Canadian Forest Products Ltd.
Grande Prairie Operations

Growth and Yield Monitoring Program

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1 Introduction

Canadian Forest Products (Canfor), Grande Prairie, is interested in developing a Growth and Yield Monitoring Program for monitoring and validating natural and regenerated stand yields on its Forest Management Agreement (FMA) area. The “Growth and Yield Monitoring Program” report prepared by Olympic Resource Management (ORM) in July 2000 provides the foundation for development an implementation framework for such a program. The purpose of this document is to describe the implementation framework required for the long-term success of the Growth and Yield Monitoring Program (GYMP) on Canfor’s Grande Prairie FMA area.

1.1 Scope of The Project

This report is intended to provide a vision of the Growth and Yield Monitoring Program and how the program can help Canfor address the various initiatives, plans and regulations that affect its FMA area. Short-term needs, such as the methodology for monitoring yield forecasts in the Detailed Forest Management Plan (DFMP) and Sustainable Forest Management Plan (SFMP) will be addressed. Ongoing long-term requirements for improving and monitoring yields will also be addressed, along with an analysis of the general data requirements for both short- and long-term needs.

1.2 Background

It is true -- "The only constant these days is change." Monitoring change has become one of the core concepts supporting the evolving principles of sustainable forest management. Criteria and indicators of sustainable forest management are being worked out at international (e.g., Kyoto), national (e.g., Montreal), provincial and local/licensee levels. The Alberta Forest Legacy frames the government's vision for sustainable, ecologically based forest management in the province. Canfor's own Forest Principles echoes many of the same fundamental concepts, and both include a strong emphasis on monitoring.

New provincial policies and standards are already reflecting this emphasis on monitoring. The controversial reforestation policies announced by Alberta’s Land and Forest Service (LFS) in March 2000 include the beginnings of the expanding monitoring framework. The companion paper *Implementation Framework for Enhanced Forest Management (EFM) in Alberta* indicates the government expects licensees to substantially increase their monitoring efforts in exchange for claiming allowable cut effects (ACE) under an EFM program. Monitoring also plays a prominent role in Canfor’s Sustainable Forest Management Plan recently developed in conjunction with ORM and approved in fulfillment of the requirements for certification under the Canadian Standards Association (CSA) Sustainable Forest Management System Standard CAN/CSA-Z809-96. Canfor manages to and/or complies with these various standards, policies and initiatives in its proactive effort to maintain both its "regulatory" and "social" licenses to cut.

1.3 What is Monitoring?

In 1994, the International Union of Forestry Research Organizations (IUFRO) released international guidelines for forest monitoring and set forth the following definition:

"*The periodic measurement or observation of selected physical, chemical, and biological parameters for establishing baselines and for detecting and quantifying changes over time*."

This definition is intentionally broad. It is meant to encompass the entire range of resource values including growth and yield, biodiversity, habitat, carbon sequestration, etc. IUFRO also emphasizes that the development of monitoring strategies should always begin with a needs-assessment to define the purpose and scope. Although it sounds trite, the information collected must be able to address the questions at hand – this takes planning and forethought.

The IUFRO definition focuses on physical or biological "change monitoring". Sustainable forest management rests on our ability to predict, to some degree, the future forest conditions resulting from various management plans and practices. Monitoring provides the necessary feedback on those predictions, and supports adaptive management – another core concept supporting the practice of sustainable forest management.

Of course, monitoring can apply to more than just physical or biological change over time. The concept of monitoring can be applied to management plans and activities, as well. A plan represents intended (predicted) activities, which can be monitored for implementation (e.g., hectares planted) as well as outcome (e.g., acceptable stocking).

The practice of sustainable forest management within a profitable forest company requires a holistic monitoring program that is well integrated with management practices and data systems. The goal of such a system would be production of effective and regular "report cards" to help guide and adjust forest plans and practices.

Monitoring is generally required at different scales for different purposes.

1. National level – for international environmental accords and initiatives, and to maintain world market access for Canadian products in general. The new National Forest Inventory (NFI) addresses monitoring at this scale.

2. Provincial level – no unique monitoring efforts are currently envisioned at the provincial-level. The Alberta government will rely on NFI data and roll-up summaries of FMA area and regional data (DFMPs, Alberta Vegetation Inventory [AVI], etc) for provincial-level reporting and monitoring.

3. FMA area-level – Canfor is only indirectly associated with national- and provincial-level monitoring, but it bares full responsibility for implementing monitoring at the FMA area-level to address regulatory, resource management and certification issues. Issues such all provide specific monitoring needs at the FMA area-level.

   A whole host of issues drive Canfor's monitoring efforts including:

   - Canfor's Forest Principles
   - Alberta Forest Legacy
   - The FMA area's DFMP
   - ACE under EFM
   - CSA certification
   - Corporate profits

There are several rationales for choosing to implement a monitoring program. Monitoring is an integral component of the Canadian Standards Association certification program, and therefore a monitoring program is required in Canfor's Sustainable Forest Management Plan for fulfillment of the requirements for forest certification. Monitoring is also important as an audit process, improving the ability of government (as representative of the public) and forest companies (as a component of internal audit processes) to establish whether defined goals have been met by management practices. A rigorous monitoring program encourages public acceptance and lends credibility to the pursuit of more flexible forest management, and provides an alternative to a rigid regulatory framework. Finally, a monitoring program is a required component when designing an adaptive management plan. If an adaptive management approach is to be applied correctly, a monitoring program is a necessary component that enables the assessment of how actions actually affect key indicators. This information then permits evaluation of the effectiveness of alternative actions, adjustment of hypotheses, and enables correction of actions. Monitoring can also determine if actions were implemented as planned, and may detect unexpected events

Within the general context of forest management, there are two types of monitoring:

1. **Forest resource monitoring**: this refers to the physical and biological characteristics of various forest resources and their attributes. This includes ecological and habitat values, plus spatial distribution of timber types and growth and yield. Objectives focus primarily on monitoring <u>predictions</u> of future forest conditions found in plans (e.g., DFMP yield tables, SFMP, EFM, etc) and <u>performance</u> against these plans and regulatory standards (reforestation standards, etc).

2. **Forest activity monitoring**: this entails tracking forest management activities to ensure they take place as planned. In addition to resource intervention activities (e.g., harvesting, planting, etc), this also includes all the planned data collection and data management activities which support decision making, including monitoring.

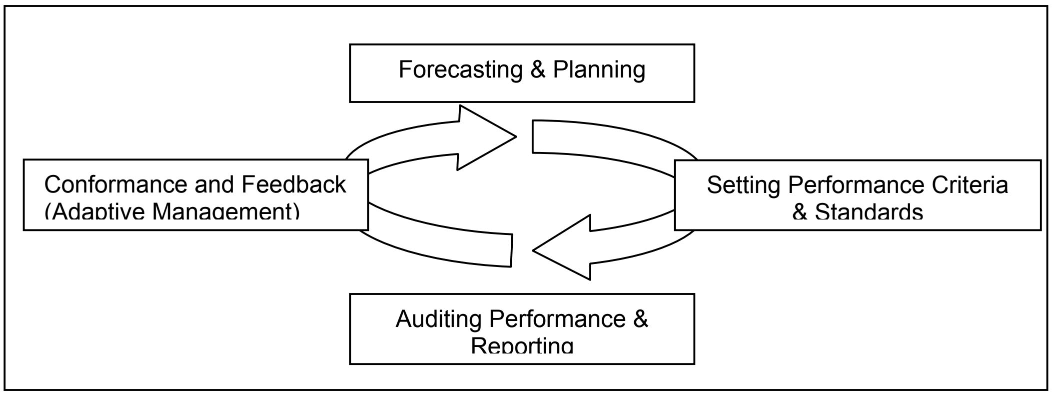
2. Growth and Yield Monitoring

Growth and yield monitoring is just one subset of forest resource monitoring. It can be defined as the process of observing the growth and yield of a forest and comparing this with the predicted growth and yield of that forest to assess the risk and uncertainty around predictions (BC Growth and Yield Monitoring Task Force, 1997)

2.1 Aspects of Growth and Yield Monitoring

Figure 1

Generalized Monitoring Cycle



Forecasting is the process of projecting yields. Yield tables or yield curves provide the projections for each stand or yield group (stratum). Within a growth and yield framework, scientifically valid and statistically defensible growth and yield models form the basis of credible forecasts of yield in natural and regenerated stands.

Performance standards are a set of pre-determined, measurable, conditions that must be realized in order to place stands on the forecasted yield trajectory (yield curve), thereby maintaining confidence in harvest yield projections.

Auditing involves sampling stands to compare actual performance against the predetermined performance standards. This process relies on statistically validate sampling in order to provide defensible estimates to indicate whether predicted yields are expected to be attained. Some form of reporting is needed to compile and document the audit results in a format that facilitates effective evaluation.

Conformance completes the monitoring cycle and provides feedback in support of the next planning cycle. Information from a well-designed monitoring program can also become a key component of an adaptive management program.

2.2 Fundamental Questions of Growth and Yield Monitoring

There are two fundamental types of questions that traditional growth and yield information is used to address:

- Land base (inventory) questions: How much wood is available today and in the future? Change in the standing inventory is the primary focus. Depending on specific needs, this may utilize static data (e.g., AVI, Temporary Sample Plots [TSP]) or change data (e.g., growth, Permanent Sample Plots [PSP]) data and it often involves examining interactions with other resources (e.g., age-class distributions and caribou habitat). The important distinction is that inventory estimates are singular estimates that incorporate the inseparable, cumulative effects of all management practices and natural processes combined.

- Treatment (silviculture) questions: What responses can we expect, or have we experienced, from various management practices? How will they affect our investment decisions and future wood supply? Treatment response is the primary focus. Response implies two yield estimates, in essence, one for the treated plot and one for that same plot had it not been treated. In the case of two or more separate plots (treated and untreated), normal variability within stands makes it virtually impossible to separate treatment response from the background noise of natural variation without intensive (expensive) experimental designs (randomization and replication).

The two types of questions require fundamentally different forecasting, monitoring and data collection procedures. Both types of information are needed to address the full range of Growth and Yield-related management issues. However, the unique aspects of these two types of information are often confusing. Management prescriptions are built on the expectations of individual practices. Response expectations for individual practices can be derived from practical experience, expert opinion, experimental data and/or decision support tools (models) that integrate these information sources. The expense of installing and maintaining experimental programs makes them an attractive focus for co-operative ventures. The knowledge of treatment response can be used in silviculture investment analysis, broad based strategic planning, stand prioritization and strategic crop planning.

Our inability to monitor treatment response at a broad operational level is a major source of frustration to silviculturists. At an extensive operational scale, we can only monitor our forecasted yields, not response. While our yield forecasts incorporate response predictions, these responses cannot be teased out, after-the-fact, from extensive operational monitoring or inventory data.

2.3 Linkages

Growth and Yield monitoring addresses a special aspect of monitoring for Canfor. There are several, often inter-linked monitoring areas that must also be addressed. This can only be achieved with the development of an *overall monitoring strategy*. For example, wildlife habitat monitoring and growth and yield monitoring is linked by the need of projecting timber attributes over time for habitat suitability index modeling (e.g., large diameter poplar trees are a key habitat component for pileated woodpecker).

2.4 Data Requirements

Monitoring data must come from an independent data source that was collected in a statistically defensible way.

One cannot use a data set to develop growth and yield models and then validate the model based on the same information. As most analyses of growth and yield monitoring data revolve around hypothesis testing, it is imperative that the sampling design and analytical methods are statistically sound.

It is very important to distinguish between collecting data *to develop* growth and yield estimates and collecting data *to monitor* growth and yield estimates. Making this distinction is important because it can translate into different data collection strategies. For example, to examine the amount and distribution of timber volume on the FMA area, procedures have been developed for detailed sampling within the Alberta Vegetation Inventory. Audit sampling may be used to check timber volumes. Each of these sampling strategies was developed to answer two different questions. Alone, the audit plots are sufficient to answer audit questions, but the data collected would be insufficient for inventory purposes.

Consistency in field data collection, measurement and compilation protocols will ensure the success of long-term monitoring. Changing definitions over time may result in faulty conclusions based on 'apples to oranges'.

Compatibility in sampling design and/or data collection protocols is desirable as data sharing agreements between various companies and government becomes increasingly common.

There are two major kinds of statistical designs that are commonly used in monitoring:

- Stratified random sampling and
- Systematic design (Continuous Forest Inventory [CFI]-type sampling).

Stratified random sampling is based on pre-defined strata that generally involve ecological and/or yield-group classifications. In theory this would provide a more balanced sampling of the different strata, however, natural succession and forest management practices cause these strata to “move around” the landscape (FMA area) over time. Consequently, the initial sampling scheme will not be maintained over time, plots will have to be dropped and established to maintain the intended sample distributions. This approach is not considered appropriate for long term monitoring. Canfor’s PSP data is based on this type of stratified sampling design.

The alternative sampling design based on the systematic placement of fixed sample points is arguably the better approach to take in a monitoring program since the target population (FMA area) is defined in geographic terms. A random (systematic) network of PSPs will continue to represent the target population over time and the distribution of sample points will always be appropriate (sample sizes proportional to area). Post-stratification of the plots takes place at the analysis stage. The major disadvantage of this sampling design is that rare growth strata will likely be poorly represented in the FMA area. It is also recognized that the number of plots that may fall in young stands (regenerated PSPs) during a given time period (e.g., ten years) will not provide sufficient sample size for monitoring purposes. The latter could be addressed by temporarily increasing the sampling intensity while retaining the sampling grid. The systematic design also provides a common platform for long-term monitoring of non-timber attributes and it provides the potential for linkage to higher-level (provincial, national) monitoring programs, like the NFI.

2.5 Model Requirements

The discussion paper on the *Implementation Framework for Enhanced Forest Management (EFM) in Alberta* outlines broad expectations about growth and yield models. The following list is intended to be a guideline for the Growth and Yield Monitoring Program:

- Model is biologically realistic and consistent with established theories of growth and yield;
- Functional form is published;
- Statistical properties and error should be evaluated and known;
- Model results are validated against independent data sets;
- Data range used to fit the model is published;
- Major model assumptions are identified;
- Model is peer-reviewed; and
- Whenever applicable, the model is consistent with the Alberta ecological classification framework.

3. Implementation Framework

One of Canfor's key goals, as described in "Canfor's Forestry Principles", is to use "forest ecosystem management…that forecasts the future condition of forests". Implicit within this statement is the requirement to establish monitoring programs for the variety of components required to assess forest condition. Forecasting future conditions is directed by a number of elements including:

- Establishment of baselines and the natural range of variation for ecosystems;
- Projection of potential future forest conditions within the range of natural variability;
- Ongoing measurement and monitoring of key indicators;
- Ongoing research to validate assumptions and to test new ones;
- Continuous checking of practices and continual improvement of practices and strategies when required.

An effective monitoring program will incorporate these elements and facilitate the long-term management of the forest. The monitoring program will have to be transparent. The defined analytical processes must be repeatable and well documented.

Figure 2 shows how monitoring fits into the overall framework and process of adaptive management. Figure 2 also illustrates the steps and feedback mechanism of a performance monitoring program fits within the context of the DFMP and SFMP. The timber flow policy and regeneration strategies adopted in the DFMP reflect the management objectives agreed upon for the forest area. Growth rates of stands may have implications on Annual Allowable Cut (AAC) but they are only one factor. At the forest-level, the AAC is not a simple summation of stand-level growth. Other factors such as spatial constraints (adjacency, green-up rules), age class gaps, and the consideration of non-timber values (e.g. biodiversity) have considerable effects on the AAC.

The general objectives of any monitoring framework are:

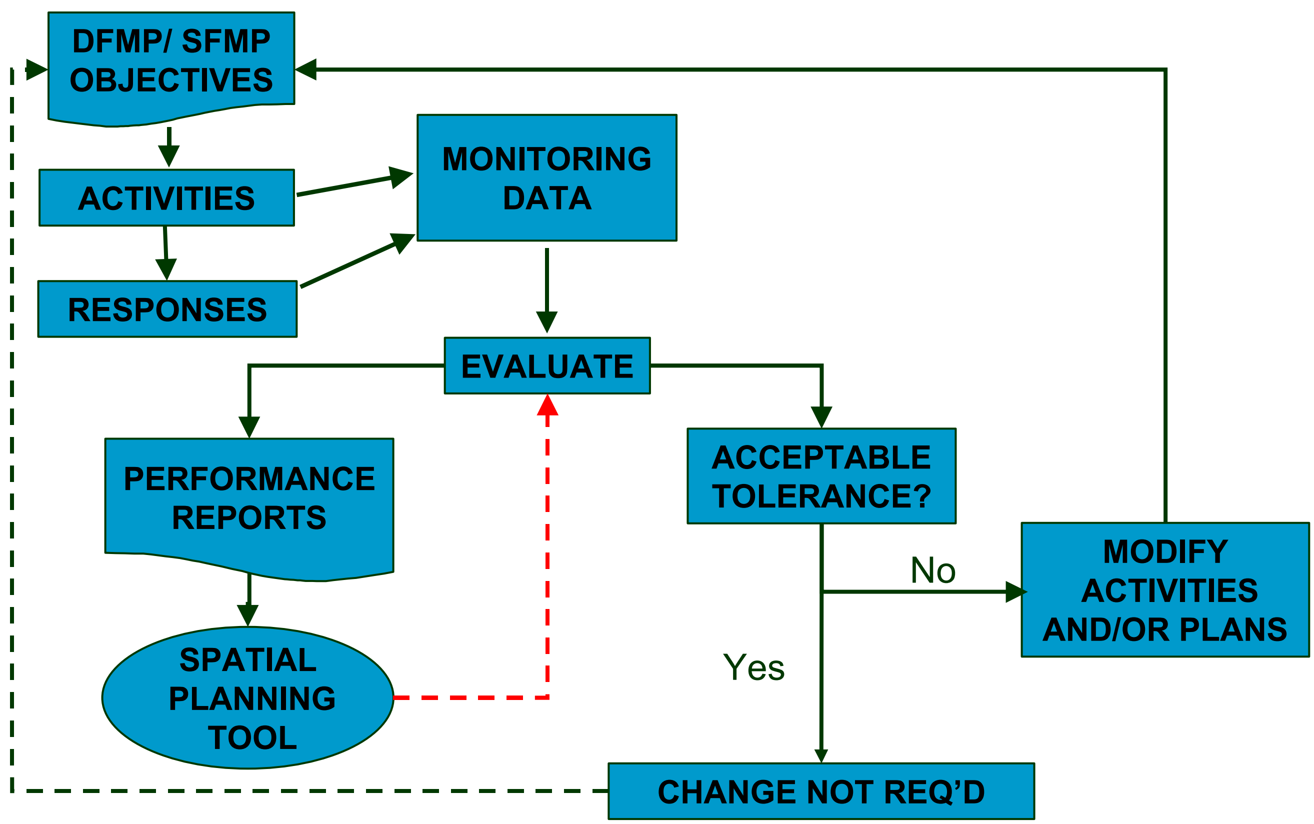
- To detect change in various criteria from pre-defined standards across spatial and temporal scales, for attributes such as timber, habitat, total productive land, etc;
- To provide reports on the status of these attributes on a regular basis;
- To meet regulatory and corporate commitments for establishing monitoring programs;
- To provide data for assessing and improving sustainable forest management activities.

The DFMP describes the timber flow policy and regeneration strategies defined by the objectives established for the FMA area. Data collected from the pre-defined management activities and their outcomes are monitored and analyzed. Performance reports can be generated on a defined reporting cycle, which summarize the planned and actual outcomes for any number of performance indicators. Reporting may coincide with the SFMP Annual Performance Report or with the five-year Forest Stewardship Report (DFMP).

Performance report cards can be used to assess conformance with the original performance standards identified in the DFMP. Management activities and plans may or may not be modified, depending whether the performance results are found to be within the acceptable range of variability or not.

Figure 2

Implementation Framework for Monitoring



4. Technical Protocols

This section of the report describes the technical protocols and the analytical process for growth and yield monitoring. These technical protocols are built on the principles laid down in the Implementation Framework for Enhanced Forest Management in Alberta (March 2000).

The analytical procedures focus on monitoring change in timber attributes at the forest (FMA area) and yield group level. The analysis of change due to treatment response and the interactions of various management practices are not discussed here.

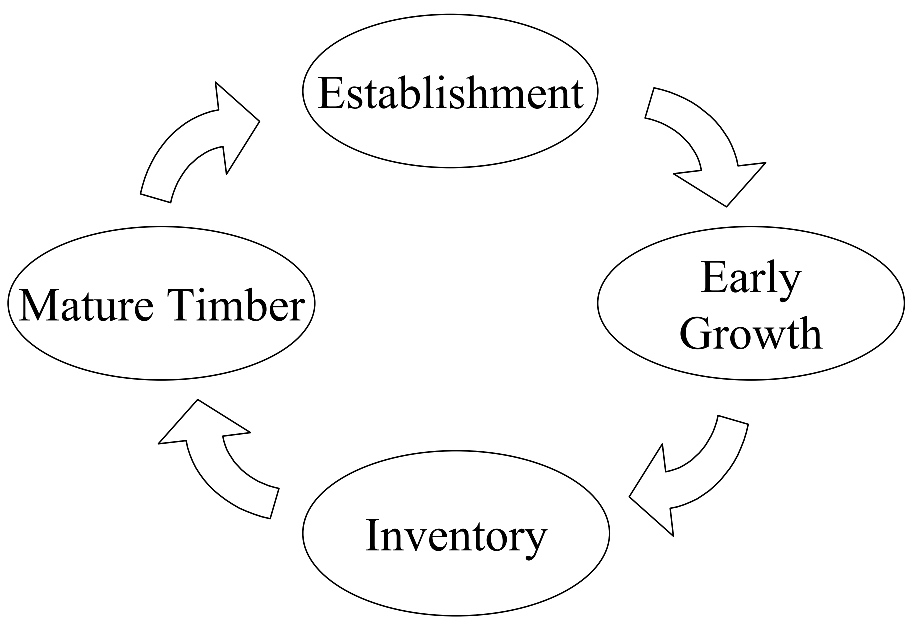
The analytical process and reporting must follow the principles of transparency and repeatability. Data and model requirements are discussed in Section 2.

4.1 The Four Phases of Stand Development

Data quality, the intensity of data collection, growth and yield variables and modeling techniques differ at various stages of stand development. The analytical framework is built upon four major phases stand development as shown in Figure 3.

Figure 3

Stand Development Lifecycle



Establishment Phase is the time period from harvest to the successful establishment of a new stand. Early Growth Phase spans from establishment to free to grow status (performance survey). These two stages are generally characterized by more intense data collection utilizing operational silviculture surveys that provide stand level performance monitoring. The characteristics of early stand development generally require unique modeling techniques for timber attributes (e.g. growth intercept models for juvenile site index modeling).

The Inventory Phase is a period from the time a particular stand becomes part of the general inventory. Silviculture updates may be carried out, but we often lose sight of each individual stand. This stage spans from the free to grow status to late stand conditions when the stand becomes 'visible' again during forest development planning (FDP). This stage is characterized by much broader and less intense data collection. Permanent and/or temporary sample plots laid out on a statistically defensible framework are collected as part of the monitoring process.

The Mature Timber Phase includes the period from FDP and timber cruising to actual harvest and analysis of check scale data for the block. In this stage, detailed information may become available from cruise data.

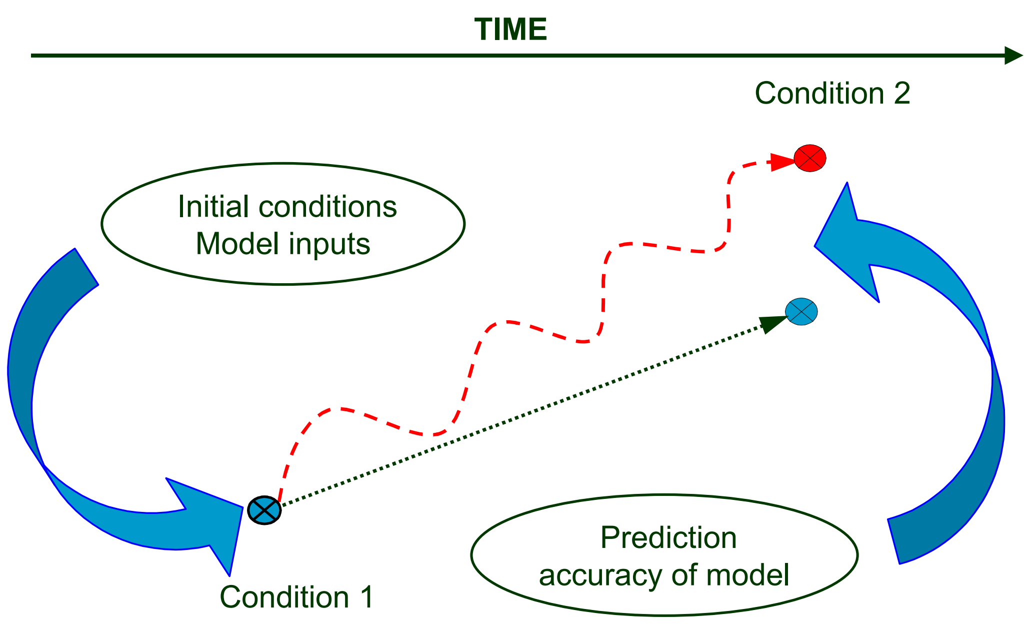
4.2 Analysis Framework

As defined earlier, growth and yield monitoring is the process of observing growth and yield of the forest and comparing this with our expectations (predictions) to assess the risk and uncertainty around predictions.

The principle sources of error in projecting change are the error in the initial stand conditions that are used as input to the models and error in the predictive ability of the models (Figure 4).

Figure 4

Sources of Errors in Monitoring



4.2.1 Analysis Techniques

Analytical techniques in growth and yield monitoring can be separated into three different categories. Static analysis focuses on ***one-time*** measurements of a single attribute (e.g. yield). Dynamic analysis evaluates the rate of ***change*** (e.g. growth). Interaction analysis examines the impact one variable may have on another (e.g. the influence of density on height growth).

Static Analysis

The static analysis looks at a snapshot of direct and indirect measures (Figure 5) collected from a statistically valid framework of PSPs, TSPs, growth intercept data and/or operational silviculture survey data; and compares them to performance standards (validation criteria) established during the DFMP process.

The comparison is done using statistical hypothesis testing at both the yield stratum and forest-level. The actual mean value of the selected direct or indirect measure for the FMA area, area-weighted by the stratum area, must be above or below the stratum area-weighted target value (validation criteria).

Dynamic (Change) Analysis

The dynamic analysis looks at the change in the direct and indirect repeated measures over time. Observed height and volume growth trajectories are compared to predictions from the height-age model and volume-age model. Trend analysis and the evaluation of average observed rate change versus predicted growth rate can reveal problems that static analysis cannot address. Significant deviations from expected growth rates might indicate serious shortfalls in yield 'down the road'. Minimum criteria must be defined to ensure that the risk of future problems is minimized.

Interactions

Interactions between certain measures such as site index and density can be analyzed. This is especially important in regenerated stands given the range of different starting densities and different levels of interspecific competition.

4.2.2 Direct vs. Indirect Measures

Unfortunately, not all growth and yield variables are directly available at all stages of a life of a stand. In very young stands, yield validation must rely on indirect yield comparisons including height, age (site index), density and years to reach breast height. Direct yield comparisons will only be possible once regenerated stands grow above merchantability thresholds, but indirect comparisons will still be needed to provide additional evidence that final harvest predictions will be attained. These direct volume estimates can be used to validate the DFMP yield estimates or estimates from other models.

Using indirect measures, like stocking proportion as a surrogate to predict future stand density, makes it necessary to constantly evaluate our models' ability to link early stand conditions to stand conditions at rotation age.

Figure 5

Indirect and Direct Measures

VARIABLES TO VALIDATE		
INDIRECT	Stratum Variables	Species Composition
		Density
	Predictor Variables	Site Index
		Years To BH
		Stand Height
		Age
DIRECT	Volume	Merchantable volume (15/10)

4.3 Data Sources

Many different data sources can contribute information to the growth and yield monitoring process:

- Temporary Sample Plots;
- Permanent Sample Plots;
- Operational Silviculture Surveys;
- Growth Intercept Data;
- Stem Analysis Data;
- Realized Gain Trials;
- Experimental Design Data; and
- Other

It is important to mention the difference in spatial and temporal scale of these data sources. The PSPs are fairly small, localized samples, offering a reasonable statistical representation over the area of the FMA area by yield group. They also provide growth and yield information over a longer timeframe through their re-measurement. Growth intercept information is somewhat static, providing an early 'snapshot' of site productivity and juvenile height growth. Operational silviculture surveys have the obvious advantage of providing average information for the entire cutblock. This information is important because it can be used to see how closely it relates to the growth and yield information derived from the other two data sources located in the same cutblock. Another advantage is that operational surveys do not incur additional costs to the company – they are a legislated requirement.

Realized gain trials and various data collected in controlled experimental designs are addressing the issue of separating the effects of treatments from the untreated expectations (treatment response questions).

In this section, independent data sets addressing inventory and landbase-related questions relevant to Canfor are discussed.

4.3.1 Permanent Sample Plots

The Permanent Sample Plot program is designed to provide up-to-date volume and growth information for the Management Area. This information can then be used to verify estimates of stand development obtained through forecasts developed from temporary sample plot data. Within the FMA area all PSPs are maintained, and those within a block to be harvested, will be reestablished after harvesting is complete (W.R. Dempster and Associates, November 1992).

PSPs were used in the validation of the growth and yield models. Information will be collected through re-measurements and additional plot allocation, which can be used in the validation of the growth and yield estimates in fire-origin and regenerated stands and to validate the assumptions made during the modeling process.

Preliminary analysis of the Permanent Sample Plots can be found in Appendix I. As PSPs will likely form an important part of the overall Growth and Yield Monitoring Program, more detailed analysis of the existing information gaps, data cleaning, data collection protocols will be necessary.

4.3.2 Growth Intercept Data

The models used to fit traditional height/age curves (site index) perform poorly in young stands. As an alternative, equations are developed to relate site index to the observed height growth that occurs for a given period above a reference height (e.g. 5 years height growth above 1.3 m). This height growth is referred to as growth intercept (GI).

In Alberta, the performance survey of regenerated stands is usually carried out 8 to 14 years after harvesting. It would be convenient if the site index of regenerated stands could be estimated at the time of the performance survey. However, as it may take from 6 to 13 years in pine and 9 to 20 years in a white spruce to reach 1.3 meters, therefore growth intercept models are usually not applicable at the time of the performance survey. In addition, because of the difficulty of actually identifying whorls in a field survey situation, alternative models predicting site index from total tree height and age at breast height were also developed. Juvenile Site Index models (JUSI) could be developed to deal with this problem.

4.3.3 Operational Silviculture Surveys

Operational Silviculture Surveys are carried out in accordance with the provincial Reforestation Regulations. The new Reforestation Regulations were legislated on March 2000. The regulations are currently under revision.

There are two different kinds of surveys, Establishment Survey (EST) and Performance Survey. For the Conifer and Mixedwood Standard, the EST needs to be conducted 4-8 years after harvest and the Performance Survey 8-14 years after harvest.

The EST determines if a new stand has been successfully established. The EST is also used to guide treatments needed to ensure that the stand continues to grow in a manner that will meet the standards of the Performance Survey. Key elements of the survey are stocking amount (percent), density (stems/ha) and height (cm) of crop trees and competition.

The Performance Survey is used to assess if established stands have continued to grow and are in a condition likely to mature into vigorous stands that will generate harvest volumes in accordance with predictions.

Regenerated stand forecasts at the sapling-seedling stage should logically be linked to stocking and crop tree heights as measured in establishment and performance surveys. Operationally, and from the regulatory standpoint, ***operational silviculture surveys are the first steps in benchmarking and validating expectations for regenerated stands***. Site index, species composition and crown closure classes are estimated using data collected at the time of the regeneration survey (preferably the performance survey).

4.4 Models

Stratification provides a means for reducing variability and thus data collection costs. Variables included in the yield group definition are generally not considered as independent (predictor) variables during model building.

Seventeen yield groups were developed through discussions with Canfor's forest planners (Table 1). The groups were defined based on AVI stand attributes of species composition, crown closure, density (stocking), height, age and timber productivity (Site index). The methodology used is detailed in Report #2 of the Growth and Yield Information Package of the DFMP (Olympic Resource Management, June 1999).

Table 1

Yield Groups in the Canfor GP FMA Area

Yield Group Number	Description
1	AW+(S)-AB
2	AW+(S)-CD
3	AWSW/PBSW/BWSW
4	BW/BWAW+(S)
5	FB+OTH
6	H+(S)/S
7	PB+(S)
8	PL/PLFB+(H)
9	PLAW/AWPL
10	PLSB+OTH
11	PLSW/SWPL+(H)
12	SBLT/LTSB(G,M,F)
13	SBLT/LTSB(U)
14	SBPL/SBSW/SBFB
15	SW/SWFB+(H)-AB
16	SW/SWFB+(H)-CD
17	SWAW/SWAWPL

The product of the growth and yield modeling effort is the yield table. The yield tables for Canfor's DFMP were developed using a Multiple Utilization Yield Table System. Various adjustments to the final yield table results were carried out. To account for a wide range of environmental conditions in the FMA area and the expected geographic variation in volume-height relationships, site index seeds were assigned to corresponding natural subregions by yield group. Within an individual yield group, the natural subregion (NSR) with the greatest number of representative PSPs was defined as the default NSR for that yield group.

Due to the non-declining nature of the two-stage yield modeling approach, stand volume decline was implemented within each coniferous yield groups to account for stand succession and mortality. Gross merchantable volumes predicted by the yield curves were also adjusted based on softwood and hardwood cull factors to generate net merchantable volumes. This reconciliation was achieved through the application of Growing Stock Adjustment Factors to the yield tables.

Detailed information on the yield table development process, using a Multiple Utilization Yield Table System, can be found in the Report #5 of the Growth and Yield Information Package of the DFMP (Olympic Resource Management, June 1999).

4.4 Key Variables and Assumptions

The following section on key variables and assumptions includes discussions about the issues related to the growth and yield models used in the Canfor DFMP. It is intended to be more detailed than what would be necessary for the analysis as defined by the scope. Many of the recommendations for future data collection, the extension of the PSP program, analysis, modeling efforts are based on issues identified in this section.

4.5.1 Key Variables

At the sapling and seedling stage yield stratum assignments cannot be done directly from mapped inventory covertype, as that information is usually not yet available, therefore surrogate variables are necessary. The same is true for site productivity measures such as site index or growth intercept. It is also important to identify how these surrogate measures that describe early stand conditions relate to future conditions of the stand.

Site Index

Site index is one of the most important variables in growth and yield projections in natural and regenerated stands. Estimates of site indices at the stand level can have considerable implications on the AAC determination at the forest level. Underestimates of volume in regenerated stands and overestimates of rotation age and green-up can result from an underestimated site index. This in turn will reduce long range sustained yield at the forest level. Due to its nature, site index is usually underestimated, but opposite trends will occur if site index is overestimated.

For the Canfor DFMP, PSP data was used to calculate site indices based on the primary species group breast height age and site height. Site index was generated from a generalized form of the Height-Age models developed by the LFS. These site indices were then assessed for their utility by plotting the resultant PSP height growth trajectories using standardized individual tree-based site index curves. Detailed information on the validation of site indices can be found in the Report #7 of the Growth and Yield Information Package of the DFMP (Olympic Resource Management, June 1999).

Due to the different characteristics of juvenile height growth and the inability of the height-age models to estimate site index reliably in very young stands, it will be necessary to develop growth intercept models (GI) and/or juvenile site index models (JUSI) to address this problem. GI models have been successfully applied in British Columbia and in Alberta. Methodologies for development, data collection protocols are widely available in the literature.

Species Composition

Species composition is one of the two stratification variables that define the yield group for a stand. Along with stocking (density), species composition needs to be monitored to measure the impact of silviculture activities in regenerated stands. It can be determined at various stages of stand development from different kinds of data. The stand parameter that measures species composition can also be different at different stages of stand development. In young stands, the number of trees per hectare represents species composition relatively well. This is because young regenerated stands are fairly uniform, representing a small range of tree sizes. In mature stands, the most common measure of species composition is basal area per hectare, but other measures that represent different tree sizes, such as the stand density factor (Huang 1998) can also be considered as an alternative.

For the DFMP, a two-phase method was used to derive a cover type label for each stand prior to it being assigned to a yield group. The first phase involved using a set of combination rules to derive species composition. For stands where no understorey exists or that doesn't meet the conditions specified, combination was not necessary. However, a combined cover type was created for stands with an overstorey (OS) layer and an understorey (US) layer. For these stands, the species composition of the OS and of the US were weighted and combined to give a stand average species composition. An average stand height was also created in a similar manner. Density was treated as additive in these cases. Please refer to Report #2 of the Growth and Yield Information Package of the DFMP (Olympic Resource Management, June 1999), for a detailed discussion of the land base stratification.

Given the above information, monitoring performance standards for yield group assignment becomes more difficult. New PSP or OPS (Operational survey) data may have to be subjected to the same logic used to create the combined cover type label, in order to validate the yield group variables on an equal level. Conversely, "breaking up" the combined stand cover type label into its original components may be necessary to make valid comparisons at a later date.

It is imperative that studies are conducted on the 'stability' of a yield group. Ultimately, yield groups are defined from the mapped inventory label for each stand, as yield estimates must be linked to inventory. However, interim estimates of species composition and crown closure at the time of silviculture surveys (preferable the performance survey) will have to be checked against the photo-interpreted inventory call when it becomes available.

Currently, companies are responsible for developing their own internal auditing systems and issuing reports to government. These audits determine whether plans reflect the activities needed to ensure regenerated stands meet the performance standards and to verify that activities actually take place in accordance with the plans. Area summaries by yield group at the forest-level are integral part of conformance monitoring. Such summaries will enable auditing of operational activities and plans and facilitate making field checks on performance standards.

An important part of monitoring is the determination of the yield group to which a particular stand belongs. At different stages of stand development, different data may be available to determine species composition and crown closure. The DFMP and the inventory cycle will define the minimum period required to determine yield table assignments, but it is generally considered to be less than 20 years.

Operational silviculture surveys (establishment and performance surveys) are the first step in benchmarking and validating expectations. Algorithms need to be developed to link early stand parameters such as stocking proportions to species composition and crown closure as defined by the inventory mapped overstorey cover type call.

Beginning in the year 2001 harvesting season, area summaries by yield group should be reported annually for validating performance. The assignment of yield groups by area can then be balanced every five years in order to monitor conformance of actual yield group shifts to those stated in the DFMP.

Crown Closure – Density Class

As mentioned above, in the land base stratification for Canfor's FMA area, a combined cover type was desired for stands with an understorey (US). To create an average stand crown closure, the density class was treated as additive. For example, if both the overstorey and understorey AVI labels had identical density classes, the new combined density increased by one class. If the labels differed, the combination rule goes in favour of the greater of the two density classes.

As an indirect measure of yield, crown closure is a very important indicator. At the yield group level, the density class (or classes for some yield groups) in the yield group definition is identified as the performance standard. It is assumed that the crown closure remains constant for the life of a stand. However, since a stand with an OS and US has a combined density class after it has been stratified, forthcoming PSP or OPS data which separates OS and US measures (as per AVI standards) will have to be related to the combined measure in some manner.

Density – Stocking

The number of trees per hectare is regarded as the simplest and the most reasonable density measure for young stands, however it is not considered a good measure for mature stands as it does not account for different tree sizes. For mature stands, basal area per hectare becomes a better measure of stocking.

It is also necessary to consider the incorporation of initial stocking into the modeling approach in the future. This would enable silviculturists to establish performance standards that need to be met to put a particular regenerated stand on a projected growth trajectory.

This could be achieved either with:

1. the estimation of change in stocking with age or top height development, which would allow initial stocking probability to be incorporated directly into the two-stage model as an independent variable; or

2. relating stocking at the time of the performance survey to conventional stand variables and indices (basal area, density etc.), and adding this variables to the two-stage model.

As a minimum, density measures such as stems per hectare and basal area per hectare were compiled from the TSP data, and can be used as performance standards.

The current modeling approach does not address the issue of mortality and ingress. The PSP data in regenerated stands will help monitoring mortality and ingress over time. This information could be used in the development of the previously mentioned density function. Crop tree monitoring provides the basis for Free-to-Grow (FTG) status and also for assessing replacement rates. This means that different set of crop trees may exist at consecutive PSP re-measurements that affect top height calculations. Crop tree mortality rates can be established that will help assessing current regeneration standards and FTG status definitions.

Mortality and ingress should be reported during the compilation of the PSP data in regenerated stands. This may also necessitate the revision of current PSP data collection protocols.

Years to Reach Breast Height

Years to reach breast height and regeneration lag periods provide means for reviewing current regeneration standards and for reviewing FTG and crop tree status. Monitoring regeneration lag periods also helps assessing expected years to green-up and it also assists in reviewing the efficacy of silviculture practices. Stem analysis data, operational silviculture data and PSP data in regenerated stands can be used in monitoring and validation.

A key assumption by Canfor was to model the number for years to breast height as specific numbers, depending on the yield group and the natural subregion. For fire-origin stands, the numbers were based on provincial averages obtained from the Alberta Vegetation Inventory Standards Manual (v 2.1, 1991). Table 2 summarizes the number of years to reach breast height by yield group for existing stands. The number represents the primary species for that yield group.

Table 2

Years Required to Reach Breast Height by Yield Group

Yield Group	Years to Breast Height*
1	6
2	6
3	15
4	6
5	15
6	15
7	6
8	10
9	10
10	10
11	10
12	20
13	20
14	20
15	15
16	15
17	15

* from point of germination

Previously harvested areas were identified with a year of cut, yield group and flag to indicate if they have been weeded. Using performance survey results, a regeneration lag and years to breast height were assigned on the basis of yield group, weeding history and whether harvesting occurred prior to 1991. Table 3 summarizes the regeneration lags and breast height age adjustments used for Timber Supply Analysis (TSA). Please refer to Report #9 of the Growth and Yield Information Package of the DFMP (Olympic Resource Management, June 1999), for a detailed discussion of the TSA.

Table 3

Regeneration Lag and Years to Breast Height for Harvested Areas

Yield Group	Natural Subregion	Veg. Mng.	Harvest Year	Regeneration Lag (yrs)	Zero to Breast Height (yrs)	Total to Breast Height (yrs)
3	All	Y	Pre-1991	4	15	19
8	All	Y	Pre-1991	4	8	12
9	All	Y	Pre-1991	4	8	12
11	All	Y	Pre-1991	4	8	12
16	All	Y	Pre-1991	4	8	12
17	All	Y	Pre-1991	4	8	12
3	All	N	Pre-1991	9	15	24
8	All	N	Pre-1991	9	8	17
9	All	N	Pre-1991	9	8	17
11	All	N	Pre-1991	9	8	17
16	All	N	Pre-1991	9	8	17
17	All	N	Pre-1991	9	8	17
9	CMW, DMW, LFH, PRP	Y	1991-1999	4	1	5
9	UFH, SAL	Y	1991-1999	4	4	8
3	All except UFH	N	1991-1999	1	7	8
3	UFH	N	1991-1999	1	10	11
8	CMW, DMW, LFH, PRP	N	1991-1999	1	4	5
8	UFH, SAL	N	1991-1999	1	7	8
9	CMW, DMW, LFH, PRP	N	1991-1999	1	4	5
9	UFH, SAL	N	1991-1999	1	7	8
11	CMW, DMW, LFH, PRP	N	1991-1999	1	4	5
11	UFH, SAL	N	1991-1999	1	7	8
16	CMW, DMW, LFH, PRP	N	1991-1999	1	7	8
16	UFH, SAL	N	1991-1999	1	10	11
17	CMW, DMW, LFH, PRP	N	1991-1999	1	7	8
17	UFH, SAL	N	1991-1999	1	10	11

Values for years to reach breast height were assigned to the coniferous understorey in deciduous stands, comprising yield groups 1, 2, 4, and 7. Table 4 summarizes the performance standards set in the TSA for these yield groups, by natural subregion.

Table 4

Years to Breast Height Age for Deciduous Stands with Conifer Understorey

Yield Group	Natural Subregion	Years To Breast Height
1	CMW, PRP, SAL	15
1	DMW	15
1	LFH	15
1	UFH	15
2	CMW, UFH, PRP, SAL	15
2	DMW	15
2	LFH	15
4	CMW	15
4	DMW	15
4	LFH, UFH, PRP, SAL	15
7	CMW, UFH, PRP, SAL	15
7	DMW	15
7	LFH	15

Table 5 summarizes the regeneration strategy used in the TSA. The numbers reflect information gained from field surveys, NIVMA (Northern Interior Vegetation Management Association) PSPs, tree improvement programs and general observations. The implementation of this strategy establishes the benchmarks needed for validation of yield table shifts, reduced years to breast height, and volume multipliers for tree improvement.

Table 5

Regeneration Strategy (2000-)

Yield Group	Natural Subregion	Regenerated Yield Group	**Primary Species** Years to Breast Height*	**Secondary Species** Years to Breast Height**	Tree Improvement Multiplier***
1	All	2	4	16	0.50
2	All	2	4	15	0.50
3	CMW, DMW, LFH, PRP	3	8	10	1.00
3	UFH, SAL	3	11	12	1.00
4	All	4	5	15	0.50
5	CMW, DMW, PRP	16	8	10	1.00
5	UFH, LFH, SAL	5	0	4	1.00
6	CMW, DMW, LFH, PRP	17	8	10	1.00
6	UFH, SAL	17	11	15	1.00
7	All	7	4	10	0.5
8	CMW, DMW, LFH, PRP	8	6	10	1.07
8	UFH, SAL	8	9	12	1.00
9	CMW, DMW, LFH, PRP	9	6	10	1.07
9	UFH, SAL	8	9	12	1.00
10	CMW, DMW, LFH, PRP	8	6	10	1.07
10	UFH, SAL	8	9	12	1.00
11	CMW, DMW, LFH, PRP	11	7	10	1.07
11	UFH, SAL	8	9	12	1.00
12	All	12	15	6	1.00
13	All	13	23	9	1.00
14	CMW, DMW, LFH, PRP	14	7	10	1.00
14	UFH, SAL	14	10	12	1.00
15	DMW, PRP	15	9	10	1.00
15	CMW, LFH	16	9	10	1.00
15	UFH, SAL	16	12	12	1.00
16	CMW, DMW, LFH, PRP	16	9	10	1.00
16	UFH, SAL	16	12	12	1.00
17	CMW, DMW, LFH, PRP	17	9	10	1.00
17	UFH, SAL	16	11	12	1.00

* Includes an allowance for plantation failures; includes an allowance for regeneration delay; and an entry of 0 indicates understorey protection

** Values based on provincial averages obtained from the Alberta Vegetation Inventory Standards Manual (v 2.1, 1991).

*** Tree improvement multiplier includes an allowance for non-treated areas.

4.5.2 Assumptions

Because of imperfect knowledge and/or lack of data, making assumptions is inevitable in model development and during the application of these models. However, it is very important to identify these assumptions in order to define the applicability of the model in various situations and to identify where to concentrate validation and monitoring efforts.

In the case of growth and yield predictions in regenerated stands, the assumptions can be grouped as:

1. Modeling assumptions: directly related to the models and model development; and

2. Application assumptions: closely related to the application of the growth and yield models during the planning phase and timber supply analysis.

<u>Modeling assumptions</u>

Yield group assignments to regenerated stands are based on the assumption that species composition and stocking (density) remain constant for the entire life of the stand.

Assumptions around stand decline and cull also need to be validated and monitored when new natural stand PSP measurements become available.

<u>Application Assumptions</u>

Growth and yield models are being applied at the yield group- and the FMA area-level during the planning process and timber supply analysis. Stands with similar characteristics are grouped and yield tables are applied to groups of stands. Average site index values are applied by yield groups and stand origin. Average site indices for regenerated stands are generated from juvenile stand surveys and regenerated stand inventories. The application of these site index values to current cutblocks is a statistically valid representation of the site productivity of today's regenerated stands. Future cutblocks in natural stands may change the averages of not only the regenerated stands, but also the averages of the remaining natural stands at the FMA area-level.

Regeneration strategies related to regeneration lags and yield table "shifts" need to be monitored and conformance with planned activities needs to be reported. Operational silviculture surveys support the monitoring efforts, therefore regeneration survey data must be integral part of the Growth and Yield System (GYS).

4.6 Validation Criteria (Performance Standards)

Validation criteria are determined based on published values and assumptions that were used in the development of natural and regenerated stand yield tables in the DFMP. Performance standards must be applicable to natural and regenerated stands of any age. However, these standards need not be the same for all ages. If we think of yield at final harvest as the "ultimate" performance standard, we can work backward all the way to standards applicable at time of stand establishment. This set of "interim" standards is needed to provide continued confidence that the forecast final harvest yields will be attained. Each stratum yield function provides forecasts of yields (a yield trajectory) over time. Along with the final harvest forecast, these interim yield forecasts serve as direct performance standards. Additional indirect performance standards are also needed for two reasons: 1) merchantable volume (yield) is not present in young stands for the first 20-40 years and 2) other yield-related standards provide collaborative assurance that the yield trajectories will continue to be realized over time.

These indirect performance standards take two general forms: 1) yield-related mensurational data (e.g., height, density, etc) and 2) the body of relevant policies and plans that may include stratum definitions, regeneration standards, silvicultural plans and other related management plans.

Each performance standard must be auditable. To be auditable, the standard itself must be quantifiable, pre-determined and the associated factor(s) must be operationally accessible and measurable.

The validation criteria for every identified growth and yield variable. The method for calculating the validation criteria site index and years to breast height (BH) in fire-origin stands is presented in Tables 6 and 7. Please note that the published numbers are considered preliminary until the DFMP is approved.

Table 6

***Example:* Validation Criteria for Site Index and Years to BH by Yield Group**

Yield Group	Description	Species	Area (ha) THLB*	% of Total Area	Site Index	Years to BH
1	AW+(S)-AB	AW	11,523.9	2.4	18.5	6
2	AW+(S)-CD	AW	77,941.2	16.4	17.7	6
3	AWSW/PBSW/BWSW	SW	29,049.7	6.1	18.1	15
4	BW/BWAW+(S)	BW	1,282.8	0.3	16.7	6
5	FB+OTH	FB	7,600.5	1.6	12.0	15
6	H+(S)/S	SW	49,737.7	10.5	17.0	15
7	PB+(S)	PB	22,323.7	4.7	17.7	6
8	PL/PLFB+(H)	PL	48,294.4	10.2	14.7	10
9	PLAW/AWPL	PL	18,251.7	3.8	16.9	10
10	PLSB+OTH	PL	9,555.7	2.0	11.0	10
11	PLSW/SWPL+(H)	PL	20,358.7	4.3	16.4	10
12	SBLT/LTSB(G,M,F)	SB	34,448.9	7.3	10.5	20
13	SBLT/LTSB(U)	SB	11.4	0.0	7.8	20
14	SBPL/SBSW/SBFB	SB	16,686.4	3.5	11.7	20
15	SW/SWFB+(H)-AB	SW	24,058.1	5.1	13.8	15
16	SW/SWFB+(H)-CD	SW	32,909.2	6.9	13.9	15
17	SWAW/SWAWPL	SW	45,171.3	9.5	15.7	15
US	Decid to Decid w. Con. US	SW	24,987.6	5.3	18.1	15
Total			**474,193.0**	**100.0**	**15.7**	**12.4**

* Total Harvestable Landbase

Table 7

***Example:* Validation Criteria for Site Index and Years to BH by Species Group**

Leading Species	Site Index	Years to BH
AW	17.8	6.0
BW	16.7	6.0
FB	12.0	15.0
PB	17.7	6.0
PL	15.1	10.0
SB	10.9	20.0
SW	16.1	15.0
Softwood	**15.0**	**14.4**
Hardwood	**17.8**	**6.0**
Overall	**15.7**	**12.4**

4.7 Graphical and Statistical Analysis

There are several simple graphical and statistical tests that can be carried out, provided that data and modeling requirements as described in Section 2 have been met.

The graphical and statistical methods presented here are intended as tools to examine the data for possible overall trends of over- or under-prediction. If the analysis suggest deviations from our expectations (e.g. observed volumes are lower than yield table predictions), the possible sources of errors and the action to be taken should be identified.

4.7.1 Graphical Analysis

Graphical comparison of actual and predicted values provides a visual assessment of how our observations compare to our expectations.

1. *Plot measured values versus yield or site curves*

For example plot observed volume per hectare versus total age against a composite yield curve for the entire population (Static Analysis - Figure 6). We can also plot height growth trajectories observed in PSPs against height age curves for a selected species to examine trends and visually evaluate change (Dynamic Analysis – Figure 7)

2. *Plot measured values versus predicted values*

If our predictions are accurate, then most of the points should fall on the 45 degree (1:1) line. Outliers can be flagged and examined to determine if any potential problems in prediction are indicated. A theoretical example is presented in Figure 8.

3. *Plot the difference between actual and predicted values*

This technique could help identify possible trends of over- or under-prediction in different age or height classes. Expressing the difference as relative (percentage) value rather than the absolute values will provide a better view of data trends (J.S. Thrower and Associates Ltd., 2000).

Figure 6

Graphical Validation of PSP Data Versus Conifer Composite Yield Curve

Harvest Priority: CONIFER
Source: VRR Model 2
Plot Data: PSP By 20-year Age Class

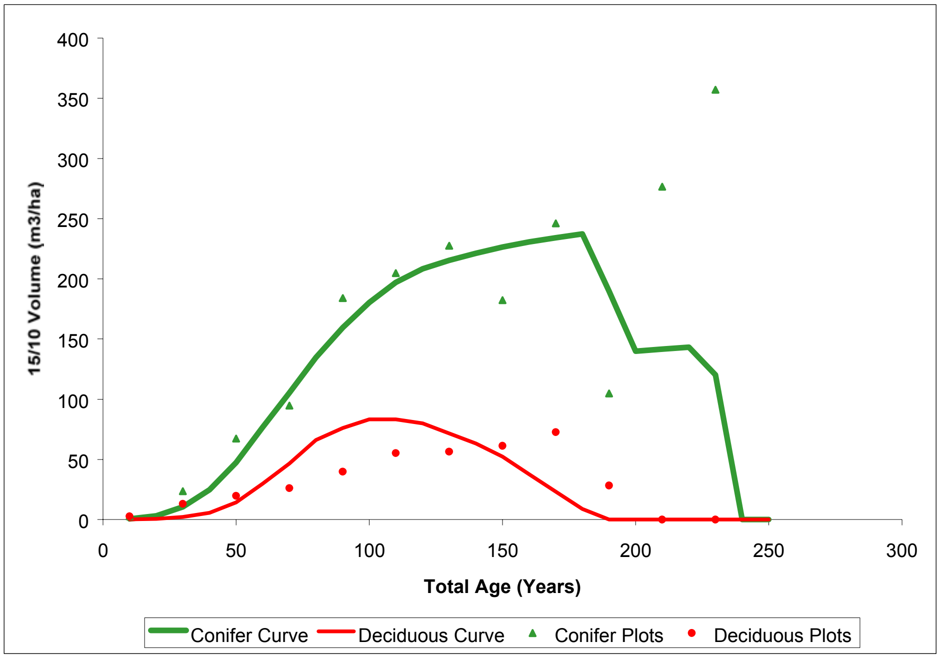
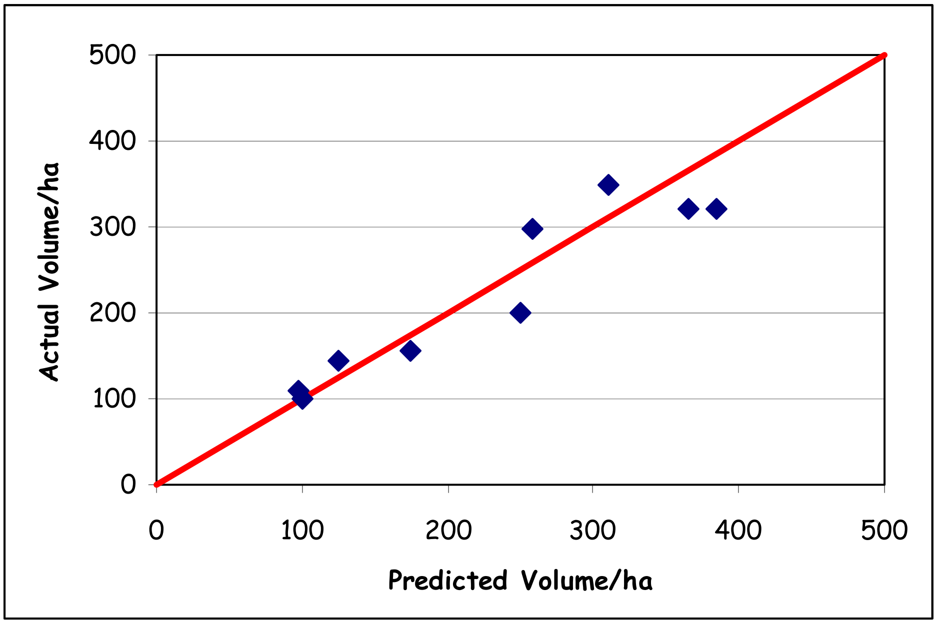


Figure 7

Example of Graphical Validation of Height-Age for Lodgepole Pine

Figure 8

Example of Graphical Validation of Actual versus Predicted Values



4.7.2 Statistical Analysis

Graphical analysis provides a visual assessment that, by nature, is subjective. There are several simple statistical tests that can be carried out. These statistical tests are hypothesis tests that evaluate the difference between actual and predicted values. Confidence intervals and average differences can be calculated at the specified confidence level for the particular yield group. If the confidence interval includes zero, there is no significant difference between the actual and predicted values. A theoretical example for examining years to breast height values is shown in Table 8.

Detailed discussion on graphical and statistical analysis techniques can be found in J.S. Thrower and Associates Ltd., 2000.

Table 8

<u>Example:</u> Statistical Test by Species for Years to BH

Items	Pine	White Spruce	Aspen
Observed Mean	5.8	7.8	2.8
Observed StDev	0.9	0.9	0.8
Number of Obs.	97	56	29
Validation Criteria	10.0	15.0	6.0
H0:	$\mu \leq 10$	$\mu \leq 15$	$\mu \leq 6$
H1:	$\mu > 10$	$\mu > 15$	$\mu > 6$
alpha	0.05	0.05	0.05
t critical	t > 1.66	t > 1.67	t > 1.70
t value	-44.06	-58.50	-20.89
Decision:	Accept H0 and conclude that the observed years to BH value is not greater than 10 years at alpha = 0.05 significance level.	Accept H0 and conclude that the observed years to BH value is not greater than 15 years at alpha = 0.05 significance level.	Accept H0 and conclude that the observed years to BH value is not greater than 6 years at alpha = 0.05 significance level.

4.8. Growth and Yield Monitoring Report Cards

Results from measuring actual results of key indicators against performance standards have to be reported in some type of format. A record of results from the previous year is summarized into an annual performance report. Cumulative performance, tracked from the time of implementation of the monitoring program, may also be reported. Reporting periods will be defined based on requirements discussed in Section 2.

A growth and yield monitoring report card can be designed to give details for any level of administrative unit (i.e. by operating unit, block and/or treatment). Predicted and actual performance measures at the yield group-level can be reported for comparison purposes. An example of how a growth and yield monitoring report card might look is shown in Figures 9 and 10.

Performance monitoring report cards may be generated separately from the information management system holding the monitoring information, or they may be an integral component of that system. The advantage of the latter option is that, in combination with appropriate analysis tools, the reports can incorporate a measure of progress towards the set of desired objectives.

Figure 9

Growth and Yield Monitoring Report Card – Early Growth Phase

CANFOR	CANADIAN FOREST PRODUCTS LTD. GROWTH AND YIELD MONITORING REPORT CARD			
ADMINISTRATION	**OPERATING AREA**	G5C	**BLOCK NUMBER**	E63047
	TREATMENT UNIT	A	AREA (HA)	29.6
	DATE	January 28, 2001	UPDATED BY	GG
	NATURAL SUBREGION	CMW	INVENTORY TYPE	AVI 2.1
	MAP OVERSTOREY			
	MAP UNDERSTOREY			
	HARVEST METHOD	CC	HARVEST DATE	Nov-90
	TREATMENT TYPE	PLANTED	TREATMENT DATE	Apr-91
	SURVEY TYPE	ESTABLISHMENT	SURVEY DATE	Jun-98

BLOCK	**G5C - E63047 - A**	**PLANNED**	**ACTUAL**
STRATUM	REGEN. STANDARD	C	C
	SPECIES COMPOSITION	PL10	PL10
	DENSITY	D	C
	YIELD GROUP	8: PL/PLFB+(H)	8: PL/PLFB+(H)
	REGEN LAG	2	1
	YEARS TO BH	6	6
	ESTABLISHMENT LAG	8	7
PREDICTION	SITE SPECIES	PL	PL
	SECONDARY SPECIES	-	-
	BREAST HEIGHT AGE	0	1
	SITE INDEX	15.8	16.3
	CROP TREE HEIGHT	1.3	1.5
	MERCH. VOLUME/HA	0	0
	ROTATION AGE (BHA)	50	
	MVOLHA @ ROTATION	148	
NOTES	MERCHANTABILITY AT 15/10 UTILIZATION		

Figure 10

Growth and Yield Monitoring Report Card – Mature Timber Phase

CANFOR

CANADIAN FOREST PRODUCTS LTD.

MATURE TIMBER YIELD GROUP DEPLETION REPORT CARD

PERIOD	YEAR	to	YEAR	OPUNIT	ALL	BLOCK	ALL
	1997		1998				

YIELD GROUP		AREA		VOLUME		
		PLANNED	ACTUAL	PLANNED	ACTUAL	DIFFERENCE
NUM	DESCRIPTION	Ha	Ha	M3	M3	M3
01	AW+(S)-AB	15.9	15.9	569	2,848	2,280
02	AW+(S)-CD	115.2	115.2	1,804	20,372	18,568
03	AWSW/PBSW/BWSW	332.0	332.0	45,767	55,082	9,314
04	BW/BWAW+(S)	14.6	14.6	510	2,571	2,061
05	FB+OTH	91.3	91.3	16,528	25,167	8,639
06	H+(S)/S	104.3	104.3	7,109	20,128	13,019
07	PB+(S)	78.8	78.8	667	14,556	13,889
08	PL/PLFB+(H)	819.2	819.2	211,576	250,491	38,915
09	PLAW/AWPL	119.9	119.9	16,938	26,330	9,392
10	PLSB+OTH	49.0	49.0	9,179	13,614	4,434
11	PLSW/SWPL+(H)	234.6	234.6	57,484	70,355	12,871
12	SBLT/LTSB(G,M,F)	117.0	117.0	12,533	26,839	14,306
13	SBLT/LTSB(U)	5.5	5.5	154	1,163	1,010
14	SBPL/SBSW/SBFB	79.1	79.1	13,386	21,124	7,739
15	SW/SWFB+(H)-AB	430.0	430.0	79,839	92,333	12,494
16	SW/SWFB+(H)-CD	852.9	852.9	241,378	193,848	-47,530
17	SWAW/SWAWPL	1,042.3	1,042.3	184,784	188,889	4,105
Total		4,501.6	4,501.6	900,204	1,025,710	125,506

NOTES		
	MERCHANTABILITY:	CONIFER NET MERCHANTABLE at 15/10
	RIGHT OF WAY:	NOT ACCOUNTED FOR
	ROADSIDE VOLUME:	INCLUDED IN ACTUALS
	WASTE VOLUME:	NOT ACCOUNTED FOR
	ANNUAL GROWTH:	ALL STANDS GROWN TO YEAR END
	OPERATIONAL ADJUSTMENT:	NOT ACCOUNTED FOR
	OTHER:	

5. Growth and Yield Issues in the Canfor GP FMA Area

The following section details the issues that have been identified to be related to the Growth and Yield Monitoring Program. These issues were compiled by ORM based on a thorough review of the Growth and Yield Information Package, various growth and yield data sets, CSA Sustainable Forest Management Plan commitments and discussions with Canfor staff. The list of issues were put into 3 categories:

- Inventory/Landbase;
- Growth and Yield Models and Data; and
- Timber Supply Analysis

This categorization is based on the general notion of monitoring: (1) examine the initial condition (inventory/landbase); (2) predict change (growth and yield); and (3) evaluate assumptions (timber supply modeling).

The purpose of this list is to initiate discussions and help Canfor staff and consultants identify other issues and set priorities. It is anticipated that once the list of issues has been revised and priorities have been set, **short and long term growth and yield monitoring strategies** can be developed. Specific projects then can be proposed that will help meet the goals of the Growth and Yield Monitoring Program. All projects must have a work plan or sample plan reviewed by the appropriate parties before initiation.

The successful implementation of the Growth and Yield Monitoring Program will require a significant amount of organizational effort, programs to coordinate and consultation with various agencies, other licensees and the public. Canfor needs to ensure that a staff forester is dedicated to the overall management of the Program. This is to ensure that the requirements of the Forest Resource Improvement Association of Alberta (FRIAA) and other budgeting and reporting requirements are met, and to provide a long-term vision of the Growth and Yield Monitoring Program.

INVENTORY & LANDBASE			
ID	**ISSUE**	**CURRENT STATUS**	**FUTURE/RECOMMENDATIONS**
I-1	Status and Types of Inventories	* Forest inventory is AVI 2.1 standard * Ecological inventory (site series) completed by GDC * Fisheries Inventory completed by Alberta Conservation Association * DEM completed by GISMO Solutions Ltd. * Caribou Study and many other inventories maintained on GIS	* Review current status of various inventories * Review inventory schedules
I-2	GIS/Data Management/Agreements	* Each licensee has spatial data management capabilities	* Review data management and data sharing agreements with other licensees and the LFS * Combine various data sets and create a pool of information by identifying source, data manager and update status
I-3	Inventory Integration	* Ecological inventory needs to be integrated with timber inventories * Volume sampling data, cruise data and perhaps PSP data may be used to predict diameter distributions, log profiles by relating to inventory labels	* Integration will provide for spatially explicit modeling, economic analysis and silviculture investment analysis.
I-4	Inventory Update	* Each licensee has spatial data management capabilities * Spatial information is stored in 'layers'; updated forest cover is created dynamically	* Define, implement and test the inventory update process (depletion and linework, short term growth projection) * Define the formal process of deciduous cutblock updates
I-5	Silviculture Update	* Each licensee has spatial data management capabilities * Linkage of the SRMS functionalities and the timber inventory must be spatially explicit * Spatial information is stored in 'layers'; updated forest cover is created	* Silviculture update process will have to be defined and tested * Years to BH, regeneration delay, yield group at the performance survey are minimum requirements * Keep up-to-date information on backlog (not sufficiently stocked), non-liability silviculture

		dynamically	database on burned areas > 4 ha outside of harvested areas * Define the formal process of deciduous block silviculture updates
I-6	Non-Productive to Productive Areas	* Some previously withdrawn areas are brought back into productive status	* Establish protocol in consultation with the LFS * Monitor withdrawn areas and track them in the non-liability silviculture database
I-7	Deciduous Stands with Conifer Understorey	* Two basic types: deciduous stands with conifer understorey as per the AVI and stands identified based on the understorey survey plots in the TSP * Based on an understorey study, certain proportion of pure deciduous stands were assigned to conifer understorey stands	* Monitor and report on deciduous stands with conifer understorey to get a better understanding on the spatial location of these stands
I-8	Inventory Adjustment	* Photo interpreted attributes are based on AVI 2.1 standards * Well documented, clean ecological and cruise TSP data available	* Use TSP data to statistically adjust timber attributes to better reflect stand information on a polygon per polygon basis (height, age, basal area etc.)

GROWTH AND YIELD DATA & MODELS			
ID	**ISSUE**	**CURRENT STATUS**	**FUTURE/RECOMMENDATIONS**
G-1	Natural Stand Yield	* Empirical yield tables using the two-stage methodology (volume-height; height-age) * Developed from TSPs and validated using the independent PSP data set * Deciduous curves and methodology were peer-reviewed by Ainsworth/Tolko/GAP	* Monitor main assumption: stand height growth can be modeled using individual tree based height-age models
G-2	Managed Stand Yield	* 7 percent increase of conifer volume in select yield groups and natural subregion (pine stands planted with genetically improved stock)	* Monitor regenerated yields using PSP data in natural stands * Challenges: lack of PSPs in regenerated stands and strata-based sampling * Establish realized gain trials to verify projected 7 percent increase (long-term)
G-3	Natural Stand Growth	* Average growth rates are defined by the yield tables	* Monitor growth rates using PSP data in natural stands
G-4	Managed Stand Growth	* Average growth rates are defined by the yield tables	* Monitor growth rates using PSP data in managed stands
G-5	Site Productivity in Mature Stands	* Natural stand SI: by yield group and natural subregion from TSP data * Managed stand SI: 7 % increase for select yield groups and natural subregions * Linkage of site productivity and ecosites (GDC SiteLogix)	* Complete SiteLogix project * Explore opportunities of integration of ecological and site productivity information with other timber attributes from inventory * Check the accuracy of SiteLogix data using the independent PSPs
G-6	Site Productivity in Juvenile Stands	* Need to measure site index in young stands * No models have been developed to date * Site index from juvenile phase must be tied to site index models developed for mature stands	* Growth intercept (GI) models need to be developed using stem analysis data * Focus on three major species: pine, spruce and aspen * Long-term monitoring and validation on how early site productivity estimates relate to late stand conditions is key

G-7	Taper Equations	* ecologically based taper equations were developed and validated in 1997 * Provincial parameters were found to be good for most species and natural subregions for the FMA area * New parameters were developed for white spruce in the central and dry mixedwood natural subregions	* Continue to monitor and validate tree form and taper equations * Use stem analysis data to develop taper models for birch and some minor species
G-8	Height/Age Equations	* Ecologically based height/age equations were developed and validated in 1997 * Provincial parameters were found to be good for most species and natural subregions for the FMA area * New parameters were developed for pine in the upper and lower foothills natural subregions	* Use stem analysis data to develop height-age models for birch and some minor species * Continue to monitor and validate site index equations using PSP data * New and improved model forms become available from research conducted by the LFS * PSP-based stand height-age equations will be desirable in the future
G-9	Juvenile Height Growth	* Early stand height development plays a very important role in modeling stand availability in timber supply analysis * Green-up/adjacency ground rules are modeled based on early height growth * Hydrologic recovery (ECA) is also modeled based on early height growth	* Develop juvenile height-age curves to better model early height growth * Use these models to verify greenup assumptions
G-10	Years to Reach BH/ Age at BH	* Key variable in performance surveys * All yield tables are based on BH age * Green-up, thus stand availability can be greatly affected	* Rigorous monitoring of years to BH in managed stands is a must * Carry this information to the inventory as part of the silviculture update process * Review years to BH by species and natural subregion for natural stands using stem analysis data

G-11	Yield Group Stability (Succession)	* Strategic timber supply analysis assumes same yield group for the entire life of the stand * Yield group must be assigned no later than 20 years from harvest (at the performance survey)	* Monitor areas of planned and actual yield groups * Use PSPs to monitor succession at the stand level * Develop algorithm that provides the yield group (species composition and density) from performance survey data * Carry yield group of stand in the inventory as part of the silviculture update process
G-12	Tree Improvement Program	* The usage of genetically improved stock was built into the regeneration assumptions * 70 % from seed orchards and 30 % from bulk seed for select yield groups and natural subregions * Bulk seed collection from 400-750 mother trees for pine and white spruce and from 50-150 trees for black spruce	* Monitor areas planted with bulk seed and areas planted with orchard stock * Build this functionality as part of the Silviculture Record Management System (SRMS) * Realized gain trials will be implemented for pine (ANC-Weyerhaeuser-Canfor) and for spruce (Weyerhaeuser-Canfor)
G-13	Treatment Response	* Treatment effects can only be separated in controlled experiments * Early stand performance will largely be based on treatments applied to young stands * Active participation in various co-ops: Foothill Model Forest Pine Coop; WESBOGY Mixedwood Coop, NIVMA	* Continue participation in various research initiatives (Foothills Growth and Yield Association, Mixedwood Management Association, WESBOGY etc.)
G-14	Cull Factors (Decay)	* Current assumptions are based on check scale data from 1992-1998	* Continue monitoring of check scale data
G-15	Utilization	* Flexible yield tables are based on multiple utilization limits * FMA area utilization is 15/10 at 30 cm stump height * Conifer merchantable waste is assumed to be 0.5 % based on waste surveys * Conifer loss from bush bucking practices is 0.5 % (sorting for pulp)	* Continue monitoring merchantable waste and utilization (15/10) * Generate more robust numbers for deciduous from waste surveys

G-16	Coarse Woody Debris	* CWD plots were established in the TSP data * CWD information is also collected in operational cruises * Averages by yield group and species groups were calculated from both, the TSP and cruise data * CWD information is used in ecological studies and wildlife habitat suitability assessments	* Review work done by GDC * Develop method to measure CWD on site post-harvesting * Stratify data by natural subregion and size class, if sufficient data are available * Develop targets for CWD
G-17	Mixed Species Stands	* Yield table methodology may not fit well for detailed modeling of mixed species stands * Definition includes conifer-conifer (e.g., Pl-Sw) stands as well as conifer-deciduous (e.g., Pl-Aw) stands * Management of DC stands is built into the regeneration strategy	* Performance standards need to be established * Site productivity and early height modeling needs to be addressed * Utilize results from WESBOGY and explore the usability of MGM in the FMA area * Monitor and report on the status of DC stands
G-18	Understorey Protection	* Understorey protection and the management of DC stands (yield group 3) are built into the yield table and regeneration assumptions * Years to BH value is assumed to be 0	* Monitor and report on the status of deciduous stands with conifer understorey * Monitor balsam stands with understorey
G-19	Predicted versus Actual Harvest Volumes	* Ultimate test of yield tables in mature timber stands	* Establish a protocol to prepare a report on check scale data, yield table predictions, planned and actual areas harvested * AOP, FDP can also be used to indirectly assess yield table performance from cruise data
G-20	Forest Health	* The impact of pest/disease/fire were not modeled in the yield tables and the TSA * Participation in the NW Boreal Integrated Pest Management Working Group	* Review current methods of monitoring forest health in the FMA area * Ensure that the PSPs include health data whenever possible * This is a potential area for cooperatives

G-21	Products/Log Profiles	* Diameter distributions are currently not modeled in yield tables * Canfor's product objectives are not incorporated in the timber supply analysis	* Build on the ecological and timber inventories to generate diameter distributions (tree lists) for each stand * Utilize this information in future spatial planning (product forecasts, economic analysis)
G-22	Mortality/Competition Modeling	* Managed stand yield tables are based on fully stocked fire-origin stand yield tables * Initial planting density was not a variable in the managed stand yield tables	* Mortality and ingress can be monitored and modeled from PSPs * Develop stand-level mortality or survival models for major species (pine and spruce) * Incorporate initial stocking into next generation of yield tables * Validate 'no-impact' assumption of density on site index (fire-origin pine)
G-23	Early Stocking and Density	* Operational silviculture surveys are currently based on mil-hectare plots that may not capture density effectively * Stocking proportion is a key variable in performance surveys	* Models need to be developed that link early stocking to late stand densities and by yield group * Continue participation in various research initiatives (Foothills Growth and Yield Association, Mixedwood Management Association, WESBOGY etc.)
G-24	Stand Decline	* Artificial stand declines are imposed on yield curves to address the non-declining nature of the yield tables	* Use PSPs to monitor growth rate decline in mature stands
G-25	Crop Tree Status Monitoring	* Crop trees play a significant role in stocking, top height and site index calculations	* Use PSPs to monitor crop tree replacement rates
G-26	Minor Yield Groups	* Natural stand timber attributes are well represented at this time (a minimum of 30 TSPs per yield group)	* Not enough data to model them effectively in the future * Identify types that have high relevance for non-timber values
G-27	Variable Retention	* New silviculture systems are not modeled at this time in the timber supply analysis	* Partial harvest/ US protection may make it necessary to develop some new yield tables * Consider this in the future when combined operations become realistic

G-28	PSP Data	* Stratified random sampling based (Phase 2) * 839 PSPs (only about 25 in regenerated stands), fixed area plots * Average re-measurement cycle is 9 years * No measurements were made in 1999 * Digital raw and compiled data files currently reside with ORM (up to 1997)	* Clean existing database * Transfer digital files to Canfor * Introduce data loggers * Expand the PSP program based on a gap analysis * Incorporate key non-timber attributes
G-29	TSP Data	* 1395 TSPs in natural stands measured in 1997 * Prism plots, very clean data * Ecological and timber information collected	* Use this information in the short-term * Depletion of plots is possible (majority of plots are spatially referenced) * TSP data could be used for inventory adjustment, stand and stock table development etc.
G-30	Stem Analysis Data	* The provincial stem analysis database has 289 trees from the Canfor GP FMA area * Digital raw and compiled data files currently reside with ORM	* Transfer digital files to Canfor * Keypunch stem analysis data currently in hard-copy format * Use the data in further validation of taper and site index equations * Use data to calibrate models for birch and some minor species
G-31	Silviculture Surveys	* Provide the benchmark for monitoring young stands * Standards are under review by Alberta Reforestation Standards Science Council * Variable standards linked to the DFMP are proposed (objective orientated) * ARIS (LFS) reporting standards are not yet determined	* Variable standards and data collection protocols should be compatible with the Province's basic regeneration standards * Review key Growth and Yield variables and their current status, collection protocols in silviculture surveys * Incorporate monitoring needs * Develop regeneration survey strategy

TIMBER SUPPLY ANALYSIS			
ID	**ISSUE**	**CURRENT STATUS**	**FUTURE/RECOMMENDATIONS**
T-1	Regeneration Strategies	* Regeneration strategies and years to reach BH assumptions are defined in Report #9 of the GYIP	* Monitor planned and actual regeneration pathways
T-2	Regeneration Delay	* Regeneration delay (time from skid clearance to successful establishment) is built into the regeneration strategies (18 months) * Reducing regeneration delay may shorten the rotation age of regenerated stands	* Monitor regeneration delay from silviculture records * Carry regeneration delay for stand in the inventory as part of the silviculture update process
T-3	Greenup/Adjacency	* Ground rules are modeled using greenup height of 2 m for conifer and 3 m for deciduous harvest priority areas in the timber supply modeling * Greenup requirement of 30 years is applied in the caribou zone * Reducing greenup period may shorten the rotation age of regenerated stands	* Develop height-age model that better reflect juvenile height growth * Explore different definitions of greenup
T-4	Treatment Types and Schedule	* Treatment types and schedules were not specified in the TSA, however, tree improvement and usage of genetically improved seeds is expected on 70% of select yield groups and natural subregions	* Monitor and report on areas treated (pre and post performance survey) using silviculture records * Continue participation in research associations ((Foothills Growth and Yield Association, Mixedwood Management Association, WESBOGY, NIVMA etc.) and setup realized gained trials based on controlled experiments
T-5	Current/Future Roads/Landings	* The TSA netdown process has identified current amount of roads and landings * Future permanent roads and landings assumed to account for 2 % of the landbase	* Monitor actual road development * Review current status of road inventory
T-6	Cutlines	* A 1 % yield reductions was applied to yield tables to account for area loss due to cutline width (4m)	* Monitor the proportion of area in cutline (cutline inventory)

T-7	Block Size	* Block size and aggregation algorithm in the timber supply modeling play an important role by affecting greenup/adjacency constraints * Maximum of 500 ha aggregated block sizes are used in the TSA (1000 ha in the caribou zone)	* Monitor average block sizes by operating areas
T-8	Harvest Age	* Minimum harvest ages and average harvest ages can be determined from the TSA	* Monitor harvest ages of all cutblocks and calculate average years above minimum harvest age by yield group and overall
T-9	ECA by Watershed	* Hydrologic recovery is based on height growth in harvested areas	* Develop height-age models that better reflect juvenile height growth * Sensitivity analysis (may not need to embark on costly monitoring program, if impact is minimal
T-10	Low Productivity Sites (YG13)	* It is assumed that low productivity sites are not going to be harvested	* Monitor harvested areas in YG 13 * Delineate all low productive sites > 1 ha within harvested areas as 'no harvest zones'
T-11	YG Assignment for Harvested Areas	* Harvested blocks were assigned with a yield group based on harvest year (pre or post 1991) and treatment (weeded/not weeded)	* Monitor yield group proportions in harvested areas
T-12	Growing Stock Adjustment	* Yield table predictions were adjusted to the growing stock by age class in each yield group using the TSP data	* Growing stock adjustment factors can be re-evaluated in the short term using the depleted TSP data
T-13	Habitat Suitability Models	* Habitat suitability index (HSI) models were applied for marten, moose, pileated woodpecker and barred owl * HSI models necessitates the modeling of timber attributes, such as large deciduous snags * Due to habitat constraints, it maybe necessary to leave certain proportion of large deciduous snags in harvested areas (e.g., barred owl)	* Commitments related to habitat constraints must be documented and monitored * Explore new methods for habitat modeling (e.g. habitat dependency groups)

6. Preliminary Recommendations

This section summarizes recommendations developed to serve as an example. Detailed recommendations will be developed once growth and yield issues have been prioritized.

1. Collect growth intercept data in performance surveys.

Notes: Growth intercept data provide an alternative site index estimation tool for use in the age range (young sapling) where standard site index (height/age) functions tend to have greater bias. Collecting local site index information will provide better criteria for statistical validation, rather than using generalized site index curves for graphical validation only.

GI plot information can be used to validate the specific numbers for years to reach breast height used in the DFMP timber supply analysis. Stem analysis will provide this information.

Data collection procedures for performance surveys will have to be modified to include years to breast height and growth intercept estimates on a subset of crop trees. An exact procedure on growth intercept data collection in performance surveys needs to be established.

2. Develop new growth intercept models, or calibrate existing ones.

Notes: In order to provide growth intercept models applicable at the time of the performance survey, it is recommended that Canfor develop new, or calibrate existing, growth intercept models. In addition, because of the difficulty of actually identifying whorls in a field survey situation, alternative models such as Juvenile Site Index models (JUSI), which predict site index from total tree height and age at breast height could also be developed.

3. Participate in co-operatives and other research trials.

Notes: An alternative to collecting GI data, or a supplementary source of information. The assessment of stand-level forecasts for all individual management practices and the separation of treatment effects can only be done through a controlled, statistically defensible experiment. Conducting research and developing sophisticated models for regenerated stands is expensive. In addition, the limited range of stand conditions and management history on any one FMA area severely restricts any efforts toward self-sufficiency in this area. Consequently, it is more efficient and productive for individual companies to pool their regenerated stand data and make use of public domain research and models wherever possible. Using common public domain tools makes the resulting management decisions more transparent and acceptable to the general public and the regulatory agency(s). After all, it is the cost-effective application of information that ultimately creates the competitive edge for a company, not proprietary control of the information itself.

4. Establish "realized gain" trials to measure growth for tree improvement activities.

Notes: It is currently difficult to assess the potential yield gain of the yield groups in which genetically improved Lodgepole Pine seed has been used. The separation of treatment effects must be done through a controlled, statistically acceptable experiment, in order to determine if forecast yield is being realized.

5. Use performance surveys for validating regeneration strategy.

Notes: Determining if expectations for regeneration lags and yield group shifts are being met requires measuring performance standards. As only one survey is desired to collect this information, use of the performance survey is recommended. Stand-level performance measures can be compiled to determine if the yield group shift is as projected. Regeneration lag can be confirmed against planting records and leading species age.

6. Develop models that relate the early stand conditions to late stand conditions.

Notes: The relationship between early stocking and photo-interpreted crown closure is very important. Crown closure is part of the yield group definition. Yield group assignments at the early stages of stand development will have to be in line with future crown closure. Relationships between early stocking information from OPS surveys and late seral stage conditions of crown closure and density can be represented using models. The viability of other models, like TIPSY (developed by the BC Ministry of Forests for managed stands), GYPSY (developed by the LFS), SPS etc. should also be explored.

7. Develop algorithms to assign regeneration survey data to yield groups.

Notes: It is critical that the "stability" of yield groups be addressed. Yield groups are defined from the mapped inventory label for each stand in the FMA area, as yield estimates must be linked to the inventory. However, at the time of the Operational Silviculture Surveys, provisional estimates of species composition and crown closure will have to be checked against the photo-interpreted inventory calls when they become available. Long term monitoring of the stability of the yield groups can be addressed by developing algorithms to assign OPS data to yield groups appropriately.

8. Future stand-level growth and yield models will need to include density as an independent variable.

Notes: Volume-height equations in the DFMP were developed from TSPs located in fire-origin natural stands, therefore these equations could over-or under-estimate volumes in regenerated stands, depending on whether the stands are under-or over-stocked. It may also be necessary to consider the incorporation of initial stocking into the modeling approach in the future. This would enable silviculture personnel to establish performance standards that need to be met to put a particular regenerated stand on a projected growth trajectory. This could be achieved either with: (1) the estimation of change in stocking with age or top height development, which would allow initial stocking probabilities to be incorporated directly into the two-stage model as an independent variable; or (2) relating stocking at the time of the performance survey to conventional stand variables and indices (basal area, density etc.) and adding these variables to the two-stage model.

9. Link PSP data, TSP data and operational silviculture survey data to a silviculture record management system.

Notes: To aid in tracking conformance, the information on PSPs must be linked to operational silviculture surveys and block treatment information in order to better evaluate growth and yield information. As PSPs are currently located by GPS, spatial linkage of plots to regenerated blocks and treatments could be done from within the forestry information system.

10. Identify 'holes' in the current PSP data and develop strategy for the establishment of new plots.

Notes: Canfor's PSP program is based on a stratified random sampling scheme. Changing regeneration strategies, changing yield group definitions and new inventories necessitate the review of the distribution of PSPs from time to time. Identifying strata with insufficient number of plots help develop a strategy where to establish new PSPs. Such strategy is based on not only the statistical representativeness, but also on the efficient use of available resources and the size and importance of the strata.

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Appendices

Appendix I

Preliminary PSP Analysis

Canadian Forest Products Ltd.
Grande Prairie Operations

Permanent Sample Plot Summary

June 29, 2001

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1. Data

The PSP database consists of 174,969 tree measurements being made in 805 unique PSP's between 1977 and 1997. In total, 1,509 were included in the database with 704 of the plot records being re-measurements. Because of linkage problems to Alberta Vegetation Inventory (AVI) data, 13 measurements were excluded, leaving 1,496 plot measurements and 173,939 tree measurements for compilation.

Report # 4 of the document "*Growth and Yield Information Package – Detailed Forest Management Plan 1999 Volume1*", Canfor June 1999, summarizes the data compilation procedures that were applied before the development of the multiple utilization stand yield tables. This document explains how to compile inventory databases based on Temporary Sample Plot (TSP) and Permanent Sample Plot (PSP) data.

2. PSP Data Summary

A summary was prepared for the latest measurement date for the 805 PSPs (Table 1). The summary contains the following data : PSP ID, Rotation, Last Measurement Date, Last Measurement Year, Number of Measurements, Meridian, Range, Township, LSD, Section, Stand Origin, Tree Plot Size, FMA PSP ARCLINK, Map Overstorey, Map Understorey, Natural Subregion, Yield Group and Yield Strata.

Table 1

Number of PSP's by Rotation

Number of Unique PSPs		
Rotation 1 only	**Rotation 2♣ only**	**Both Rotations**
736	35	34

Altogether there are 805 PSP locations. Measurements on these plot locations were divided into Rotation 1 and Rotation 2. Rotation 1 means that the measurement was on the original stand (before harvest). Rotation 2 means that the measurement is on a stand that was disturbed by harvesting. For 34 PSP's there were measurements done in Rotation 1 and Rotation 2.

An example of the PSP Summary is shown in Appendix I.

3 Number of Plots and Measurement Summaries

3.1 Relative number of plots (PSP's) by Yield Group and Natural Subregion compared to relative area (ha) by Yield Group and Natural Subregion in the Canfor FMA:

This comparison was done in order to find out if the number of PSP's by Yield Group and Natural Subregion actually represent the relative area by Yield Group and Natural Subregion in the Canfor FMA.

Table 2 shows the number and percentage of PSP's by Yield Group and Natural Subregion.

♣ PSPs measured in areas disturbed by harvesting.

Table 2

Number and Percentage of PSP's by Yield Group and Natural Subregion

Yield Group (1-17)	Data	Natural Subregion						Total
		CM	DM	LF	SA	UF	PRP	
0	**# of Plots**	19	10	46		12		**87**
	Percentage	21.8	11.5	52.9	0.0	13.8	0.0	**100.0**
1	**# of Plots**	24	4	12		1		**41**
	Percentage	58.5	9.8	29.3	0.0	2.4	0.0	**100.0**
2	**# of Plots**	73	42	26		2		**143**
	Percentage	51.1	29.4	18.2	0.0	1.4	0.0	**100.0**
3	**# of Plots**	15	5	15		2		**37**
	Percentage	40.5	13.5	40.5	0.0	5.4	0.0	**100.0**
4	**# of Plots**	10	1	5				**16**
	Percentage	62.5	6.3	31.3	0.0	0.0	0.0	**100.0**
5	**# of Plots**	1		14	1	9		**25**
	Percentage	4.0	0.0	56.0	4.0	36.0	0.0	**100.0**
6	**# of Plots**	40	4	20				**64**
	Percentage	62.5	6.3	31.3	0.0	0.0	0.0	**100.0**
7	**# of Plots**	17	1	7				**25**
	Percentage	68.0	4.0	28.0	0.0	0.0	0.0	**100.0**
8	**# of Plots**	4	10	27	13	41		**95**
	Percentage	4.2	10.5	28.4	13.7	43.2	0.0	**100.0**
9	**# of Plots**	3	5	19		5		**32**
	Percentage	9.4	15.6	59.4	0.0	15.6	0.0	**100.0**
10	**# of Plots**	2		5	2	1		**10**
	Percentage	20.0	0.0	50.0	20.0	10.0	0.0	**100.0**
11	**# of Plots**		1	14	2	13		**30**
	Percentage	0.0	3.3	46.7	6.7	43.3	0.0	**100.0**
12	**# of Plots**	13	5	34	2	8		**62**
	Percentage	21.0	8.1	54.8	3.2	12.9	0.0	**100.0**
13	**# of Plots**	10	5	5	1	1		**22**
	Percentage	45.5	22.7	22.7	4.6	4.6	0.0	**100.0**
14	**# of Plots**	4		12	4	9		**29**
	Percentage	13.8	0.0	41.4	13.8	31.0	0.0	**100.0**
15	**# of Plots**	12	3	25		12		**52**
	Percentage	23.1	5.8	48.1	0.0	23.1	0.0	**100.0**
16	**# of Plots**	14	3	16		2		**35**
	Percentage	40.0	8.6	45.7	0.0	5.7	0.0	**100.0**
17	**# of Plots**	20	2	11		1		**34**
	Percentage	58.8	5.9	32.4	0.0	2.9	0.0	**100.0**
Total :	**# of Plots**	**281**	**101**	**313**	**25**	**119**	**0**	**839**
Total :	**Percentage**	**33.5**	**12.0**	**37.3**	**3.0**	**14.2**	**0.0**	**100.0**

Table 3 shows the actual area and percentage by Yield Group and Natural Subregion for the FMA.

Table 3

Actual Area and Percentage by Yield Group and Subregion for the FMA Area

Yield Group (1-17)	Data	Natural Subregion						Total
		CM	DM	LF	SA	UF	PRP	
0	Area (ha)	26915	10021	15222	607	3625	474	**56864**
	Percentage	47.3	17.6	26.8	1.1	6.4	0.8	**100.0**
1	Area (ha)	10942	2776	4498	12	1018	137	**19383**
	Percentage	56.5	14.3	23.2	0.1	5.2	0.7	**100.0**
2	Area (ha)	56709	27123	18963	39	3216	1303	**107353**
	Percentage	52.8	25.3	17.7	0.0	3.0	1.2	**100.0**
3	Area (ha)	12248	2112	15678	7	1889	119	**32053**
	Percentage	38.2	6.6	48.9	0.0	5.9	0.4	**100.0**
4	Area (ha)	5973	1284	8080		106	6	**15449**
	Percentage	38.7	8.3	52.3	0.0	0.7	0.0	**100.0**
5	Area (ha)	178	6	4100	367	3795		**8445**
	Percentage	2.1	0.1	48.5	4.3	44.9	0.0	**100.0**
6	Area (ha)	32723	3237	16757	7	682	54	**53460**
	Percentage	61.2	6.1	31.3	0.0	1.3	0.1	**100.0**
7	Area (ha)	20082	2717	4888	2	21		**27709**
	Percentage	72.5	9.8	17.6	0.0	0.1	0.0	**100.0**
8	Area (ha)	3525	4275	14599	4749	25939		**53088**
	Percentage	6.6	8.1	27.5	8.9	48.9	0.0	**100.0**
9	Area (ha)	2684	2052	11901	121	2843	2	**19602**
	Percentage	13.7	10.5	60.7	0.6	14.5	0.0	**100.0**
10	Area (ha)	484	189	4374	966	4606		**10618**
	Percentage	4.6	1.8	41.2	9.1	43.4	0.0	**100.0**
11	Area (ha)	1026	767	9162	1254	10937		**23145**
	Percentage	4.4	3.3	39.6	5.4	47.3	0.0	**100.0**
12	Area (ha)	15083	3815	27909	1693	8688		**57187**
	Percentage	26.4	6.7	48.8	3.0	15.2	0.0	**100.0**
13	Area (ha)	11340	6279	7852	1513	3032		**30017**
	Percentage	37.8	20.9	26.2	5.0	10.1	0.0	**100.0**
14	Area (ha)	2281	323	8782	1386	6132		**18904**
	Percentage	12.1	1.7	46.5	7.3	32.4	0.0	**100.0**
15	Area (ha)	8811	1851	12643	521	6097	59	**29981**
	Percentage	29.4	6.2	42.2	1.7	20.3	0.2	**100.0**
16	Area (ha)	13728	2890	16127	470	3140	131	**36486**
	Percentage	37.6	7.9	44.2	1.3	8.6	0.4	**100.0**
17	Area (ha)	18325	3231	24734	0	3038	88	**49416**
	Percentage	37.1	6.5	50.1	0.0	6.1	0.2	**100.00**
Total	**Area (ha)**	**243057**	**74948**	**226268**	**13713**	**88801**	**2373**	**649160**
Total	**Percentage**	**37.4**	**11.5**	**34.9**	**2.1**	**13.7**	**0.4**	**100.0**

The following table (Table 4), shows the difference (Percentage) in PSP allocation (number of plots), compare to the actual area of the FMA Area.

Table 4

Difference in Plot Allocation Number of PSP's vs. Actual FMA Area

Yield Group (1-17)	Natural Subregion					
	CM	**DM**	**LF**	**SA**	**UF**	**PRP**
0	-25.5	-6.1	26.1	-1.1	7.4	-0.8
1	2.1	-4.6	6.1	-0.1	-2.8	-0.7
2	-1.8	4.1	0.5	0.0	-1.6	-1.2
3	2.3	6.9	-8.4	0.0	-0.5	-0.4
4	23.8	-2.1	-21.1	0.0	-0.7	0.0
5	1.9	-0.1	7.5	-0.3	-8.9	0.0
6	1.3	0.2	-0.1	0.0	-1.3	-0.1
7	-4.5	-5.8	10.4	0.0	-0.1	0.0
8	-2.4	2.5	0.9	4.7	-5.7	0.0
9	-4.3	5.2	-1.3	-0.6	1.1	0.0
10	15.4	-1.8	8.8	10.9	-33.4	0.0
11	-4.4	0.0	7.1	1.2	-3.9	0.0
12	-5.4	1.4	6.0	0.3	-2.3	0.0
13	7.7	1.8	-3.4	-0.5	-5.6	0.0
14	1.7	-1.7	-5.1	6.5	-1.4	0.0
15	-6.3	-0.4	5.9	-1.7	2.7	-0.2
16	2.4	0.7	1.5	-1.3	-2.9	-0.4
17	21.7	-0.7	-17.7	0.0	-3.2	-0.2
Total :	**-3.9**	**0.5**	**2.5**	**0.9**	**0.5**	**-0.4**

The plot allocation difference, shown in the Table 4 above, is the PSP distribution percentage (Table 2) compared with the actual FMA area distribution percentage (Table 3). For example, YG 4 NSR CM (Table 4), shows that the current PSP distribution (62.5% in Table 2), over-represents the actual FMA YG 4 NSR CM area distribution (38.7% in Table 3) by 23.8 %.

3.2 Number of PSP Measurements by Year

For all PSP's (805) the overall number of measurements was 1,496. This includes multiple Measurements (e.g. M1, M2 and M3), and different Rotations (e.g. R1 or R2) for each PSP.

Table 5 shows the number of PSP measurements by Year. The latest measurement year was 1997.

Table 5

Number of PSP Measurements by Year

Measurement Year	# of Measurements
1977	2
1979	16
1980	17
1981	96
1982	16
1983	14
1984	21
1985	71
1986	114
1987	118
1988	59
1989	65
1990	69
1991	38
1993	161
1994	127
1995	173
1996	165
1997	153
N/A	1
Total :	**1496**

3.3 Average Measurement Cycle

Of the 839 PSP's (Rotations 1and 2), 653 plots were re-measured once, 3 plots were re-measured twice. 183 plots were not re-measured.

For the re-measured plots, the average re-measurement cycle was 8.92 Years.

3.4 Average Measurement Cycle by Inventory Age Class

For the re-measured plots (as shown in 3.c.), the Inventory Age was assigned. Some of the re-measured plots didn't have an Inventory Age value. The Inventory Age was assigned at the point of re-measurement e.g. if a plot was measured in 1988 (M1) and re-measured in 1996 (M2), the Inventory Age was assigned for M2 in 1996. After that, the Inventory Age was grouped into Inventory Age Classes. The classes are divided in 20 year steps (Class 1-20, 21-40, 41-60 and so on).

Table 6, shows the average re-measurement cycle by Inventory Age Class.

Table 6

Average Re-Measurement Cycle by Inventory Age Class

Inventory Age Class (Years)	# of Measurements *	Re-Measurement Cycle (Years)
1-20	13	6.00
21-40	15	7.00
41-60	122	7.32
61-80	109	9.65
81-100	165	9.59
101-120	109	9.03
121-140	42	9.05
141-160	34	9.21
161-180	5	8.20
181-200	3	6.67
201-220	6	8.17
221-240	1	11.00
Total	**624**	**8.83**

* = Not all of the 656 re-measurements had an Inventory Age assigned.

3.5 Number of Plots (Percentage) by Yield Group and Re-Measurement Period

This summary (Table 7) shows for each Yield Group the percentage of re-measured plots by re-measurement period (0-5 Years, 6-10 Years, 11-15 Years and 16-20 Years re-measurement interval).

3.6 PSP Measurement Schedule

For all 839 PSP's (Rotation 1 and 2), a table was created that shows the latest measurement, the year when the next measurement is due and the time lag between the due date and the latest measurement. This summary is done with available PSP data up to the Year 1997. Table 8 shows an example of that summary.

Table 7
Percentage of Re-Measured Plots by Re-Measurement Period

YG	Data	Re-Measurement Period (Years)				Total
		0-5	6-10	11-15	16-20	
0	# of Plots	2	11	13	3	**29**
	% of Plots	3.1	26.7	55.2	15.1	**100.0**
1	# of Plots	10	9	3	8	**30**
	% of Plots	15.1	24.0	15.1	45.9	**100.0**
2	# of Plots	15	41	41	17	**114**
	% of Plots	5.8	26.2	45.0	23.0	**100.0**
3	# of Plots	9	19	4	2	**34**
	% of Plots	15.7	53.7	19.2	11.4	**100.0**
4	# of Plots	2	3	5	1	**11**
	% of Plots	7.1	19.5	59.3	14.2	**100.0**
5	# of Plots	4	9	6	0	**19**
	% of Plots	12.7	43.3	44.0	0.0	**100.0**
6	# of Plots	13	25	12	2	**52**
	% of Plots	11.7	42.4	38.8	7.2	**100.0**
7	# of Plots	3	6	11	2	**22**
	% of Plots	5.0	19.4	62.4	13.2	**100.0**
8	# of Plots	32	48	6	1	**87**
	% of Plots	25.8	59.0	12.5	2.8	**100.0**
9	# of Plots	5	20	2	1	**28**
	% of Plots	11.9	69.3	10.9	7.9	**100.0**
10	# of Plots	1	8	0	1	**10**
	% of Plots	5.8	75.9	0.0	18.4	**100.0**
11	# of Plots	11	14	2	0	**27**
	% of Plots	29.2	58.9	11.9	0.0	**100.0**
12	# of Plots	8	23	18	1	**50**
	% of Plots	8.0	38.2	50.3	3.5	**100.0**
13	# of Plots	0	2	12	1	**15**
	% of Plots	0.0	9.0	82.6	8.4	**100.0**
14	# of Plots	6	11	6	1	**24**
	% of Plots	14.5	44.0	33.8	7.7	**100.0**
15	# of Plots	10	23	8	1	**42**
	% of Plots	13.8	50.6	31.1	4.5	**100.0**
16	# of Plots	3	20	8	1	**32**
	% of Plots	4.5	55.1	34.9	5.5	**100.0**
17	# of Plots	6	20	3	1	**30**
	% of Plots	11.7	64.8	17.0	6.5	**100.0**
Total # of Plots :		**140**	**312**	**160**	**44**	**656**
Total % of Plots :		11.0	40.7	36.0	12.2	100.0

Table 8

Example - PSP Measurement Schedule

Yield Group (1-17)	PSP_ID	Rotation	Last Measurement	Last Measurement Year*	Number of Measurements	Next Measurement Due**	Difference since Due Date (Years)
4	G3101NW	1	24-Apr-79	1979	1	1989	-12
6	G1724NW	1	08-Jan-81	1981	1	1991	-10
0	G0822NE	1	27-Jan-81	1981	1	1991	-10
0	G1522NE	1	11-Aug-81	1981	1	1991	-10
0	G1524NW	1	15-Sep-81	1981	1	1991	-10
2	G0906NE	1	23-Oct-81	1981	1	1991	-10
7	G0904NW	1	20-Nov-81	1981	1	1991	-10
17	G0916SW	1	26-Nov-81	1981	1	1991	-10
13	G0922NE	1	14-Dec-81	1981	1	1991	-10
6	G0903NE	1	06-May-82	1982	1	1992	-9
13	G0924NW	1	11-May-82	1982	1	1992	-9
1	G2822NE	1	19-Jan-83	1983	1	1993	-8
15	G2713SW	1	17-Feb-83	1983	1	1993	-8
12	G1501NW	1	19-Jan-84	1984	1	1994	-7
11	S252401	1	01-Sep-84	1984	1	1994	-7

* = PSP's were updated last in 1997
** = Assuming Max. 10 Year Measurement Cycle for Fire Origin PSP's
Assuming Max. 5 Year Measurement Cycle for Regenerated PSP's

As of PSP data from 1997, this Year (2001) there are 126 plots due for re-measurement.

An additional table (Table 9 next page) was created that summarizes for each Yield Group the number of plots to be re-measured by due period (years).

Table 9

Number of plots to be re-measured by Yield Group and Due Period (Years)

Yield Group	Years since Due Date and Present (2001)																		Total # of Plots
	-12	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	
0		3			1	5	9	5	3	16	12	1	2	2	5	6	8	9	**87**
1				1			1	1	2	5	2		1	7	4	1	7	9	**41**
2		1					2		2		1			27	12	27	41	30	**143**
3									3	1				6	6	8	3	10	**37**
4	1					1				1				3	2	3	2	3	**16**
5							2	1	3	3				1	2	4	3	6	**25**
6		1	1				1		1		1			14	11	13	14	7	**64**
7		1												2	4	5	7	6	**25**
8							1		1	1		2	1	26	13	17	21	12	**95**
9						1			2					11	1	7	6	4	**32**
10														3	3	2	2		**10**
11					1		1		1	1				5	1	3	14	3	**30**
12					1									11	9	25	6	10	**62**
13		1	1							1				3	2	3	2	9	**22**
14							1							7	2	8	3	8	**29**
15				1		1		1	2	3	2	1		6	7	10	15	3	**52**
16									1					3	7	12	4	8	**35**
17		1							1					4	7	5	4	12	**34**
Total	**1**	**8**	**2**	**2**	**3**	**8**	**18**	**8**	**22**	**32**	**18**	**4**	**4**	**141**	**98**	**159**	**162**	**149**	**839**

Appendix i

Example PSP Summary

Example PSP Summary

PSP_ID	Rotation	Last Measurement	Last Measurement Year	Number of Measurements	Next Measurement Due	Meridian	Range	Township	LSD	Section	STAND ORIGIN	Tree Plot Size	FMA PSP ARCLINK	Map Overstorey	Map Understorey	Natural Subregion	Yield Group (1-17)	Yield Strata (1-40)
E600112	1	08-Aug-96	1996	2	2006	6	5	60	12	01	1910	0.08	6.0056E+13	C16Pl 9Sw1 0 0 0		UF	11	26
E600201	1	29-Jul-96	1996	2	2006	6	5	60	01	02	1900	0.08	6.0056E+13	D20Pl10 0 0 0 0		UF	8	18
E600211	1	29-Jul-96	1996	2	2006	6	5	60	11	02	1940	0.08	6.0056E+13	B13Pl 7Aw2Sw1 0 0	2 0 0 0 0 0	UF	8	19
E610101	1	22-Jul-96	1996	2	2006	6	4	60	01	01	1910	0.08	6.0046E+13	C17Pl 9Sb1 0 0 0	A10Sb 9Pl1 0 0 0	SA	8	19
E610201	1	30-Jul-96	1996	2	2006	6	4	60	01	02	1900	0.1	6.0046E+13	B 9Sb 7Sw2Pl1 0 0		SA	14	31
E610303	1	07-Aug-96	1996	2	2006	6	4	60	03	03	1900	0.08	6.0046E+13	C22Pl10 0 0 0 0		UF	8	18
E610701	1	28-Jul-96	1996	2	2006	6	4	60	01	07	1900	0.08	6.0046E+13	D22Pl 9Sw1 0 0 0		UF	11	25
E610915	1	27-Jul-96	1996	2	2006	6	4	60	15	09	1910	0.08	6.0046E+13	C17Pl 9Sw1 0 0 0		UF	11	26
E611101	1	21-Jun-94	1994	2	2004	6	4	60	01	11	1900	0.1	6.0046E+13	A15Sb 9Pl1 0 0 0	B10Sb 8Pl2 0 0 0	SA	12	28
E611401	1	22-Jun-94	1994	2	2004	6	4	60	01	14	1900	0.08	6.0046E+13	C21Pl10 0 0 0 0		SA	8	18
E611601	1	27-Jul-96	1996	2	2006	6	4	60	01	16	1900	0.08	6.0046E+13	B21Sw 7Pb2Pl1 0 0		UF	15	32
E611701	1	28-Jul-96	1996	2	2006	6	4	60	01	17	1940	0.1	6.0046E+13	B15Sw 5Pl3Aw2 0 0		UF	11	26
E612101	1	13-Aug-96	1996	2	2006	6	4	60	01	21	1900	0.08	6.0046E+13	C23Sw 6Pb3Fb1 0 0		UF	17	38
E612810	1	22-Nov-91	1991	1	2001	6	4	60	10	28	1900	0.08	6.0046E+13	C17Pl 8Sb1Aw1 0 0		UF	8	19
E620901	1	14-Aug-96	1996	2	2006	6	3	60	01	09	1900	0.08	6.0036E+13	C18Pl10 0 0 0 0		UF	8	19
E621701	1	14-Aug-96	1996	2	2006	6	3	60	01	17	1900	0.1	6.0036E+13	B24Pl 8Sw1Aw1 0 0		UF	8	18
E622801	1	24-Jun-94	1994	3	2004	6	3	60	01	28	1900	0.08	6.0036E+13	C22Pl10 0 0 0 0		UF	8	18

Appendix II

Glossary of Acronyms

AAC	Annual Allowable Cut
ACE	Allowable Cut Effect
AOP	Annual Operation Plan
ARIS	Alberta Regeneration Information System
AVI	Alberta Vegetation Inventory
BH	Breast Height
CFI	Continuous Forest Inventory
CSA	Canadian Standards Association
CWD	Coarse Woody Debris
DFMP	Detailed Forest Management Plan
ECA	Equivalent Clearcut Area
EFM	Enhanced Forest Management
EST	Establishment Survey
FDP	Forest Development Plan
FMA	Forest Management Agreement
FRIAA	Forest Resource Improvement Association of Alberta
FTG	Free-to-Grow
GDC	Geographic Dynamics Corporation
GI	Growth Intercept
GP	Grande Prairie
GYIP	Growth and Yield Information Package
GYMP	Growth and Yield Monitoring Program
GYPSY	Growth and Yield Projection System
GYS	Growth and Yield System
HSI	Habitat Suitability Index
IUFRO	International Union of Forestry Research Organizations
JUSI	Juvenile Site Index
LFS	Alberta Land and Forest Service
MGM	Mixedwood Growth Model
NIVMA	Northern Interior Vegetation Management Association
NFI	National Forest Inventory
ORM	Olympic Resource Management
PSP	Permanent Sample Plot
SFMP	Sustainable Forest Management Plan
SI	Site Index
SPS	Stand Prognosis System
SRMS	Silviculture Records Management System
TIPSY	Table Interpolation Program for Stand Yield Information
TSA	Timber Supply Analysis
TSP	Temporary Sample Plot
NSR	Natural Subregion
OPS	Operational Surveys
OS	Overstorey
US	Understorey
WESBOGY	Western Boreal Growth and Yield Association
YG	Yield Group