PFMS.

Old large forest patches have become an increasingly important part of forest management planning. It is recognized that many species require large forest patches to survive. The planning standard includes an interior core patch target of 100 ha or greater. In Patchworks, old patches of greater than 120 ha are targeted as a proxy for the 100ha interior forest target. The 120 size is used to account for edge effects. This analysis ignored the linework not cut into the TSA analysis, though these areas did not add to the patch sizes. Though this target may not create patches that are always greater than 100 ha from an interior forest target, it will aggregate the interior forest target. The area by strata in patches greater than 120ha on the gross landbase can be seen in Figure 5-40. The old patches on the gross landbase by size class can be seen in Figure 5-41.

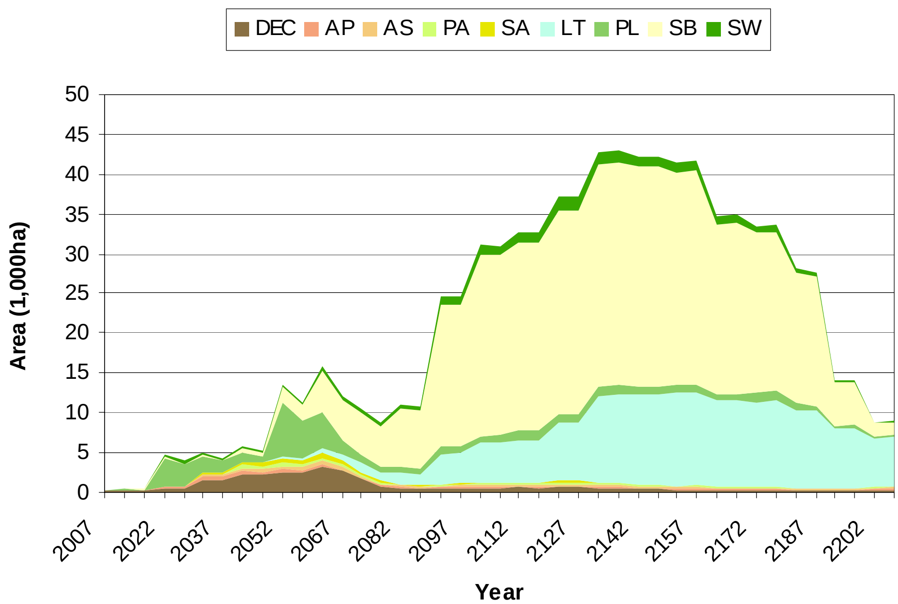


Figure 5-40. Old patches greater than 120 ha by strata on the landbase from the Sundance PFMS.

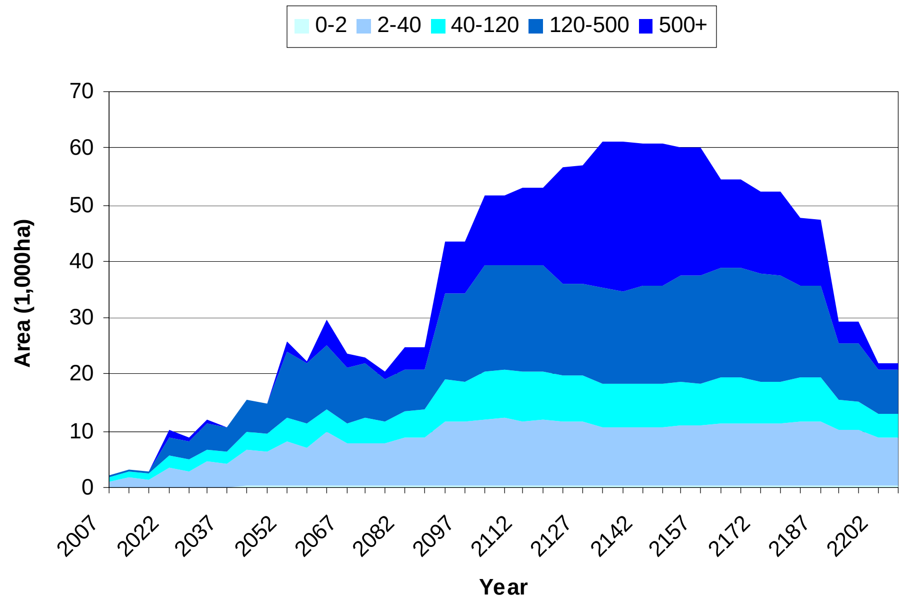


Figure 5-41. Old patches by size class from the Sundance PFMS.

5.8 Road Costs

Theoretical road costs are included in the PFMS to aggregate harvest and balance road building and maintenance costs. A Patchworks-created road lattice and Sundance's road network are overlaid to create a Patchworks road network. Costs are assigned to builds based on whether they crossed rivers, of any class, or steep slopes. Maintenance costs are also applied to the model. Maintenance costs are paid when the model opens a section of road for hauling in a period. If the road is not used there is no maintenance costs paid.

Generally, Patchworks will build as many roads as possible early in the planning horizon if left unconstrained. In the PFMS, a target is placed to limit road building early in the planning horizon (Figure 5-42). Additionally, there is a similar target placed on the maintenance costs for hauling. These two targets were achieved for the periods in which they were active.

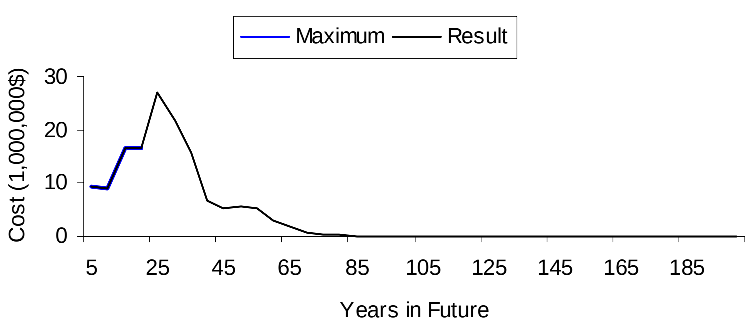


Figure 5-42. Road build cost target from the Sundance PFMS.

Figure 5-43. Road maintenance cost target from the Sundance PFMS.

5.9 Target interaction

There are 6 general areas with targets on them in the Sundance PFMS. They are related to harvest, growing stock, MPB, old growth, patches, and roads. There are complex relationships between each of these different targets, therefore none of the targets can be analyzed individually. For example, coniferous harvest volume and coniferous growing stock interact directly, as harvest increases growing stock generally decreases. An example of a more complex relationship is between the Erith Operating Area coniferous harvest targets and the deciduous harvest target. Though the targets for harvest are on coniferous volume, they directly affect the deciduous volume because the Erith Operating Area has more mixedwood stands than the remainder of the FMA. This harvest area produces more deciduous volume than harvest in other areas.

Another example is the old forest targets and harvest levels. Generally, these two conflict. As well, stable growing stock can also conflict with old growth as old stands generally lose volume through time, therefore the model would need to harvest old forest to stabilize growing stock. Finally the patch targets and road costs, through all of the other interactions ensure the sequences seen create operational targets.

5.10 Target Weighting

The weighting of individual targets impacts the model's ability to achieve the target values desired by the management team. Target weighting is not a mathematical process representing higher or lower values for a specific indicator but rather, determining the actual weights is a process of ensuring a desired outcome for each of the target values. Even flow is desired for some targets, while fluctuations are permitted for others, and still others can have significant deviation from the desired value and still be within accepted limits. Once the desired outcome is decided, the weights are adjusted in an attempt to achieve the targets.

Some targets are difficult to achieve and the weighting will necessarily be higher. Other targets will achieve their values with very little encouragement, thus very little weighting is required. The relative weighting between targets does not reflect their relative importance, but simply reflects the required weighting to achieve the desired outcome.

6. Issues and Decisions

There were many decisions that needed to be made throughout the TSA process to create the desired PFMS. These decisions covered a wide range of topics, including harvest levels, old growth area, and patch sizes as some examples. Many of these issues were related, and decisions were made throughout the process of PFMS creation sometimes with incomplete information. The Forestry Corp, produced and distributed documents that explained the background, methods, results, and discussions around these issues for the purpose of explanation and tracking required decisions. These documents were distributed to the client, and any stakeholders that required the information to make decisions. Therefore, to allow the tracking of the decision process and the comprehension of the information that was available at the time of the decisions, which was sometimes incomplete, the issues documents have been included in this document. The documents have been slightly modified for flow and presentation purposes but content was maintained. The exception is the answers sections which have been modified to include the decisions made rather than a question posed as in the original documents. This format will include some duplicate information but it is believed that this is the best manner for presenting this information to show; the issues identified; information presented; and the decisions made.

These issues documents are laid out to first identify a question posed by Sundance, a stakeholder, or government through the planning standard or other communications. Subsequently, background information is presented along with the methodology used to analyze the problem. The results of the scenario are then presented along with any other indicators that were affected by the analysis. Indicators that were not affected by the issue were not presented in these documents but were available through digital distribution when the issues were presented. The results were then discussed in the next section along with recommendations. Finally, when the issues were initially distributed, a question was posed for the involved parties to make decisions. In these versions, the decisions made are presented along with a discussion of this decision process.

6.1 Objective Function and Curve Set

6.1.1 Question

What objective function and volume yield curve sets should be used in the 2007 Sundance TSA?

6.1.2 Background

The objective function used in the TSA can have a large impact on the model results. There were three objective functions analyzed, which are commonly used in TSA's in Alberta. The first was the maximization of total harvest, both coniferous and deciduous volume combined. The second was the maximization of the coniferous volume harvested, while the third was the maximization of the deciduous volume harvested.

Six scenarios were presented in this summary; these provided enough information to enable a decision to be made regarding the most suitable objective function to be used in this TSA (Table 6-1).

Table 6-1. Effect of different objective functions and yield curve assumptions on harvest levels.

Scenario		Harvest Level (m^3/yr)			Change in Harvest Level (m^3/yr)		
		Conifer	Deciduous	Total	Conifer	Deciduous	Total
Natural Only							
Sun_W2010	Max Total	410,394	50,405	460,799		- - - Baseline - - -	
Sun_W2011	Max Conifer	411,143	47,826	458,970	749	(2,578)	(1,829)
Sun_W2012	Max Deciduous	385,778	53,555	439,334	(24,616)	3,151	(21,465)
Natural and Managed							
Sun_W2013	Max Total	424,408	55,180	479,588		- - - Baseline - - -	
Sun_W2014	Max Conifer	425,143	53,476	478,619	736	(1,705)	(969)
Sun_W2015	Max Deciduous	402,013	58,150	460,163	(22,395)	2,970	(19,425)

Additionally, the scenarios in Table 6-1 allowed the decision of whether managed stand yield curves should be used in the TSA. Managed stand yield curves represent volume curves created from only stands with C or D densities. This practice has been used as current regeneration standards force companies to regenerate harvested areas back to a fully stocked state. Therefore the curves representing these areas should represent the actual state of these stands. Managed curves were only created for the Dec, Sw, and Pl strata, which represents all of the pure species strata. There were not curves created for the other strata due to a lack of fully stocked plots in these strata. Runs were completed using all 3 objective functions and either the natural only or the natural and managed yield curves.

6.1.3 Results

Changing from a maximize total volume to a maximize coniferous volume objective function caused a coniferous harvest increase of approximately 750m^3/yr when only the natural curves were used and 1,700m^3/yr when the natural and managed curves were used (Table 6-1). When the coniferous objective function was used over the total volume with either curve set the deciduous harvest decreased by approximately 2,500m^3/yr. The deciduous objective function caused a decrease of approximately 24,000m^3/yr of coniferous harvest and increased the deciduous harvest by approximately 3,000m^3/yr for either curve set.

When natural and managed curves were used rather than just natural curves, an increase of approximately 14,000 m^3/yr of coniferous volume was seen in all scenarios. The deciduous harvest also increased by approximately 5,000m^3/yr when using natural and managed curves.

Analysis of the other outputs from these runs showed that there was no large difference between these scenarios for the other indicators. One exception was a slightly higher level of old growth in the runs that maximized deciduous harvest, due to the lower harvest levels associated with these scenarios.

6.1.4 Discussion

The maximize total volume and maximize coniferous volume scenarios had similar results, while the maximize deciduous scenario produced lower coniferous volumes with a small increase in deciduous harvest and area of old growth. Overall the maximize total harvest and maximize coniferous harvest objective functions did not have significant differences. As Sundance is mainly a coniferous operator the use of the deciduous objective function was discounted. Using either curve set there was a slight increase in coniferous harvest at the cost of deciduous harvest; approximately a one half to one third tradeoff between coniferous and deciduous volume. Though this was not a significant reason for using a maximize coniferous volume objective function, it would allow for different constraint sets to be used in this analysis, such as those presented in (section 6.2). Therefore it was recommended that the maximize coniferous harvest objective function was used in this FMP process.

Regarding the assumption of fully stocked regeneration, it was seen that there was a significant positive effect on coniferous harvest of assumed fully stocked regeneration. As Sundance must regenerate all of their harvested areas to a fully stocked state it was recommended that the fully stocked curves be used in this analysis.

6.1.5 Assumptions

The primary assumptions made were:

- Round 2 landbase,
- Round 2 Yield Curves, and
- No other constraints.

6.1.6 Answer

It was decided that the objective function for this FMP would be a maximization of coniferous harvest over the length of the planning horizon (Table 6-2). Also, it was decided that both the natural and managed curves would be used in the FMP.

Table 6-2. Decision regarding objective function and yield curve sets used in the Sundance TSA.

Decision Number	Decision Description	TFC Recommendation	Sundance Decision
1	Use Maximize Total Harvest Objective	No	
	or		
	Use Maximize Conifer Harvest Objective	Yes	YES
	or		
	Use Maximize Deciduous Harvest Objective	No	
2	Use Natural Only Curves	No	
	or		
	Use Natural and Managed Curves	Yes	YES

6.2 Timber Supply Constraints

6.2.1 Question

What basic timber supply constraints should be used in the 2007 Sundance TSA?

6.2.2 Background

Certain constraints are required to be placed on the model based on the current planning standard (version 4.1). The first of these was a non-declining yield of operable growing stock from the landbase. Secondly, the planning standard refers to even flow harvest, though not a requirement there needed to be adequate justification to implement a non-even flow harvest.

Though Sundance has the rights to harvest both coniferous and deciduous volume from the landbase, they are primarily a coniferous operator. Therefore, it was decided to analyze the effect of only constraining the coniferous volume to an even flow harvest. Two scenarios were used to show the effect of moving from an even flow coniferous and deciduous constraint to only a coniferous even flow constraint, Sun_W2014 and Sun_W2016 respectively.

PFMS's are required to contain a stable operable growing stock for the final quarter of the planning horizon, specifically a non-declining yield of operable growing stock. Operable growing stock refers to volume on the managed landbase that was eligible for harvest. The effect of adding a non-declining yield of coniferous volume for the final 50 years of the planning horizon was tested. As well, the effect of adding a non-declining yield of coniferous and deciduous growing stock, separately, was tested. The scenarios used to test the effect of the growing stock constraint were:

- Sun_W2016 as a baseline,
- Sun_W2020 with operable coniferous growing stock constraint, and
- Sun_W2021 which contained an operable coniferous and deciduous growing stock constraint.

6.2.3 Results

Removing the even flow deciduous harvest constraint when the objective function was to maximize the coniferous harvest resulted in an increased even flow coniferous harvest of approximately 6,500m^3/yr; while decreasing the average deciduous harvest by approximately 1,000m^3/yr (Table 6-3). Though removing the deciduous even flow constraint caused large fluctuations in the deciduous volume harvested (Figure 6-1) the stabilization of this deciduous harvest will be discussed in Section 6.3.

Table 6-3. Harvest levels with and without an even flow deciduous volume constraint.

Scenario		Harvest Level (m^3/yr) Conifer	Deciduous*	Total	Change in Harvest Level (m^3/yr) Conifer	Deciduous	Total
Sun_W2014	Even flow Con and Dec	425,143	53,476	478,619	----- Baseline -----		
Sun_W2016	Even flow Con only	431,730	52,353	484,083	6,587	(1,123)	5,464

* Represents the average over the planning horizon

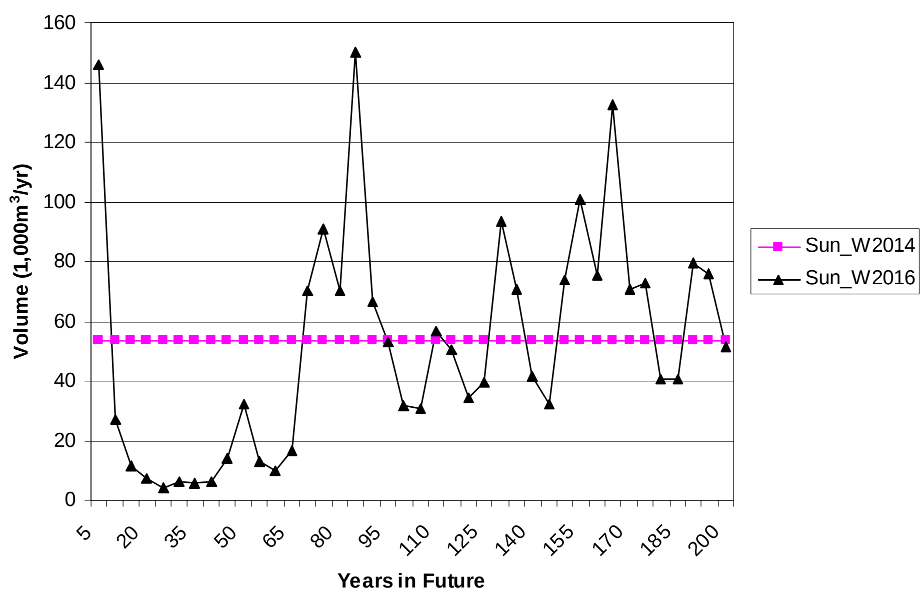


Figure 6-1. Deciduous harvest with (Sun_W2014) and without (Sun_W2016) a deciduous even flow constraint.

Adding an ending operable growing stock constraint of coniferous volume for the last quarter of the planning horizon had a negligible effect on the harvest level (Table 6-4). There was also no noticeable change to any of the other indicators, including operable coniferous growing stock (Figure 6-2). It can also be that adding an ending growing stock constraint of deciduous volume, additional to the coniferous constraint, had very little effect on the harvest level from the landbase. Figure 6-3 shows that adding the deciduous growing stock constraint simply stabilized the deciduous operable growing stock for the last ¼ of the planning horizon but did not increase it.

Table 6-4. Harvest levels as ending growing stock constraints were added to the model.

Scenario		Harvest Level			Change in Harvest Level		
		Conifer	Deciduous	Total	Conifer	Deciduous	Total
Sun_W2016	No GS	431,730	52,353	484,083	----- Baseline -----		
Sun_W2020	NDY of Con GS	431,613	52,091	483,704	(117)	(262)	(380)
Sun_W2021	NDY or Con and Dec GS	431,549	52,473	484,022	(182)	120	(62)

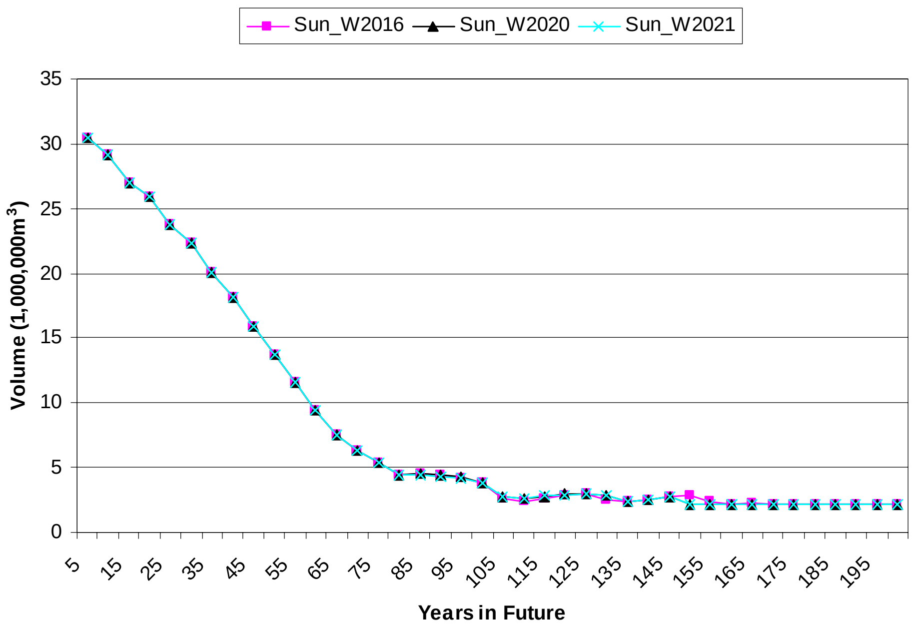


Figure 6-2. Coniferous growing stock from selected runs used to test the effect of ending growing stock constraints.

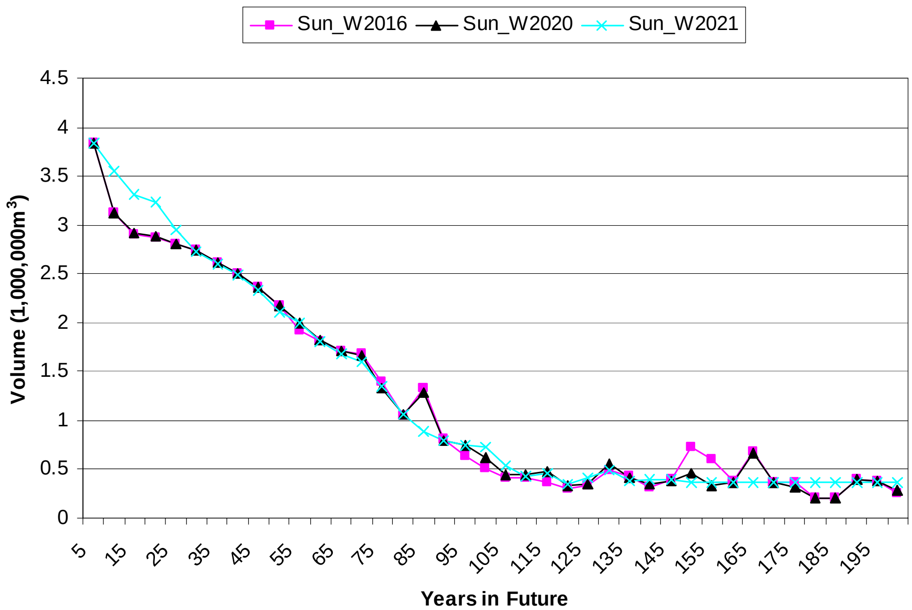


Figure 6-3. Deciduous growing stock from selected runs used to test the effect of an ending growing stock constraint.

6.2.4 Discussion

Moving from an even flow of deciduous harvest to an uneven flow caused a significant increase in the coniferous harvest from the landbase at the cost of very little deciduous volume based on average harvest over the planning horizon. However, there were large fluctuations associated with the deciduous harvest level. These fluctuations could be reduced in the early periods of the model with a constraint on the deciduous harvest. The even flow deciduous level from this FMP would not likely meet the required deciduous commitment level for the length of the planning horizon. Thought the even flow level was above the required 49,340m3/yr when other required constraints were included and when the model was made spatial this level will drop. A constraint could be placed on the deciduous harvest for a period of time to ensure in the short term that this constraint was met. This will be discussed in a issues document below. It was recommended that an uneven flow of deciduous volume would be used in this FMP, to increase the coniferous harvest.

Adding a coniferous or coniferous and deciduous non-declining operable growing stock constraint onto the model had very little effect on the harvest or other indicators from the forest. As well, the government forces such constraints to be placed on timber supply models based on the planning standard. Therefore, it was recommended that the non-declining growing stock constraints on coniferous and deciduous operable growing stock were placed on the model.

6.2.5 Assumptions

The primary assumptions made were:

- Round 2 landbase,

- Round 2 Yield Curves,
- Maximize coniferous volume harvested,
- Even flow coniferous volume over the planning horizon, and
- Unconstrained deciduous volume for all except for Sun_W2014 (with even flow deciduous).

6.2.6 Answer

It was decided that only the coniferous volume would be constrained to even flow throughout the planning horizon (Table 6-5). Additionally, both the coniferous and deciduous growing stock would be constrained to be non-declining separately.

Table 6-5. Decision on basic timber supply constraints to be included in the Sundance TSA.

Decision		TFC	Sundance
Number	Description	Recommendation	Decision
1	Use Coniferous and Deciduous Even Flow	No	
	or		
	Use Coniferous Even Flow Only	Yes	YES
2	Use NDY Operable Coniferous GS Only	No	
	or		
	Use NDY Operable Coniferous and Deciduous GS	Yes	YES

6.3 Volume Commitments

6.3.1 Question

How long should volume commitments be maintained for in the 2007 Sundance TSA?

6.3.2 Background

Sundance has both coniferous and deciduous volume commitments to be considered for inclusion in this FMP. The deciduous commitments were related to volume transfers to Weyerhaeuser. Also there were CTP commitments in the Erith compartments.

It was seen in the last Sundance FMP that it was difficult to achieve the deciduous commitment from the FMA when all of the components were included in the PFMS. The base unconstrained scenario, which maximized both coniferous and deciduous volume, achieved 53,357m^3/yr of deciduous volume. 49,320m^3/yr of deciduous harvest was required to meet the deciduous volume commitment. Once other necessary constraints were placed on the model and the modeling was moved spatial it was unlikely this volume would be achieved. As a result an alternative approach to meeting the deciduous volume commitment was proposed.

The alternative approach to meeting the deciduous commitment was a model optimized for coniferous harvest without an even flow deciduous harvest constraint; with a constraint on the deciduous volume at the beginning of the planning horizon ensuring 49,340m^3/yr of deciduous harvest. The amount of time, which the deciduous commitment should be met, had to be decided, if this approach was to be used. Four runs were presented to assess how long this deciduous harvest constraint should be placed on the model (Table 6-6).

Table 6-6. Scenarios used to analyze the length of time of the deciduous commitment.

Scenario	Time Deciduous Commitment Constrained
Sun_W2021	0
Sun_W2025	10
Sun_W2026	20
Sun_W2027	50

A separate set of scenarios were created to show the effect of meeting the CTP commitments from the Erith Compartments. These commitments were a minimum harvest of 10,00m^3/yr, 2,400m^3/yr, and 19,000m^3/yr of harvest from compartments 22, 23, and 24 respectively. The time periods these constraints were active, by scenario, can be seen in Table 6-7.

Table 6-7. Scenarios used to analyze the CTP commitments in Erith .

Scenario	Time Coniferous Commitment Constrained
Sun_W2026	0
Sun_W2060	10
Sun_W2061	20
Sun_W2062	50

6.3.3 Results

Adding a constraint on the deciduous harvest for the first 10 years of the planning horizon had little effect on model other than a slight reduction in the volume harvested (Table 6-8). Extension of this constraint to meet the deciduous commitment for 20 year also had no significant effect on the model results. The increase seen in the deciduous harvest in Table 6-8 is due to the fact that this is a 20 year average not average over the planning horizon. When increased to 50 years, coniferous harvest decreased by 1,600m^3/yr, but the other indicators were not affected.

Table 6-8. Effect of deciduous harvest commitments for varying lengths of time.

		Harvest Level (m^3/yr)			Change to Harvest Level (m^3/yr)		
Scenario	Years Active	Conifer	Deciduous*	Total	Conifer	Deciduous	Total
Sun_W2021	0	431,549	40,298	471,847		Baseline	
Sun_W2025	10	431,544	40,004	471,547	(5)	(294)	(299)
Sun_W2026	20	431,501	49,340	480,841	(48)	9,042	8,994
Sun_W2027	50	429,938	49,340	479,278	(1,611)	9,042	7,431

* 20yr harvest average

Table 6-9 shows there was little or no effect on the results, aspatially, of attaining the coniferous harvest commitments in the Erith compartments for the first 10 or 20 years. Achieving these commitments for 50 years would cause a slight decrease in the coniferous harvest level. There were no major effect any of these constraints on other indicators.

Table 6-9. Effect on harvest level of meeting the CTP commitments for varying lengths of time.

Scenario	Years Active	Harvest Level (m^3/yr) Conifer	Deciduous*	Total	Change to Harvest Level (m^3/yr) Conifer	Deciduous	Total
Sun_W2026	0	431,501	49,340	480,841	Baseline		
Sun_W2060	10	431,501	49,340	480,841	(0)	(0)	(0)
Sun_W2061	20	431,501	49,340	480,841	(0)	(0)	(0)
Sun_W2062	50	431,175	49,340	480,515	(326)	(0)	(326)

* 20yr harvest average

6.3.4 Discussion

Constraints to meet the volume commitments, either deciduous or coniferous, did not have any major effect over any length of time in these aspatial scenarios. Though in both cases meeting the commitments for 50 years had a proportionately larger affect that the shorter periods of time. As there was uncertainty surrounding forest management and the fact that FMP's must be completed at least every 10 years it was recommended that the volume commitments be constrained for only 20 years. During which time long term sustainable deciduous commitments can be discussed. As well spatial effects of harvest in the Erith compartments can be assessed.

6.3.5 Assumptions

The primary assumptions made were:

- Round 2 landbase,
- Round 2 Yield Curves,
- Maximize coniferous volume,
- Even flow coniferous volume,
- Non-declining yield of coniferous and deciduous growing stock to the final 50 years, and
- For coniferous commitment runs, ensure deciduous commitment for 20 years.

6.3.6 Answer

It was decided that the coniferous and deciduous volume commitments would both be constrained for 20 years of the planning horizon (Table 6-10).

Table 6-10. Decisions regarding volume commitment constraints for use in the Sundance TSA.

Decision Number	Decision Description	TFC Recommendation	Sundance Decision
1	Include Constraint for Deciduous Commitment	Yes	YES
2	If Yes to #1 Then		
	Include for 10 years	No	
	or		
	Include for 20 years	Yes	YES
	or		
	Include for 50 years	No	
	or		
	Include for some other time period	N/A	
3	Include Constraint for Coniferous Commitment	Yes	YES
4	If Yes to #3 Then		
	Include for 10 years	No	
	or		
	Include for 20 years	Yes	YES
	or		
	Include for 50 years	No	
	or		
	Include for some other time period	N/A	

6.4 Old Growth

6.4.1 Question

What old growth level should be constrained as a minimum in the 2007 Sundance TSA?

6.4.2 Background

The planning standard (version 4.1) states that companies must set a target on the amount of old forest on the landbase. The seral stages used in the Sundance FMP were based on the SRD seral stage classifications (Table 6-11). The steps taken to alter these curves for use can be seen in Section 4.7. In this document old growth refers to the combination of Early Old Growth and Late Old Growth from Table 6-11.

Table 6-11. Seral stages based on SRD classifications; modified for use in the Sundance FMP.

	Regenerating		Young		Mature		Early Old Growth		Late Old Growth	
Strata	Min (yrs)	Max (yrs)	Min (yrs)	Max (yrs)	Min (yrs)**	Max (yrs)	Min (yrs)	Max (yrs)	Min (yrs)	Max* (yrs)
DEC	0	20	21	60	61	130	131	160	161	245
AP	0	25	26	80	81	140	141	180	180	400
AS	0	30	31	90	91	150	151	190	191	400
PA	0	25	26	70	71	140	141	180	181	400
SA	0	30	31	90	91	150	151	190	191	400
LT	0	40	41	100	101	200	201	250	251	400
PL	0	30	31	80	81	160	161	210	211	295
SB	0	40	41	100	101	200	201	250	251	295
SW	0	30	31	90	91	180	181	230	231	295

* Based on Oct 4, 2006 Succesion rules lifespan

**Modified to align Mature to minimum harvest age where mature age was higher than minimun harvest age

A series of scenarios were completed using the above seral stages and increasing the amount of old growth required on the managed landbase for the final ½ of the planning horizon. A list of these scenarios by percent old growth required is presented in Table 6-12. For each of these runs a maximum of 50% of the area of old could come from the D and DC cover groups, the other 50% had to come from C or CD cover groups. This was included as SRD has shown that they require representation of all types in the old growth area.

Table 6-12. Percent old growth constrained for the final 100 years by scenario.

Scenario	Percent Old Growth
Sun_W2026	0%
Sun_W2040	2.5%
Sun_W2041	5%
Sun_W2042	7.5%
Sun_W2043	10%
Sun_W2044	12.5%
Sun_W2045	15%
Sun_W2046	17.5%
Sun_W2047	20%

6.4.3 Results

Table 6-13 shows that as the amount of old growth desired from the landbase increased, the achievable harvest level decreased. Though the deciduous harvest level increases, in some scenarios, this is the 20 year average, the planning horizon average decreases, which will be shown later. Figure 6-4 shows the relationship of harvest level to old growth.

Table 6-13. Harvest volume by scenario, as old growth was constraints were increased.

Scenario	% Old Growth Constrained	Harvest Level		
		Conifer	Deciduous*	Total
Sun_W2026	0	431,501	49,340	480,841
Sun_W2040	2.5	423,831	51,078	474,910
Sun_W2041	5	414,548	57,704	472,252
Sun_W2042	7.5	404,565	67,756	472,320
Sun_W2043	10	393,943	61,200	455,143
Sun_W2044	12.5	382,999	49,340	432,339
Sun_W2045	15	370,880	49,340	420,220
Sun_W2046	17.5	357,415	49,340	406,755
Sun_W2047	20	342,428	49,340	391,768

* 20 year average harvest

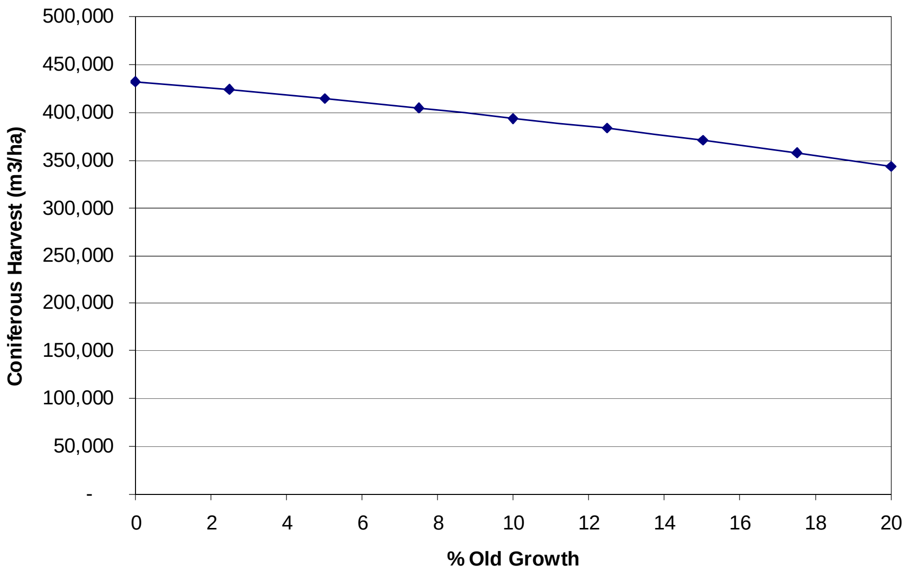


Figure 6-4. Coniferous harvest volume by % old growth on the managed landbase.

Additional to the conifer harvest level tradeoff, there was a decrease in the average deciduous volume harvested over the entire planning horizon as the desired level of old growth increased (Table 6-14). Increasing the desired level of old growth also increased the proportion of the harvest level that came from the pine strata.

Table 6-14. Average deciduous harvest (entire planning horizon) from old growth scenarios.

Scenario	% Old Growth Constrained	Average Deciduous Harvest Over the Planning Horizon	Change to Deciduous Harvest Level
Sun_W2026	0	52,694	Baseline
Sun_W2040	2.5	47,644	(5,050)
Sun_W2041	5	44,945	(7,749)
Sun_W2042	7.5	41,312	(11,382)
Sun_W2043	10	36,437	(16,257)
Sun_W2044	12.5	30,829	(21,865)
Sun_W2045	15	28,001	(24,693)
Sun_W2046	17.5	26,589	(26,105)
Sun_W2047	20	25,289	(27,405)

Additionally, changes occurred to the other indicators as the amount of old growth increased. The amount of operable growing stock, both coniferous and deciduous increased throughout the length of the planning horizon. This is associated with the retention of old high volume stands on the landbase and higher harvest levels. Age class structure also shifted to older types as seral stage and old age classes are correlated.

Due to the length of time required to create old growth (Table 6-11) the initial old growth constraint was made up of natural stands that were not harvested. Throughout the rest of the planning horizon some of these stands were harvested and replaced by managed stands that reach old growth status within the planning horizon. At the end of the planning horizon (year 200) there was still a large amount of the old growth from natural stands that were not harvested during the planning horizon.

6.4.4 Discussion

There was a direct relationship between the amount of old growth on the forest and the achievable harvest level (coniferous and deciduous). As harvest and old growth are inversely related a decision must be made as to the level of old desired from the landbase. A number of factors affect this decision:

- The approaching MPB could kill most, if not all, of the immature, mature, and old pine;
- There is natural fluctuation in old on the landbase, which can be seen by looking at the history of old growth on the Sundance landbase;
- The old classification used requires long time periods to achieve the old state. In some cases longer than the planning horizon. Therefore the TSA model will typically set aside areas as old for the length of the planning horizon. This is not the aim of old retention, therefore other tools may be better at analyzing old growth.

The overall decision of amount on old becomes a tradeoff given current information and knowledge by the professionals managing the landbase in the opinion of The Forestry Corp.

6.4.5 Assumptions

The primary assumptions made were:

- Round 2 landbase,
- Round 2 Yield Curves,
- Maximize coniferous volume,
- Even flow coniferous volume,
- Non-declining yield of coniferous and deciduous growing stock to the final 50 years, and
- Ensure deciduous commitment for 20 years.

6.4.6 Answer

It was decided to include a 2% old growth target on the forest over the length of the planning horizon, recognizing there would be large fluctuations throughout the future due to current species and age class structure (Table 6-15).

Table 6-15. Decision results from the old growth issue for the Sundance TSA.

Decision Number	Decision Description	TFC Recommendation	Sundance Decision
1	Include Old Growth Objective	Yes	YES
2	If Yes to #1 Include 2.5% Old Growth Objective or Include 5% Old Growth Objective or Include 7.5% Old Growth Objective or Include 10% Old Growth Objective or Include 12.5% Old Growth Objective or Include 15% Old Growth Objective or Include 17.5% Old Growth Objective or Include 20% Old Growth Objective		2%

6.5 MPB Targeted Harvest

6.5.1 Question

Over what time period should Sundance ranked pine stands be targeted for removal in the 2007 Sundance TSA?

6.5.2 Background

It was decided that the Sundance MPB ranking would be used as the model control for this FMP and the SRD rankings would be reported on for selected scenarios. A series of runs were completed targeting the removal of Sundance rated pine stands over various lengths of time to test the effect on the harvest level and other indicators. The length of time removal was targeted varied from 10 to 40 years (Table 6-16).

Table 6-16. Scenarios used to test the effect of a goal targeting MPB susceptible stands.

Scenario	Target Length	Harvest Level (m^3/yr) Conifer	Deciduous*	Total
Sun_W2061	No Target	431,501	49,340	480,841
Sun_W2070	Minimize in 10 years	430,358	49,340	479,698
Sun_W2071	Minimize in 20 years	431,069	49,340	480,409
Sun_W2072	Minimize in 30 years	431,135	49,340	480,475
Sun_W2073	Minimize in 40 years	431,251	49,340	480,591

* 20yr harvest average

6.5.3 Results

Targeting Sundance rated pine stands had very little effect on the harvest level (Table 6-16). Figure 6-5 shows the amount of area in the Sundance rated pine by scenario over the planning horizon. All of the scenarios, that had a target to remove Sundance rated pine, increased the rate that these stands were harvested; with the exclusion of some stands which were not operable at the beginning of the planning horizon. The non-operable stands at the beginning of the planning horizon were related to blocks harvested between the landbase effective date and the TSA effective date. This issue was not identified till later in the analysis. All of the scenarios achieved their target removal rates other than the 10-year target in Sun_W2070. There were no other differences with regards to other indicators between the scenarios.

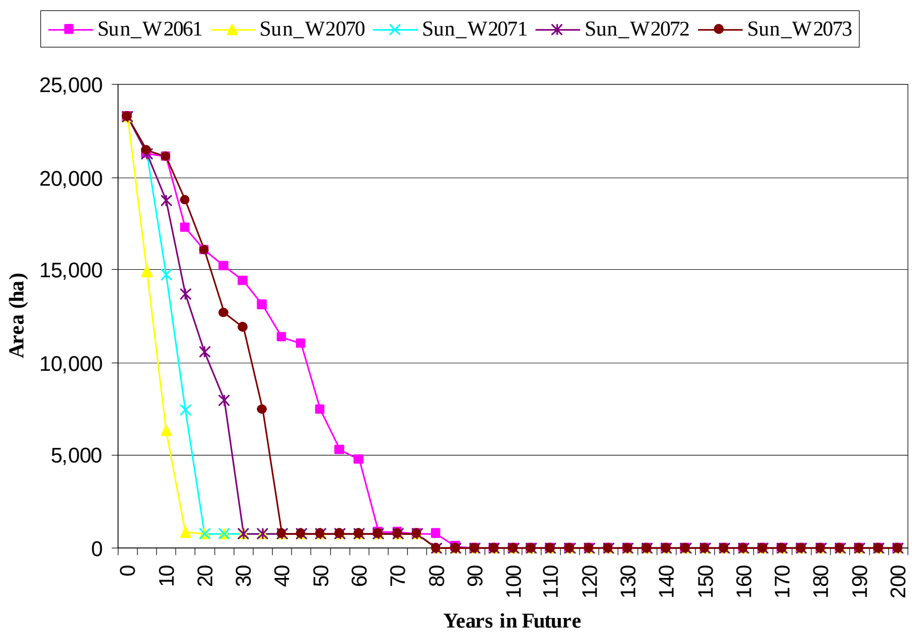


Figure 6-5. Area of Sundance rated pine by scenario.

6.5.4 Discussion

Achieving an increased removal rate of MPB susceptible stands, which typically also have a high value for timber, can be achieved, with very minimal effect on the harvest level. Since the Sundance rated pine aligns with the SRD ranking the removal of these Sundance rated pine stands will reduce both the biological and economic risks associated with MPB. Since it is not possible to meet the 10 year goal, The Forestry Corp would recommend that the a 20 year removal target be used for this FMP.

6.5.5 Assumptions

The primary assumptions made were:

- Round 2 landbase,
- Round 2 Yield Curves,
- Maximize coniferous volume,
- Even flow coniferous volume,
- Non-declining yield of coniferous and deciduous growing stock to the final 50 years,
- Ensure deciduous commitment for 20 years, and
- Ensure coniferous spatial commitments for 20 years.

6.5.6 Answer

It was decided to target the complete removal of Sundance rated pine over the first 20 years of the planning horizon (Table 6-17).

Table 6-17. Decision for removal of Sundance rated pine from the landbase for the Sundance TSA.

Decision		TFC	Sundance
Number	Description	Recommendation	Decision
1	Include Goal for MPB Removal	Yes	YES
2	If Yes to #1 Then		
	Include for 10 years	No	
	or		
	Include for 20 years	Yes	YES
	or		
	Include for 30 years	No	
	or		
	Include for 40 years	No	

6.6 Surge Cut

6.6.1 Question

Should a surge cut, and at what level, be included in the 2007 Sundance TSA?

6.6.2 Background

The current planning standard (version 4.1) allows for surge cuts to be used given one of two reasons, one of which relates to Sundance's current situation. This reason is the prevalence of older age classed forest; where a surge may decrease possible losses to insect and disease outbreaks. Given the MPB threat to the Sundance FMA, a surge cut would allow a reduction in risk associated with a MPB infestation. Albertans have recognized the risks posed by a MPB outbreak in Alberta, largely from the lessons learned from BC's current infestation. Therefore government, companies, and the public are being proactive in trying to change the course of the current BC style infestation. This in many cases takes the form of a surge cut allowing both the reduction of pine stands available for breading. It also allows the removal of infected stands, reducing the population in the subsequent year. And it also allows for the salvage of previously attacked stands reducing the loss due to MPB.

The purpose of the scenarios presented here was to explore the range of surge cuts and their effect on the post step down even flow harvest level and other indicators. These scenarios have constraints to mimic the model formulation used in the last DFMP.

6.6.3 Results

The harvest level associated with different surge levels and lengths of time can be seen in Table 6-18. Figure 6-6 shows that when the surge cut length was 10 years there was very little effect on the post step-down harvest level irregardless of the percent increase in the surge cut tested. When the length of the surge cut was 20 years it can be seen the post step-down harvest level was more sensitive to the percent increase of the surge cut. The maximum surge cut over 20 years that does not violate the 10% post surge dropdown was approximately 75%. While none of the 10 yr surges violate the 10% dropdown effect. There was an increase the amount of deciduous volume harvested from the forest as the surge level and length increased.

There was a direct relationship with the surge length and level and the growing stock (Figure 6-7). The higher and longer the surge the quicker the growing stock was liquidated from the forest. The minimum growing stock was somewhere between 65 and 90 years depending on the scenario. The 75% and 100% surges for 20 years increase the growing stock on the landbase for the final 100 years, which can be explained by the lower post step down harvest level.

Table 6-18. Harvest levels from the surge cut scenarios targeting MPB stands.

			Harvest Volume (m³/yr)					Change in Harvest Level		
Scenario	**Surge %**	**Years**	**Years**	**Conifer**	**Years**	**Deciduous***	**Total**	**Conifer**	**Deciduous**	**Total**
Sun_W2130	0	0	2007-2206	431,501	2007-2026	49,340	480,841		Baseline	
					2027-2206	11,986				
Sun_W2131	125	10	2007-2016	538,750	2007-2026	49,340	588,090	125%	100%	122%
	(of 431,000)		2017-2206	431,125	2027-2206	11,976	480,465	100%	24%	100%
Sun_W2132	125	20	2007-2026	538,750	2007-2026	49,538	588,288	125%	100%	122%
	(of 431,000)		2027-2206	429,483	2027-2206	11,930	479,021	100%	24%	100%
Sun_W2133	150	10	2007-2016	646,500	2007-2026	49,827	696,327	150%	101%	145%
	(of 431,000)		2017-2206	430,438	2027-2206	11,957	480,265	100%	24%	100%
Sun_W2134	150	20	2007-2026	646,500	2007-2026	71,272	717,772	150%	144%	149%
	(of 431,000)		2027-2206	422,317	2027-2206	11,731	493,589	98%	24%	103%
Sun_W2135	175	10	2007-2016	754,250	2007-2026	54,703	808,953	175%	111%	168%
	(of 431,000)		2017-2206	428,851	2027-2206	11,913	483,553	99%	24%	101%
Sun_W2136	175	20	2007-2026	754,250	2007-2026	125,430	879,680	175%	254%	183%
	(of 431,000)		2027-2206	392,865	2027-2206	10,913	518,295	91%	22%	108%
Sun_W2137	200	10	2007-2016	862,000	2007-2026	72,610	934,610	200%	147%	194%
	(of 431,000)		2017-2206	424,289	2027-2206	11,786	496,899	98%	24%	103%
Sun_W2138	200	20	2007-2026	862,000	2007-2026	131,518	993,518	200%	267%	207%
	(of 431,000)		2027-2206	360,555	2027-2206	10,015	492,073	84%	20%	102%

*20 yr Average Harvest

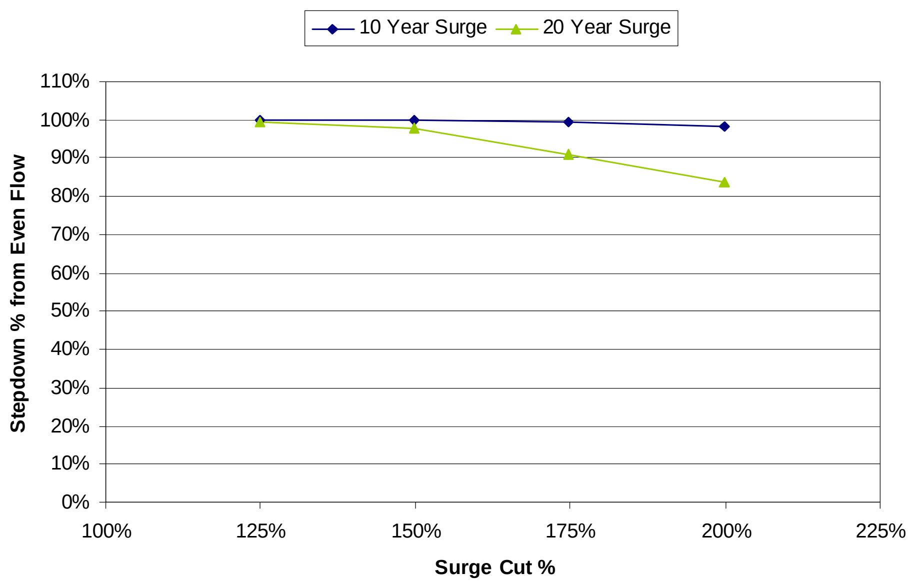


Figure 6-6. Surge cut even flow drop down percent by length and percent increase.

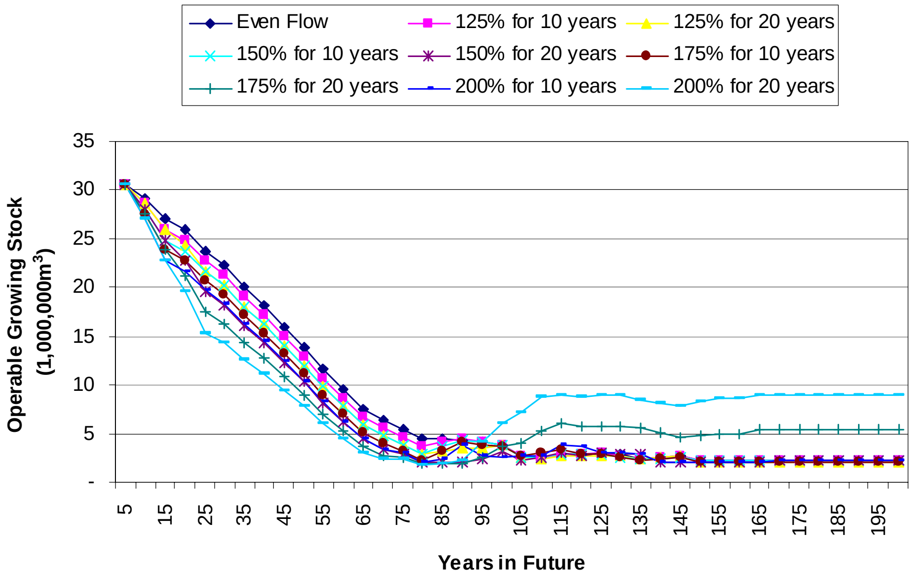


Figure 6-7. Growing stock levels given different surge levels and lengths.

There were minimal differences in the average harvest age in all scenarios. A higher and longer surge cut resulted in Sundance rated pine stands harvested from the landbase at a higher rate, though there was no target placed on the model in these scenarios to increase this rate.

The surge level and length affected the old growth area in 2 time periods in the planning horizon. With no surge cut, or smaller surge cuts, there was a larger amount of area that became old as it aged and was not cut from years 40 to 75. When the surge level was increased this area decreased as the model harvests more of the standing timber earlier. For the 75% and 100% surges over 20 years there was an increase in old growth at the end of the planning horizon.

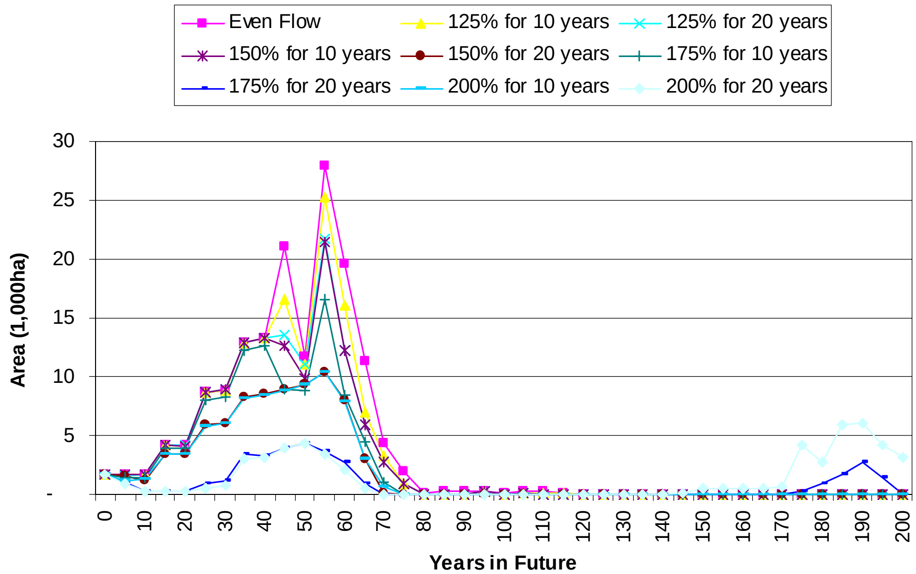


Figure 6-8. Old growth area on the managed length with different surge levels and lengths.

6.6.4 Discussion

Based on the results presented in the previous section, there was very little change when including surge cuts, up to 100%, for 10 years or 50% for 20 years. As the length of the surge cut increased to 20 years it was shown that there was an increased affect. The 100% 20 year surge would caused a decrease in the even flow level greater than the 10% allowed by the Planning Standard (version 4.1). The 75% surge for 20 years causes a dropdown of 9% therefore would be acceptable in terms of the harvest level drop down allowed by the planning standard.

For most of the surge levels, the indicators were very similar, or follow the expected trends. These expected trends being the increased rate at which the standing mature forest was harvested, which caused a quicker declines in growing stock, MPB susceptible stands, and Old growth area. Nevertheless, the 75% and 100% surge for 20 years caused an increase in the amount of Old growth towards the end of the planning horizon, related to the lower post surge step-down harvest level.

It is believed that the increased old in the 75% and 100% 20 year surges was caused by a pinch point in the timber supply at approximately 80 years, due to the increased harvest levels , which does not exist in the other scenarios. This pinch point was created when the mature timber from the landbase was liquidated and the regenerating timber has not reached the minimum harvest age. Figure 6-9 shows the shadow price values of the coniferous flow objectives. Shadow prices represent the change to the objective function (m^3/yr of coniferous harvest in this case) per unit changes to the constraint (even flow of coniferous volume). For example, if the shadow price value were 25, it would mean that relaxing the constraint by $1m^3$/yr, would increase the objective function by $25m^3$ and relaxing it by $2m^3$/yr would increase the objective function by $50m^3$. Therefore, in the even flow scenario the pinch point in the objective function was approximately 160 years in the future. As the surge cut increased, this point moves earlier in the planning horizon and became a larger number. This shows that the large surge cuts change the harvest dynamic of the forest. Alternatively, the negative shadow price values could be viewed as a slack in the system. In the case of this forest, there was a surplus of mature and over-mature timber, which could be liquidated without decreasing the even flow harvest level. This was what was seen in some of the lower surge runs. The high and long surge level runs the shadow price values were positive for the majority of the run length, showing there was very little slack in the system.

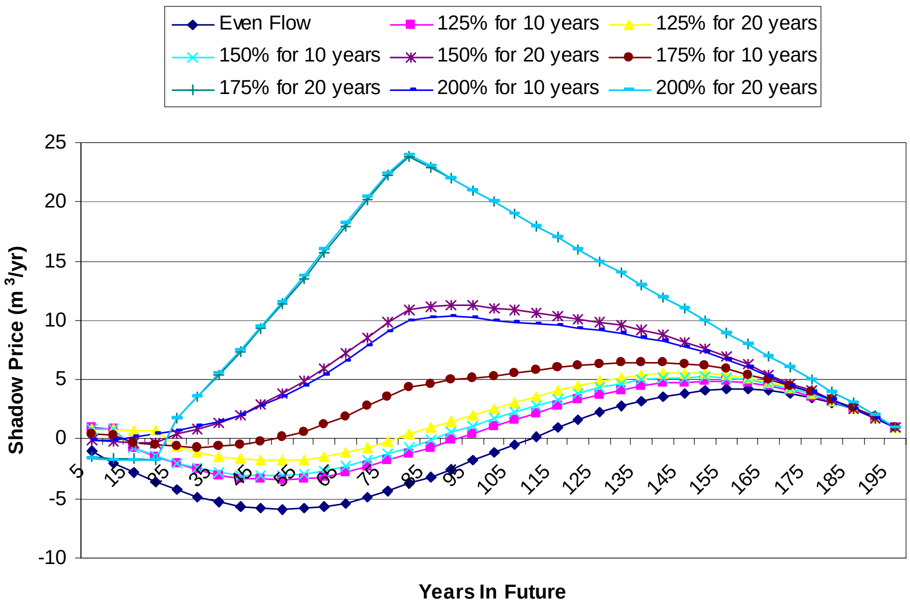


Figure 6-9. Shadow price of harvest flow constraint from surge cut runs.

6.6.5 Assumptions

The primary assumptions made were:

- Round 2 landbase,
- Round 2 Yield Curves,
- Maximize coniferous volume,
- Surge then even flow coniferous volume,
- Non-declining yield of coniferous and deciduous growing stock to the final 50 years,
- Ensure deciduous commitment for 20 years, and
- Ensure coniferous spatial commitments for 20 years.

6.6.6 Answer

It was decided to include a surge cut for 10 years at 100% of the post surge even flow dropdown level (Table 6-19). This level will reduce the biological and economic risks associated with the MPB. Subsequent FMP's can reassess the need for additional increases in harvest.

Table 6-19. Decision regarding surge cut levels and lengths for the Sundance TSA.

Decision Number	Decision Description	TFC Recommendation	Sundance Decision
1	Include Surge Cut		YES
2	If Yes to #1 Then Include for 10 years or Include for 20 years		 YES
3	If Yes to #1 Then Include a 25% surge or Include a 50% surge or Include a 75% surge or Include a 100% surge or Include a _______% surge		 YES

6.7 Planned Blocks

6.7.1 Question

Should planned blocks be included in the 2007 Sundance TSA?

6.7.2 Background

Sundance has a number of planned blocks and contingency blocks across the landbase. These blocks were in different stages of planning but resources have been put into their development. It could be assumed that the planned blocks were not the optimal model choices of blocks; therefore there would be a reduction in the objective function with the inclusion of the planned blocks. This will be tested to see the effect of including these blocks.

6.7.3 Results

Table 6-20 shows that the inclusion of planned block in the Woodstock model caused a decrease of approximately 1,250m^3/yr of deciduous harvest with no real affect on the coniferous harvest.

Table 6-20. Harvest levels with and without the inclusion of planned blocks.

Scenario		Years	Harvest Volume (m³/yr)			Change In Harvest Level		
			Conifer	Deciduous*	Total	Conifer	Deciduous*	Total
Sun_W2108	No Planned Blocks	2007-2206	422,670	50,592	473,261		Baseline	
Sun_W2109	Planned Blocks	2007-2206	422,661	49,340	472,001	(9)	(1,252)	(1,260)

6.7.4 Discussion

Given the time invested in planning the blocks and the small cost of their inclusion in terms of harvest level it was recommended that they be included in the model.

6.7.5 Assumptions

The primary assumptions made were:

- Round 2 landbase,
- Round 2 Yield Curves,
- Maximize coniferous volume,
- Even flow coniferous volume,
- Non-declining yield of coniferous and deciduous growing stock to the final 50 years,
- Ensure deciduous commitment for 20 years,
- Ensure coniferous spatial commitments for 20 years,
- Ensure 2.5% old growth for the final 100 years (>=50% for C or CD types), and
- Goal to remove all Sundance Ranked MPB in 10 years.

6.7.6 Answer

It was decided to include planned blocks in the PFMS (Table 6-21).

Table 6-21. Decision on planned block inclusion in the Sundance TSA.

Decision		TFC	Sundance
Number	Description	Recommendation	Decision
1	Include Planned Blocks	Yes	YES

6.8 Patch Targets

6.8.1 Question

Should patch targets be included in the Sundance TSA?

6.8.2 Background

Timber supply analyses historically did not include a spatial planning component in the initial planning. The spatial planning occurred subsequent to AAC calculations and was done by foresters. This type of planning did not necessarily link the harvest back to the TSA. Other issues resulting from this sequence of planning include timber isolation and harvesting stands with higher quality wood while stands with lower quality wood was ignored even though all volume from the landbase was used to calculate AAC. Recently, has become increasingly important to create large continuous old forest patches to reduce forest fragmentation. Spatial planning becomes essential to meet these continuous old forest patch goals.

There were two sets of patch targets that were analysed for inclusion in the TSA model. The first was related to opening patches. It was desired to create an opening patch distribution similar to a natural distribution. A negative exponential distribution where there were numerous smaller patches, with a few larger patches was used to achieve this natural distribution. There were 4 targets included in these targets; first 0% of opening patches under 2ha for operational reasons; second 76% of patches between 2 and 100ha; third 19% of patches between 100 and 1000 ha; finally a target of 5% of patches greater than 1000 ha.

The second patch target group analyzed was on the old forest patches. Many species require large old forest patches on the landbase. Therefore it was desired that the old forest on the landbase was aggregated to create large patches where ever possible. A 120 ha patch target was included in the model to combine these old forest patches. As the TSA landbase did not include seismic lines or some linear features. Therefore, these features did not create breaks in the old forest patches. This was not perceived as an issue because linear features greater than 8 meters wide were needed to create these breaks in the model.

All patch targets were placed on the gross landbase. Generally, wildlife and humans regard opening patches to be continuous regardless of the openings being on the gross or managed landbase. Therefore, a block next to 5 year old fire would be considered as one opening patch by most people and animals. Also it was possible to join managed and gross landbase patches to create larger old patches on the landbase than would be possible on the managed or unmanaged landbase individually.

Two scenarios were used to test the effect of adding the above two constraints into the Patchworks model. They were Sun_P2001 as a baseline and Sun_P2003, which included the patch targets. Historically it has been found that Patchworks was able to improve shape metrics with small costs on other indicators.

6.8.3 Results

The inclusion of patch targets into the patchworks model decreased the coniferous harvest level by a small amount during the surge cut, and a slightly larger amount for the remainder of the planning horizon Table 6-22. The deciduous harvest level increase throughout the planning horizon with the inclusion of patch size targets.

Table 6-22. Harvest level results from patch size sensitivities.

			Harvest Level (m^3/yr)			Change in Harvest Level (m^3/yr)		
Scenario		**Year**	**Conifer**	**Decid**	**Total**	**Conifer**	**Decid**	**Total**
Sun_P2001	No Spatial Constraints	2007-2016	839,902	71,463	911,365		-- Baseline --	
		2017-2206	419,894	53,534	473,428			
Sun_P2003	Patch Size Constraints	2007-2016	839,060	84,947	924,007	(842)	13,485	12,643
		2017-2206	418,516	57,889	476,405	(1,378)	4,355	2,977

Additional to the change in harvest level shown there was an increase in the amount of old on the landbase with the inclusion of patch targets. The average area of old forest on the managed landbase increased by 628 hectares by adding patch targets.

6.8.4 Discussion

It was shown that the coniferous harvest level decreases a small amount with the inclusion of patch targets. The deciduous harvest level, which does not have a binding constraint in these scenarios increases substantially with the inclusion of patch targets. The changes to the harvest level were largely the result of the opening patch targets on the model. These changes were caused by the model choosing more deciduous and mixedwood stands in the sequence to ensure the block shapes met the patch targets. Though there was a decrease in the coniferous harvest level through the inclusion of the patch target, this method creates a more operationally feasible sequence. Therefore it was recommended that the patch targets be included in the TSA.

The inclusion of an old patch target also negatively affects the coniferous harvest level to a small degree, though it increases the area of old in patches greater than 120 hectares on the landbase (Figure 6-10). Therefore, for the small decrease in harvest level and large increase in large old patches on the landbase it was recommended that an old patch target be included in the TSA.

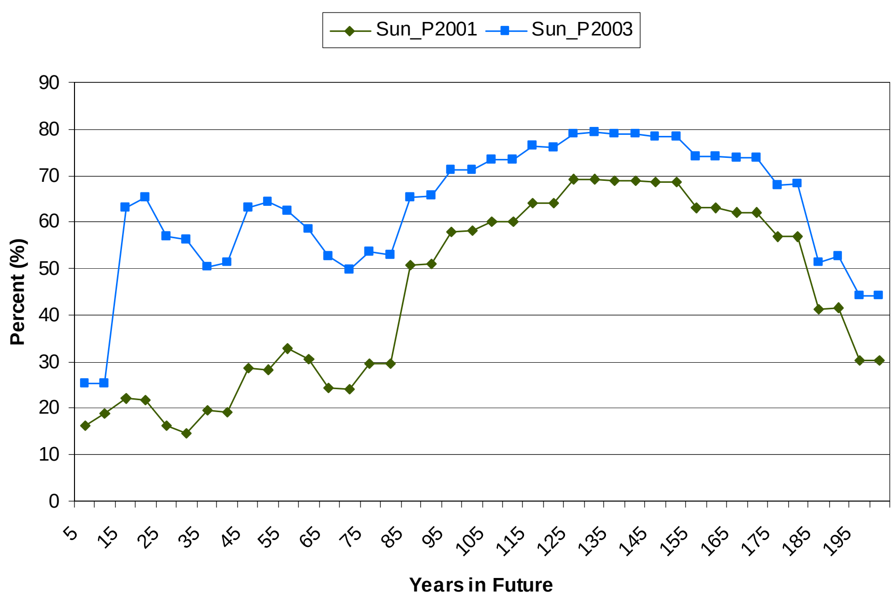


Figure 6-10. Percent of old growth area in patches greater than 120 ha in size from selected scenarios.

6.8.5 Assumptions

The primary assumptions made were:

- Round 2 landbase,
- Round 2 Yield Curves,
- Maximize coniferous volume,

- 10 year surge with subsequent even flow coniferous dropdown,
- Minimum coniferous and deciduous growing stock throughout planning horizon,
- Ensure deciduous commitment for 20 years, and
- Ensure coniferous commitments for 20 years.

6.8.6 Answer

Table 6-23. Patch target decision for use in the Sundance TSA.

Decision Number	Decision Description	TFC Recommendation	Sundance Decision
1	Include Opening Patch Targets		YES
2	Include Old Patch Targets		YES

6.9 Other Spatial Constraints

6.9.1 Question

Should roads be included in the Sundance TSA?

6.9.2 Background

The building and maintenance of roads is a major expense associated with harvesting as well as having a large negative effect on fragmentation. Throughout Alberta, there is an ever-expanding road network associated with oil and gas exploration and timber harvesting. For these reasons Sundance wishes to, where possible, avoid building new roads on the landbase while achieving the other indicators.

Patchworks has the ability to include road building, maintenance and haul costs into the model. This adds the ability to create more economically and operationally feasible scenarios. Build costs in Patchworks represents the cost of a road built from an existing road to the polygons harvested. Once a road was built by Patchworks it exists for the duration of the planning horizon. Maintenance costs were used by Patchworks whenever volume was hauled over a segment of road, this does not include any cost of upkeep on roads that were not being used for hauling. Patchworks does not have the ability to deactivate roads.

Two scenarios were created, one with road building and maintenance costs (Sun_P2002) and one without (Sun_P2001). It has historically been seen that roads can create more acceptable sequences with minimal effects on other indicators in the model. The costs used in this model were theoretical, and should not be seen as true values, but as a mechanism to control model behaviour.

6.9.3 Results

Adding roading costs to the spatial modeling caused a negligible decrease in the coniferous harvest level. There was a decrease in the short-term deciduous harvest, but it was still significantly above the required harvest level (Table 6-24).

Table 6-24. Harvest levels from selected runs with and without roading costs.

Scenario		Year	Harvest Level (m^3/yr)			Change in Harvest Level (m^3/yr)		
			Conifer	Decid	Total	Conifer	Decid	Total
Sun_P2001	No Roading Costs	2007-2016	839,902	71,463	911,365		-- Baseline --	
		2017-2206	419,894	53,534	473,428			
Sun_P2002	Roading Costs	2007-2016	839,752	70,147	909,899	(150)	(1,316)	(1,466)
		2017-2206	419,836	55,883	475,719	(58)	2,349	2,291

Adding the roading costs, when there was no target on MPB removal decreased the rate of Sundance rated pine removal from the landbase. Additionally, the build costs changed between the two scenarios (Figure 6-11). Other than the above stated differences the other indicators were consistent in both scenario.

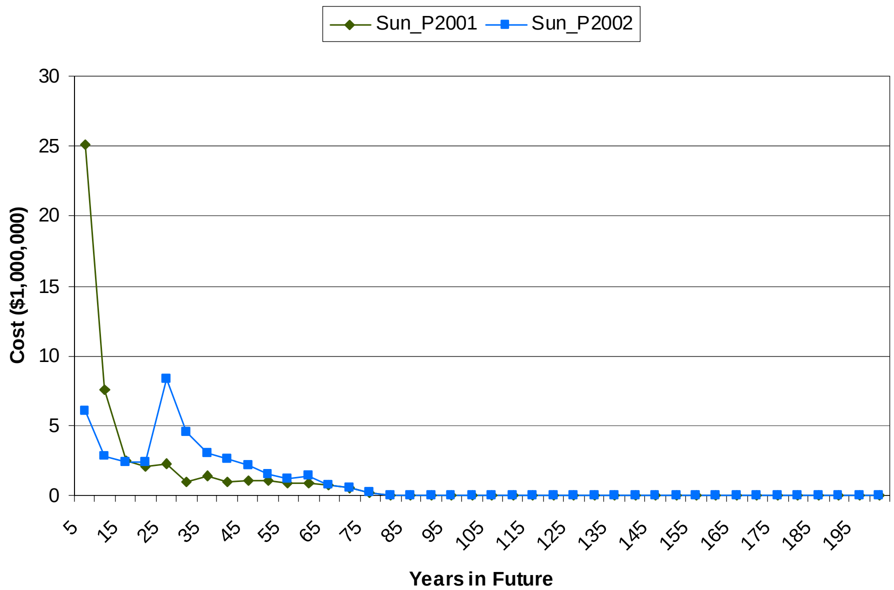


Figure 6-11. Roading building costs based on theoretical road cost data.

6.9.4 Discussion

The inclusion of roads in the Patchworks model had very little effect on the indicators, other than the build costs. This changed the location of blocks on the landbase, by bringing them closer to the roads. This aligns with Sundance's desire to not build permanent all weather roads during the first 10 years of the SHS. Patchworks, when unconstrained, tends to build large quantities of roads early in the planning horizon, as seen by the high build costs in the base scenario. The constraint placed on the model spreads the build costs out over a longer period of time, a more operationally feasible solution. Therefore, for the small cost in terms of harvest, and the increased operational feasibility it was recommended that roads be included in the TSA.

6.9.5 Assumptions

The primary assumptions made were:

- Round 2 landbase,
- Round 2 Yield Curves,
- Maximize coniferous volume,
- 10 year surge with subsequent even flow coniferous dropdown,
- Minimum coniferous and deciduous growing stock throughout planning horizon,
- Ensure deciduous commitment for 20 years, and
- Ensure coniferous commitments for 20 years.

6.9.6 Answer

It was decided that due to the increased operational feasibility of the roading scenarios it was decided that roads would be included in the TSA (Table 6-25).

Table 6-25. Decision regarding use of roads in the Sundance TSA.

Decision		TFC	Sundance
Number	Description	Recommendation	Decision
1	Include Roading Targets	Yes	YES

7. Conclusion

Sundance was required to undertake a TSA as part of the 2007 FMP. The TSA required the development of a large number of inputs and assumptions. Many of these had sensitivity analyses run on them to test the sensitivity of the timber supply model to changes to the inputs and assumptions. There were additional sensitivities completed to test the effect of constraints on the timber supply model. These above discussed sensitivities allowed the stakeholders in the FMP process to make informed decisions regarding the direction of the TSA. These decisions, inputs, and constraints were all brought together with operational considerations in a Patchworks scenario to create a PFMS.

The relative weights of the inputs for this timber supply analysis were assessed and adjusted as the timber supply runs were completed. The focus was on developing a spatial harvest sequence that would reduce the amount of susceptible pine on the landbase as much as possible while still meeting timber supply commitments and producing a non-declining growing stock in the future. Old growth, interior forest and patch size targets were also incorporated to meet ecological objectives over time. Road costs were included to reduce fragmentation of the landbase as well as operational costs. The end result was a spatial harvest sequence concentrated in pine stands that will address the present threat of mountain pine beetle and still provide a future forest that meets timber supply and ecological objectives.

The PFMS includes a 20 year SHS which Sundance will follow until the next TSA is completed. This PFMS balances all of the values of the forest to the best of the models ability given current forest management issues, and the goals of the forest managers and stakeholders involved in the planning process. The PFMS included a surge cut which targets the removal pine, which is at risk of MPB attack, to reduce the impact of this attacks in terms of biological and economic value. The PFMS harvest level of coniferous volume from 2007 to 2016 is 841,666m^3/yr and the deciduous harvest level is 60,041m^3/yr for the same period.

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