BRITISH COLUMBIA

July 15, 2005

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To All Interested Individuals

Re: **Strategies for Forest Inventory and Monitoring in MPB Areas**

I am pleased to present 'Strategies for Forest Inventory and Monitoring in MPB Areas', a report (attached) that is the result of significant effort. It brings together information from a large number of individuals who have provided important insight into the development of the strategy statements and conclusions.

To date, this work has had two project sponsors – Melanie Boyce, Director, Forest Analysis Branch, Ministry of Forests and Range, and Fern Schultz, Director, Resource Information Branch, Ministry of Agriculture and Lands. The BC government recently transferred its forest inventory function to the Ministry of Forests and Range where most positions have become part of Melanie's newly named Forest Analysis and Inventory Branch.

I would like to take this opportunity to thank Fern Schultz for her leadership and valuable contribution to this project, and also thank everyone who attended the March workshops, provided input and helped to develop the report.

The transfer of the inventory function will help to strengthen the link between forest analysis and forest inventory, and will no doubt benefit the future work as outlined by the consulting team in the report's conclusions. In her continuing role as project sponsor, Melanie has extracted the following key points from these conclusions:

Leadership and communication

- There is an urgent need to collect new data, with coordination through a new Technical-Business Advisory Group to ensure an efficient and effective inventory strategy is created. The group should communicate with a broad audience and develop an accessible list of all relevant inventory activities.

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Standards

- A new approach to forest inventory should be developed that allows for different sampling plans and different standards, which are responsive to the dynamics of the MPB infestation. For example, some new data sets should be developed that can capture updated information on a yearly basis.

Business requirements

- Four areas must be examined to ensure all business needs are considered:
    1) the location and extent of the mortality;
    2) the volume and value of attacked stands;
    3) corporate decisions such as AAC uplifts, which areas should be harvested or not, and silviculture strategies, and
    4) technical matters such as database structures and modelling requirements.

Given the urgency to gather new and improved forest inventory information, Melanie and her team have started to implement aspects of the report, for example:

- a new adaptive VRI pilot is being developed for the Quesnel TSA;

- testing a new dataset has begun in two areas that reports mountain pine beetle mortality (year of red attack and severity) using yearly satellite imagery;

- a small task group has started high-level discussions regarding strategies to consider how various types of imagery might be applicable to the strategy, and

- an inter-agency team has been established to coordinate the forest inventory-related activities, and from this, some specific technical working groups will be developed to move the work forward in various areas.

There is still much to do but I am confident 'Strategies for Forest Inventory and Monitoring in MPB Areas' provides the strategic framework we need to undertake necessary activities and possibly transform our approaches to forest inventory in the MPB-affected areas.

Yours truly,

Jim Snetsinger, RPF
Chief Forester

Attachment: *Strategies for Forest Inventory and Monitoring in MPB Areas*

Strategies for Forest Inventory and Monitoring in Mountain Pine Beetle Areas

Forest Analysis Branch
BC Ministry of Forests

Prepared for and Co-Championed by:

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Prepared by:

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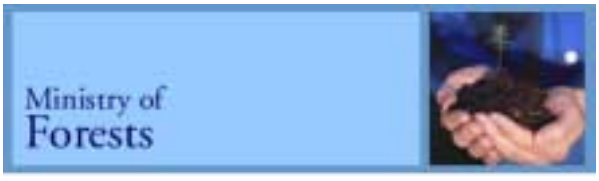

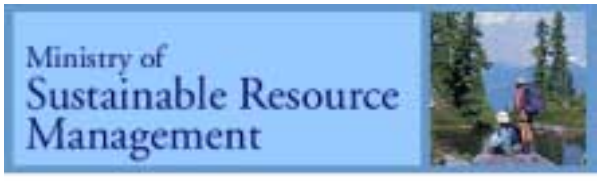

June 17, 2005

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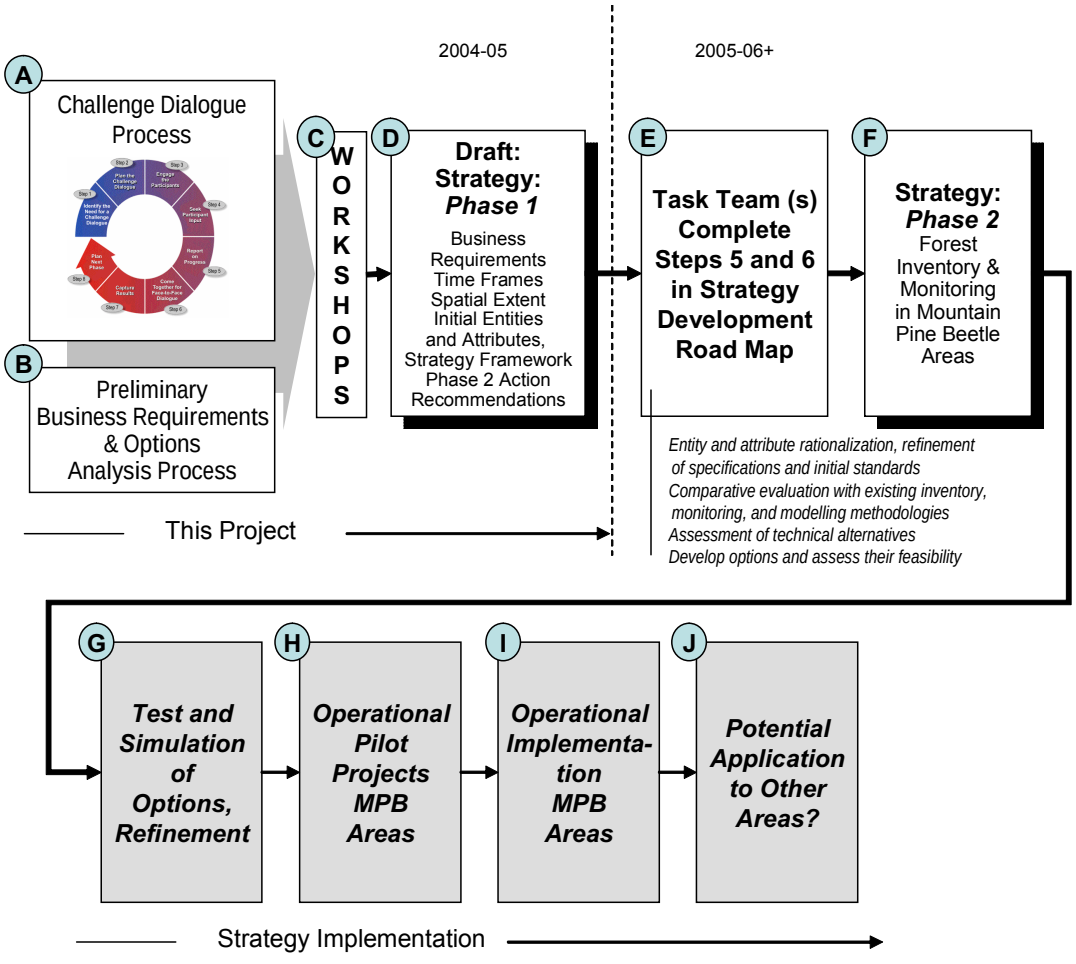
Context

The current mountain pine beetle epidemic is affecting the structure of forests in central BC to a degree that has never been experienced before. About 13 million ha of lodgepole pine and mixed-pine forestland are estimated to have been attacked so far, and there is no sign that the epidemic will abate before the majority of mature pine in the province has been killed.

Forest managers are responding to the infestation, but the existing inventory, growth and yield modelling and monitoring approaches are not designed to provide the type of information needed for rapid, informed decision-making. In particular, the timing of forest resource updates and the dynamics of stands affected by the mountain pine beetle are critical factors for both industry and government timber supply decision-making.

Assuming that the epidemic will continue, MoF and MSRM are developing a strategic plan for forest inventory and monitoring in mountain pine beetle areas. This document reports on the first phase of the strategy development process. The main steps in the process are illustrated below.



Challenge Dialogue System

The Challenge Dialogue System was used as a methodology to engage stakeholders in the strategy development process. Essentially, a Challenge Paper was developed containing background information, assumptions and key questions on the problem, together with a Key Challenge Statement; the Paper was circulated to stakeholders with an invitation for structured comments; a mini-workshop was held with stakeholders in Prince George; the Challenge Paper comments were used to help inform a two-day strategy development Workshop in Vancouver (Richmond) which was guided by a Workshop Workbook; finally, the workshop outcome was reported. Additional input into the process was received from the Quesnel TSA in the form of notes on their business drivers for updated inventory information – see Appendix 6.

Products to date include a *Challenge Paper*, an *As-Is Response Compilation,* a *Workshop Workbook*, a *Preliminary Synthesis of Challenge Paper Feedback – Selected Key Responses*, and *Strategy Workshops: Record and Outputs*. These documents contain a considerable volume of information relevant to the issues in question.

The Key Challenge

In developing the strategy the key question is "*What is it specifically about the mountain pine beetle event that is causing us to have to rethink BC's approach to the inventory and monitoring of the forest in the affected and adjacent areas?*" This question arises because of four factors specific to the mountain pine beetle event that create a unique challenge regarding the acquisition and use of resource information:

- The need for *timely* delivery of critical information to inform harvest planning and salvage operations - the beetle is affecting the timber resource at rate that conventional inventory approaches cannot accommodate.

- The need to characterize what are essentially dead or dying individual trees, forest stands, and groups of stands.

- The effects of this forest condition on spatially and temporally explicit strategic and tactical forest planning and, in particular, the need to understand the mid-term timber supply implications.

- Post-event monitoring challenges for both the live forest (in terms of survival, growth and regeneration) and the affected forest (in terms of mortality and decay rates).

Building on this question, the Key Challenge was defined as follows:

The development of a strategic plan for forest inventory and monitoring activities in and around mountain pine beetle areas that meets the short and long term business needs of government agencies, the forest industry and other key stakeholders. The plan must:

1. **consider the information requirements of forest managers;**
2. **consider the information requirements of the Chief Forester for AAC determinations;**
3. **consider the information requirements for management for other forest and resource values by government, industry and communities;**
4. **address short, medium and long term information requirements;**
5. **be achievable in appropriate timeframes;**
6. **reflect the urgency of the problem and the scale of the assets at risk.**

Developing the Strategy

The Vancouver workshop identified five priority business areas in urgent need of improved inventory and monitoring information:

- Timber Supply and AAC uplift determinations
- Harvest scheduling
- Silviculture and regeneration
- Forest health
- Declining asset values

For each of these business areas, (i) a series of key questions were developed in conjunction with the associated needs timeframes and spatial considerations, and (ii) data entities and attributes were identified which would be needed to generate the information needed to answer the key questions. From these lists, common entities and attributes were identified across all five business areas, many consistent with VRI/NFI attributes. Importantly, whilst the attributes were common across the entities, the timing requirements for the acquisition of these attributes varied significantly. A final step carried out by the project team was identification of the generic approach to data acquisition (inventory, monitoring, update, modelling) appropriate to answering each key question and a preliminary identification of method (Tables 2.1 - 2.5 in main report).

Draft Strategy Framework

The draft strategy framework is presented as a series of four types of table in the main report. In this synopsis, the strategy framework overview table has been simplified, as follows (Table S1):

Table S1: Strategy Framework - Overview

BUSINESS AREA	TIMEFRAME			APPROACH			
Key Questions	Immediate	Medium	Long	Inventory	Monitoring	Update	Modelling
Timber Supply (AAC Uplift)							
1. Location, extent, severity, timing Information							
1a. Where is the current MPB infestation (last 2 years green/red attack, extent, severity)?	●	●		●	Imagery + Ground	●	
1b. Where are the past MPB infested areas (extent, severity, date, for last 5 years)?	●	●	●	●	Imagery + Ground	●	●
1c. Where is the MPB likely to be found next (where is it going)?		●	●	●			●
1d. How long will the infestation last (10 more years/ 20 more years)?	●	●	●				●
2. Depletion Information							
2a. How much volume has been killed?	●	●	●	●	Imagery + Ground	●	
2b. How much volume has been salvaged?	●	●	●	●	Imagery + Ground	●	
2c. How much volume can be salvaged and for what products (shelf life)?	●	●	●	●			●
2d. How much green volume will be removed with salvage?	●	●		●	Ground	●	
3. Allocation / Calculation Base							
3a. What administrative unit should the uplift calculations be based on (TSA, district)?	●	●	●	●			●
3b. Should uplift be based on THLB or total landbase in the management unit?	●	●	●	●			●
4. Depletion Update							
4a. How frequently does the AAC uplift need to be reviewed / recalculated?	●	●	●	●	●	●	
5. Impact on Existing Inventory, Databases, IT Systems							

BUSINESS AREA	TIMEFRAME			APPROACH			
Key Questions	Immediate	Medium	Long	Inventory	Monitoring	Update	Modelling
5a. What is the impact of these new information requirements on the supporting databases, inventory systems, IT structures?	●			●	●	●	●
6. Growth & Yield							
6a. How do we model growth of affected stands?		●	●	●			●
Harvest Scheduling							
1. What is the current inventory of merchantable timber in stands, by species?	●	●		●	●	●	
2. What is the level of pine mortality for the district?	●	●	●	●	●	●	
3. Where is the mortality occurring?	●	●		●	●	●	
4. What was the year of main mortality in merchantable stands for the district (when did the clock start ticking)?	●	●		●	●	●	
5. What is the rate at which affected stands will deteriorate?	●	●		●	●	●	●
6. When will affected stands be unmerchantable?	●	●		●	●	●	●
Silviculture/Regeneration							
1. Where are the areas that have been killed by the MPB? What is the location and extent of the non-harvested MPB killed stands?	●	●	●	●	●	●	
2. What is the presence and condition of the understorey; of the young stand?	●	●	●	●	●	●	
3. Is there regeneration present? And if so how much is present? (Presence/condition of understorey / young stand)	●	●	●	●	●	●	
4. What is the residual volume?	●	●	●	●			

BUSINESS AREA	TIMEFRAME			APPROACH			
Key Questions	Immediate	Medium	Long	Inventory	Monitoring	Update	Modelling
5. What is the site productivity potential; is it worth treating? (Residual volumes / site productivity)	●	●	●	●			●
6. What is the growth potential of existing regeneration and of residuals? What is the regeneration delay; when will we get regeneration (artificial vs. natural)?	●	●	●	●	●		●
7. What are the characteristics (species) of the future regeneration?[1]	●	●	●				●
8. Do we have adequate models?	●	●	●				●
9. Do we have data for modelling? What model building data is required?	●	●	●				●
Forest Health							
1. Which pathogen?	●	●	●	●	●	●	
2. Which species is the pathogen affecting?	●	●	●	●	●	●	
3. What is the severity of the infestation?	●	●	●	●	●	●	
4. Where is the infestation?	●	●	●	●	●	●	
5. When did the infestation occur?	●	●	●	●	●	●	
6. What is the rate of spread of the infestation (both within and between stands)?	●	●	●	●	●	●	●
7. What are the characteristics of the infestation / spread? (Immediate + periodic updates, 3-5 yrs)	●	●	●	●	●	●	
Declining Asset Value							
1. How do we determine the pre-MPB forest asset value?	●	●		●			●
2. How do we determine and describe the dynamics of the value decline?	●	●		●			●

[1] Does not include forest health issues

BUSINESS AREA	TIMEFRAME			APPROACH			
Key Questions	Immediate	Medium	Long	Inventory	Monitoring	Update	Modelling
3. How we determine the post-MPB forest asset value?	●	●		●			●

Resource Information Themes

In addition to looking at data needs from a business requirements perspective, it is also useful to consider a resource information themes viewpoint. Tables 2 and 4 in the Strategy Framework section provide a list of key questions for each of the five priority business areas as defined during the Vancouver workshop. Many of the key questions found in each business area can be aggregated to form resource information themes or categories. These themes can assist in defining data acquisition priorities and in determining the task teams that will complete the next steps (Steps 5 and 6 of the ***Workshop and Workbook "road map"***) of the strategy development process depicted in the figure in the Context section of this Synopsis. The task teams should also be responsible for identifying and assessing technical alternatives and feasible options for operational testing of different components of the "MPB Resource Information System".

Table S2 identifies four potential resource information themes that share key questions for the five business areas. Following each question in Table S2 is a one or two-letter code combined with a number in parentheses identifying the business area and key question within that business area. For example, a code "S-1" refers to the first key Silviculture business area question identified during the Vancouver Workshop.

Four main themes are defined:

- **Location and Extent**
- **Volume and Value**
- **Corporate Decisions**
- **Technical Considerations.**

- **Location and Extent Theme**

  This theme aggregates similar questions where clear evidence of MPB attack and the time of attack occurrence is necessary to answer the question. The theme of questions is further subdivided into a) current (inventory) and b) where the infestation will spread in the future.

  For the current (inventory) sub-theme, a set of standard forest/vegetation attributes, including information on regeneration and productivity, are ascribed to current infested or MPB-killed areas. Non-conventional data on dead forest conditions including date of death is required. Stand attribute data required by existing or yet to be developed forecasting models that will guide forest management strategies also needs to be collected as well as information on tree species other than pine and pathogens that may affect these tree species.

  The information and method to collect this information is required immediately at an operational scale for planning salvage operations, silviculture activities, harvest rates and harvest schedules for both the leading edge and salvage of MPB-infested areas.

Identifying the backlog of MPB-infested areas (location and extent) is the priority followed by the development of an update procedure.

The identification of current MPB infested areas including date of death combined with the inventory-monitoring update system and existing or yet to be developed prediction models are important for developing near-term and mid-term forest management strategies. To be effective, these strategies require integrating the prediction of future spread and extent of MPB infestations.

- **Volume and Value Theme**

  The questions aggregated for this theme apply to both dead and live portions of MPB-affected stands. This theme relies upon information from the ***location and extent*** theme and expands the data required in order to determine stand volume and value. This theme is also subdivided into a) current and b) future stand volume and values. Shelf life or rate of deterioration is an important consideration of this theme and is critical and is required immediately for managing salvage operations of MPB-killed stands and developing a MPB silvicultural strategy.

- **Corporate Decisions Theme**

  The aggregate of questions in this theme require corporate management decisions and frequently rely on technical information and data summarization derived from the previous two themes.

- **Technical Considerations**

  Although not specific, the questions in this theme identify general technical questions that need to be considered to identify required attributes and develop options for different methods and approaches to answer the questions in the other three resource information themes. Of particular importance are the questions on growth and yield modelling as such modelling is a key component of all harvest and silvicultural planning exercises.

In summary, based on the four resource information themes, the "MPB Resource Information System" has three basic components. These components are:

(i) **an inventory** that defines location and extent of MPB infested areas and other forest stands and provides attributes describing both dead and live stands that can also be used for operational activities, planning and modelling;

(ii) **an update procedure with a monitoring aspect** (e.g. growth and yield) to keep the inventory attributes current or provide data for modelling; and

(iii) **a modelling component** to predict derived attributes, future spread of infestation, rate of deterioration, and future changes in inventory attributes.

The mapping scale and update frequency of different attributes needs to be considered in each component as well as other resource information (e.g. BGC, TRIM) required for the modelling component. Task teams may require subtask committees to address more complex and specific questions within each theme. The teams and committees should be based upon a combination of the four resource information themes and three components above, and on the complexity of each question in Table 5 or new questions arising during the process.

Table S2: Strategy Framework - Resource Information Categories based on Information Needs

Resource Information Categories		Information Needs
1. Location and Extent	**Current**	1. Location of current MPB infestation (green, red and grey attack)
		2. Severity and extent of the infestation within the stand
		3. Location of past MPB infested areas (extent, severity, date, for last 5 years)
		4. Year of main mortality of merchantable volume in a stand
		5. Location of mortality by year of mortality
		6. Current inventory of merchantable timber in stands, by species
		7. Presence and condition of the understorey
		8. Regeneration presence and condition
		9. Site productivity potential
		10. Species affected - by pathogen
	Future (Modelling)	1. Forecasts of where the MPB is likely to be found in next 3-5 years
		2. Forecasts of duration and intensity of infestations by stand within watershed/district
		3. Forecasts of the rate of spread of the infestation both within and between stands
		4. Analysis of the characteristics of the infestation / spread
2. Volume and Value	**Current**	1. Mortality volume and quality within stands, within Districts
		2. Amount of volume already salvaged
		3. Expected volume which can be salvaged by product class
		4. How much green volume will be removed with salvage (TS-2d)
		5. When will affected stands be unmerchantable? (HS-6)
		6. What is the rate at which affected stands will deteriorate? (HS-5)
		7. How do we determine the pre-MPB forest asset value? (DAV – 1)
		8. How do we determine the post MPB forest asset value (DAV – 3)
	Future (Modelling)	1. How do we model growth of affected stands? (TS-6a)
		2. How do we determine and describe the dynamics of the value decline? (DAV-2)
		3. What is the growth potential of existing regeneration and of residuals? (S-6)
		4. What is the regeneration delay; when will we get regeneration (artificial vs. natural)? (S-6)
		5. What are the characteristics (species) of the future regeneration? (S-7)
3. Corporate Decisions		1. What administrative unit should the uplift calculations be based on (TSA, district)? (TS 3a)
		2. Should uplift be based on THLB or total landbase in the management unit? (TS-3b)
		3. How frequently does the AAC uplift need to be reviewed / recalculated? (TS-4)
		4. Which pathogen should we monitor or manage? (FH-1)
		5. What MPB stands are they worth treating silviculturally (Residual volumes / site productivity)? (S-5)
4. Technical Considerations		1. What is the impact of these requirements on the supporting databases, systems, IT structures? (TS-5a)
		2. Do we have adequate models? (S-8)
		3. Do we have data for modelling? (S-9)
		4. What model building data is required? (S-9)

The resource information theme table suggests ways of combining data capture tasks and establishing task priorities. For example, information for the location and extent theme can be derived via various remote sensing approaches and can be implemented immediately. Information for the Volume and Value theme will require supplementary ground information and thus will not be so easily collected and compiled.

By storing the various datasets in their own individual GIS coverages (layers), data from many different sources and from different sampling designs can be easily stored and utilized as long as

the data samples can be geo-referenced and information on the sampling designs used and the standards to which the data were collected is known. This approach enables the collection, storage and use of data from operational cruises, various licensee-based inventory projects, special studies and research projects, as well as traditional VRI/NFI large-scale inventory projects.

Next Steps

The urgency of the challenge, including the physical need for piloting inventory and monitoring solutions in the July - August seasonal window, suggests the following six action items:

Table S3: Recommended Action Plan

No.	Action	Lead Agency	Timeframe	Milestones	Dependencies / Relationships
1	*Create governance and coordination group for strategy implementation*	MoF/MSRM	Immediate	• ToR • Group establishment • Executive responsibility assigned	Coordinate with MPB Action Plan, COFI
2	*Form technical & business advisory committee*	MoF/MSRM	Immediate	• ToR • Proposed list of members • Committee establishment	Coordinate with MPB Action Plan, COFI
3	*Develop catalogue of all MPB-inventory and monitoring projects*	MoF/MSRM	Immediate	• Reports: - FIA funded projects - Federal projects - Industry - Other •	(2), (3)
4	*Prepare workplan for Strategy Phase 2 – use Resource Information Themes + Business Requirements approach.*	MoF/MSRM	Immediate	• Workplan – use Resource Information Theme concepts to define tasks and set priorities and business requirements to define attributes.	(1)
5	*Verify business requirements & themes with industry and other key stakeholders.*	MoF/MSRM	Immediate	• Formalized Strategy Framework and Action Plan	(2), (3)
6	*Pilot projects*	MoF/MSRM	Immediate (July-August start with Oct finish)	• Outline pilot project plans based on information gaps • Approve pilot project plan • Commission pilot projects	Depends on gaps identified in (5)

1. Purpose, Background and Approach

In this Chapter, we set the stage for the Strategy development process. The Strategy is being developed in an incremental manner in two Phases (ref Figure 1 below). Phase 1 has been largely focused on making key clients and stakeholders aware of the Strategy intent and to solicit their views on the dimensions of the challenge, the driving business needs and the scope of the Strategy. Phase 1 has also included the development of a Strategy Framework and the identification of series of immediate action recommendations, many of which will be acted upon in Phase 2 of the Strategy.

Phase 2, beginning in June and with the benefit of the business requirements analysis in Phase 1 and in relation to the Strategy Framework, will be focused initially on identifying, in detail, the series of technical alternatives identified in Phase 1 and evaluating them against the business requirements (the resource information questions in the framework). Next, the various technical alternatives will be assessed for their feasibility - i.e. costs, resource capacity, time frames, availability, etc. (Note: see Steps 5 and 6 in the *Workshop Workbook*).

Purpose

The purpose of this Strategy Report Phase 1 is:

- To provide context, background information and approach used to identify the scope and dimension of business needs which the Inventory and Monitoring Strategy must address.

- To identify, based upon feedback information derived from key clients and stakeholders, the key factors and parameters which a suitable strategy must include in order to meet the identified priority business needs.

- To provide a strategic framework and recommended action plan to coordinate a systematic approach for implementing alternative strategies to address current and future business needs. It is expected that these alternatives will be fleshed out in detail and field tested in Phase 2, leading to a recommended operational activities that can be implemented during the winter of 2005/2006.

Background

As stewards of 95% of the forest resources in British Columbia, the government of British Columbia maintains the responsibility for policies regarding forest management. One important input to forest management is the province's forest inventory. Forest resources continue to fuel the province's economic engine by providing jobs, economic rent through taxation, community development, and many secondary and spin-off benefits.

The mountain pine beetle is affecting the structure and inventory of forests in central BC to a degree that has never been experienced before. Each year, the beetles are incrementally killing parts or all of many lodgepole pine forests in central BC. The current estimates indicate that over 13 million hectares of lodgepole pine and mixed-pine forestland have been attacked to date. The current approaches to provincial forest resource inventories (VRI), the limited scale of growth and yield activities within the Ministry of Sustainable Resource Management (MSRM), and the new forest inventories being undertaken by forest licensees are not suited or designed to provide the level and frequency of information now required to assess and mitigate the beetle infestation.

All indications are that the current mountain pine beetle infestation will continue to expand for the next decade or longer and will have a significant impact on a large proportion of the lodgepole pine forests in the province. 2006 is expected to be the worst year in terms of merchantable pine volume affected: 90 million m^3 (Eng *et al.* 2005)[2]. Pine makes up some 30% of the timber volume on the timber harvesting landbase, and of this some 1.2 billion m^3 is regarded as being at risk (Eng *et al.* 2005).

Up to 25% of BC's timber supply is comprised of lodgepole pine and is at risk from being attacked and killed. The infestation is likely to continue to spread until either its preferred pine host is consumed (up to 80% of the pine), or cold winter weather abates the spread.

Given the infestation's affect on the forest resources, a significant effort is required to co-ordinate the implementation and completion of new forest resource inventories, growth and yield studies and monitoring systems in the affected timber supply areas (Tsars) in order to meet the needs of resource agencies and the forest industry in their struggle to minimize the effects of the infestation.

A principle driver for inventorying the forest cover within TSAs is the timber supply review schedule and allowable annual cut determinations. Other equally important drivers are the development of silviculture strategies and operational plans designed to slow infestation spread and mitigate infestation effects on near-term and long-term wood supplies and other non-timber resources. The changes in wood supply brought on by the MPB infestation directly impact tenure management, corporate strategies on manufacturing and marketing, habitat supply, biodiversity strategies, state of the forest reports, and other types of land management plans, including forest stewardship and forest development plans.

With the rapid expansion of the mountain pine beetle epidemic in central BC, the schedule and responsibility for regular timber supply reviews for three of the more severely infested areas - Lakes, Prince George and Quesnel TSAs - can no longer be based on a regular five-year update cycle and to some degree may not be led by the licensees as part of the proposed defined forest area management (DFAM) initiative. The currency of the traditional approach to forest inventory in these areas has been overwhelmed by the effects of the rapid expansion the beetle infestation. The timelines required to complete new, traditional forest inventories are too long to responsively reflect the annual levels of mortality and stand structure changes which affect operational needs and the resolution of traditional forest inventories is inadequate to capture and describe these within-stand changes.

There are many uncoordinated processes and initiatives underway regarding forest inventories and the mountain pine beetle infestation:

- Since the Core review and the inception of the Forest Investment Account (FIA), the forest industry has taken on a bigger role in carrying out forest inventories and establishing and re-measuring some growth and yield plots. At present, some companies are proposing (with FIA funding) to undertake forest inventories of the grey wood in the more severely infested Tsars. However, its uncertain what forest inventories they or other licensees may initiate related to the timber supply review program and other resource values and issues.
- Forest Analysis Branch and possibly DFAM groups will be required to complete new timber supply reviews for the infested areas repeatedly over the next two decades. However, without updated or new forest inventories of these areas, the timber supply reviews will not

[2] Marvin Eng et al. Provincial Level Projection of the Current Mountain Pine Beetle Outbreak: An Overview of the Model (BCMPB v2) and Results of Year 2 of the Project, April 2005.
http://www.for.gov.bc.ca/hre/bcmpb/BCMPB_MainReport_2004.pdf

reflect the extent of the beetle kill or how non-harvested stands are responding to the infestation.

- Forest Practices Branch continues to complete detailed aerial surveys of the active infestation areas in the southern interior, as well as the regular Forest Health aerial overview surveys. The imagery from these flights may be useful for forest inventories.
- Research Branch is currently not able to provide new growth and yield data or conduct the re-measurement of existing growth and yield plots to report on changes to forest structures due to the outbreak. The forest industry is not planning a growth and yield program or a monitoring program designed to address the infestation.
- MSRM - Resource Information Branch has proposed satellite imagery to update the forest cover maps in the infested areas. However, it is not certain exactly what the objectives should be for satellite imagery besides updating logging disturbances. Furthermore, without a strategy, it is uncertain what type of aerial coverage is appropriate to meet the business needs for programs such as the timber supply review and allowable annual cut determinations and multi-resource, sustainability objectives.
- MSRM - Land use planning processes will likely need to have spatial infestation data if they are to proceed with reviewing land use plans to reflect the effect of beetle attack.
- CFS has initiated inventory-related studies, such as the Provincial Level Projection of the Mountain Pine Beetle in BC (Marvin Eng's research), as well as a number of new proposals this summer.
- A number of independent consultants are pursuing contract proposals to initiate a variety of approaches to updating the forest inventories to account for the mountain pine beetle infestation.

There are a number of government agencies and groups interested in participating or receiving information about new forest inventories for the infested areas. The Ministry of Forests has been named as the main coordinating agency with direct business needs in terms of the timber supply review program and the mountain pine beetle action plan. The Ministry of Sustainable Resource Management is the agency responsible for maintaining standards and assisting the forest industry by maintaining forest resource inventory databases. Given the complexity of the impact of the mountain pine beetle infestation on forest inventories and the number of interested agencies and groups, a coordinated strategy is a priority to ensure that up-to-date inventories are available in a timely and efficient manner for timber supply reviews, and for operational and tactical forest and resource planning.

In summary, the development of a significantly different and coordinated strategy for forest resource inventories, resource updates, data collection and storage and monitoring activities related to the mountain pine beetle infestation is required immediately.

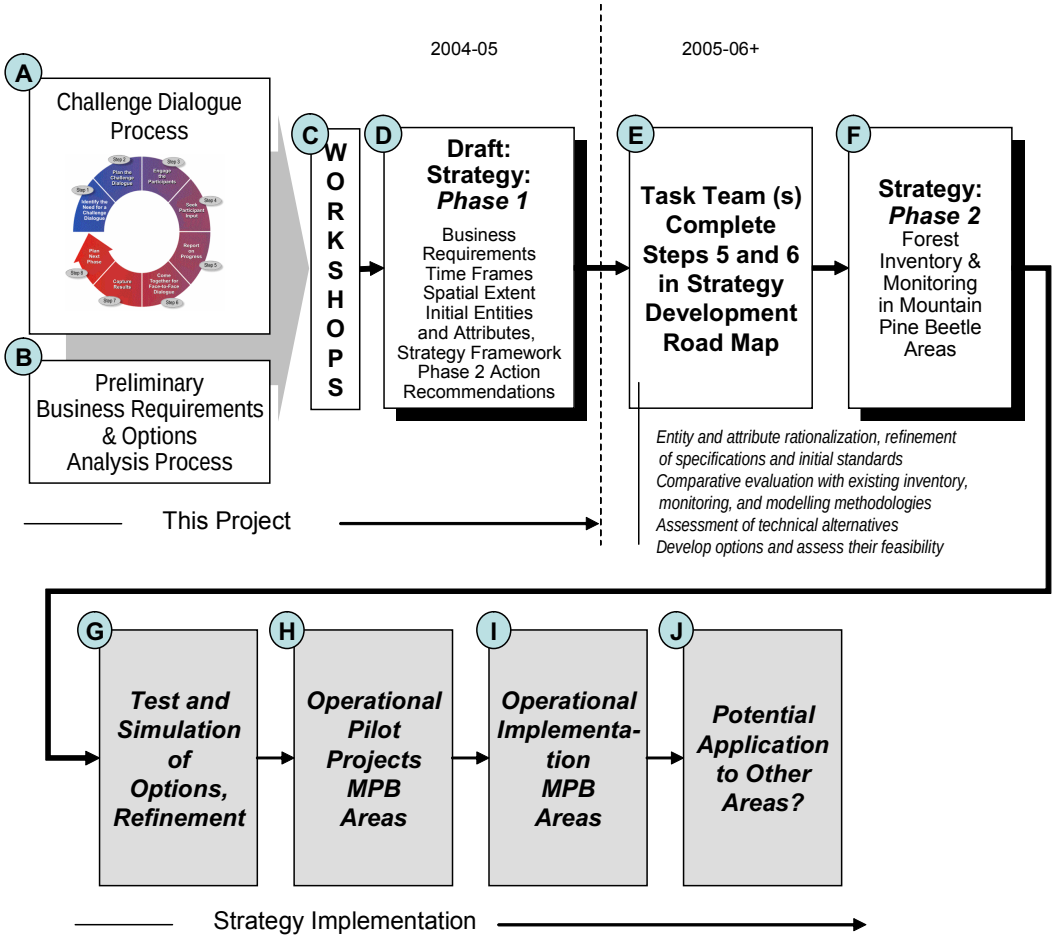
Strategy Development Approach - Phase 1

Figure 1 provides a graphic depiction of the process used to develop the new strategic forest inventory and monitoring strategies.

The Challenge Dialogue Process (Box A in Figure 1) was used to assist in the development of the strategy. A Challenge Paper was prepared to develop the initial Key Challenge statement based upon Background Statements. The paper also put forward Expectations for the process, Assumptions and initial ideas and Questions to stimulate dialogue. One hundred and forty (140) experts in various fields of forestry from industry, academia and government were solicited for feedback through the challenge paper. Thirty-nine (39) responses were received. The feedback was assembled into a Response Compilation document and a number of preliminary business

requirements and options were identified (Box B in Figure 1). Several of the key points identified from the feedback were used to guide the next step of the Challenge Dialogue process (the Face-to Face Workshop - Box C) that allowed everyone to get onto the same page.

Figure 1: Strategy Framework - Overview of Framework Development Process



Two workshops were held to align stakeholders on the need for a strategy and to set the context in which the strategy is being developed. The first workshop was held in Prince George March 11, 2005 and had 9 participants. The second workshop held in the Lower Mainland on March 30 and 31st, 2005 had more than 35 participants (mostly but not all government staff).

The Vancouver Workshop used a Strategy Development Road Map to guide participants through an incremental process. First, this set context to align stakeholders. This alignment is articulated through the "key challenge" statement. Once the challenge statement was defined, the high-level business areas were identified, and then the Strategy's scope and assumptions were defined to bound and frame the strategy (spectrum of business needs, spatial extent-geographic scope and temporal scope). Twenty-one business drivers with specific business needs for the five priority business areas were identified through a series of questions developed by the participants. Finally, the entity and attribute data required to help answer or measure the specific business needs were determined.

This process permitted preparation of this Phase 1 Strategy report (Box D in Figure 1), which contains a Strategy Framework and Recommended Action Plan for Phase 2.

During the Challenge Dialogue a series of "working documents" have been generated to guide and inform the strategy development process. These documents are available on the MOF website http://www.for.gov.bc.ca/ftp/HTS/external/outgoing/ and will continue to be used as the foundation for strategy development as it moves into Phase 2. The following documents are posted to the website and may be reviewed and/or downloaded:

- **Challenge Paper** - proposes a draft set of context, scope and objectives statements for the tasks at hand (the Challenge), and poses a series of questions to which respondents are asked to provide feedback.

- **Challenge Paper As-Is Response Compilation** - is a synopsis of all the responses received.

- **Preliminary Synthesis of Challenge Paper Feedback - Selected Key Responses** - the first round attempt to try to draw out the common threads/points being made by the respondents with respect to the key challenges we are trying to address.

- **Workshop Workbook** - provided the necessary background and context information, the preliminary synthesis of the Challenge Paper Feedback, the Workshop Agenda and Timetable. This was provided to all attendees at the March 30-31 workshop.

- **Strategy Workshops: Record and Outputs** - documents the discussions and topics covered at the workshop as well as a summary of workshop results. Of particular note is the high degree of overlap on forest resource data needed to address the range of land management issues discussed.

This report (**Strategy Report - Phase 1**) provides the strategy framework and recommended action plan for the next step. To answer the series of questions or specific business needs, task teams are formed to determine different data acquisition approaches and technical alternatives to answer the questions. These alternatives may include various options in the following activities:

- Monitoring
- Modelling
- Regeneration
- Remote Sensing tools
- Data and Information Management Issues.
- Growth and Yield Issues

The technical alternatives are tested and assessed through operation Pilot projects by the technical teams in relation to other important non-technical factors to evaluate the feasibility of different options including organizational, cost and resources and various business-decision factors.

Key Challenge

The Key Challenge is the development of a strategic plan for forest inventory and monitoring activities in and around mountain pine beetle areas that meets the short and long term business needs of government agencies, the forest industry and other key stakeholders. The plan must:

1. **consider the information requirements of forest managers;**
2. **consider the information requirements of the Chief Forester for AAC determinations;**
3. **consider the information requirements for management for other forest and resource values by government, industry and communities;**
4. **address short, medium and long term information requirements;**
5. **be achievable in appropriate timeframes;**
6. **reflect the urgency of the problem and the scale of the assets at risk.**

2. Strategy Assumptions

The development of the strategic framework and action plan recognizes that the existing forest resources inventory, current growth and yield modelling and current monitoring approaches are not designed to provide the required stand-level resolution and were not designed to collect, compile and report using yearly or shorter update cycles. The framework also recognizes that the resulting new system, while meeting the increased resolution and update/reporting requirements, must be operationally affordable, from a staffing and facilities viewpoint, and technically do-able.

The key assumptions for this strategy are divided into three categories: (a) assumptions related to **business drivers and management**; (b) assumptions of an **organizational and resources nature**; (c) assumptions related to **inventory and monitoring technology/methodologies**.

Assumptions Related to Business Drivers and Management

1. Vast and contiguous areas of beetle-susceptible timber in the Interior remain at risk of infestation outbreak. The Mountain Pine Beetle outbreak will continue, - current model outputs show the majority of merchantable pine will be killed over the next two decades.
2. Focus must now be on how to best deal with the consequences. In the short term, by decisions about salvage harvest location and harvest rates, taking into consideration shelf life and potential product usage. In the long term, we need to plan for the future forest, - life after the beetle. This includes regeneration and rehabilitation options, improved management of remaining stands and establishing programs for monitoring and mitigation of future outbreaks.
3. Removal of infested trees in affected stands is the only way to address the issue in the short-term (Mountain Pine Beetle Action Plan Update 2004).
4. Other tree species and pathogens need to be considered “for life after the beetle” as these tree species and pathogens will be managed in the mid- to long-term.
5. **Mitigation Strategies.** Industry currently recognizes two fundamental situations in their management efforts[3]: (a) strategies and actions for mitigating the epidemic **at the leading edge**; and (b) strategies and actions for mitigating the epidemic **after the leading edge has passed**. Leading edge strategies and actions focus on detecting and removing those stands and trees that still have beetles in them, the *green attack* stands. Taking action to remove these trees and thereby reducing the beetle population will reduce the rate of spread until Mother Nature can come to our assistance with a killing cold event. Following Strategies, for after the leading edge has passed, will help mitigate the medium and long-term timber supply impacts. For those areas of the province where the leading edge of the epidemic has passed through, attention is shifted to salvage harvesting and to “life after beetles” strategies, to manage timber supply and community-level economic development issues. At issue are mid-term and long-term economic and community stability.
6. Current forest inventory data and the entire timber management system focuses on green/standing volumes and ‘products’. We must also now focus on the primary, secondary and tertiary ‘products’ as related to applicable volumes and shelf life of MPB-killed timber. Shelf life or rate of wood deterioration of dead pine is influenced by site and climate conditions.

[3] http://www.mountainpinebeetle.com/action_activities.html

7. The focus of the strategy needs to be on the most imminent issues, - fast support of harvest and silviculture planning business areas - but within the context and business requirements of long-term AAC - affecting decisions. The need for timely information on the location and extent of infested stands, infestation severity levels and the history of infestation is required by the majority of stakeholders.

8. The five primary business drivers are: Timber Supply, Timber Harvest Scheduling, Silviculture, Forest Health and Declining Asset Values. Inventory and monitoring activities related to these business drivers will overlap with the business requirements of the majority of the other 21 identified groups of business drivers.

9. Technical teams for key clients and stakeholders need to confirm and refine the respective business driver key questions and data attributes identified in this report.

Assumptions Related to Organizational and Resources Challenges

1. The complex and broad nature of the MPB problem requires a multi-disciplinary and multi-organizational approach to find a solution to the inventory and monitoring challenge and for its implementation. Options that are generated will need to consider a blend of conventional and new innovative approaches. Collaborative thinking and actions will be critical factors for achieving success quickly.

2. All options for a solution need to carefully balance the benefits of any new protocols with financial realism and sustainability.

3. It is possible that the inventory, monitoring and update protocols that are decided upon will venture into new somewhat uncharted territory each with their own set of inherent risks and while the “MPB clock” continues tick. This likely means that executives, managers and practitioners will need to embrace and manage these risks with due consideration of the reality of the circumstance. Staff charged with implementing these protocols will need to be open to operating within a “Risk Management Environment”, learning and applying quickly what could be quite different methodologies. Rapid new skills training will probably be another important component of the whole solution.

4. It is anticipated that some solutions may necessarily require new and different kinds of partnerships with the forest and other sectors, technology firms, and data suppliers such as those for some remote sensing platforms. Among many factors, flexibility, fairness, timeliness, data ownership, data sharing, and public access, will be important elements in defining these partnerships and for their success.

Assumptions Related to Inventory and Monitoring Technology & Methodologies

1. The key challenge lies in timely acquisition of spatial information on infestations. The narrow temporal window for mapping of recent red attack and decreasing detectability of change detection with time dictate strategies based on **multiple options and data sources.** The strategy needs to consider acceptable mapping methods, data and standards. Subsequent pilot projects would determine cost/benefit of each method.

2. Resource information implications:
    - Precision (forest cover type averages vs. stand-level/polygon-level averages vs. sub-polygon levels of information);
    - Timing (multi-year, periodic inventory updates vs. annual activity updates vs. with-in year resource changes);
    - Data capture cycles(precision, applications requirements);
    - Accuracy/reliability (Provincial level, TSA level, forest cover types, polygon-level data, sub-polygon data);
    - Data and information storage and archiving systems (date stamps/versions). The system must be capable of addressing these requirements for intermediate and final levels of reporting and summarization as well as the raw data.

3. The strategy needs to consider incorporation of the forest health monitoring activities of recent MPB activity into the forest cover inventory. The strategy must find an approach to update of the degree of disturbance that would reduce the inventory life cycle significantly (to a year or less). This approach will likely have to require minimal fieldwork.

4. The current VRI and NFI sample designs are not set up to address the dynamic change of the catastrophic MPB event and the needs of key clients and stakeholders.

5. The VRI was designed for a living and growing forest. Stand decay models and standards for integrating MPB information are required.

6. The VRI lacks inventory information on young stands that may potentially be affected by MPB.

7. The use of airborne multi- and hyper-spectral scanners as means of detecting “green attack” (subtle chlorophyll changes detectable in the infrared spectral range) has not been effective. The majority of the scientific community favours infrared imagery over visible imagery for detection of stressed and unhealthy vegetation.

8. Recent advances in digital aerial imaging using manned and unmanned vehicles hold promise in the acquisition of digital infrared imagery at a resolution allowing individual tree detection (sub-metre pixel size). These images allow reliable detection and mapping of red attack and die-back. Cost/benefit advantage of these techniques over sketch mapping lies in a greater value of acquired imagery, which can be used for a multitude of applications.

9. Few jurisdictions have experienced an outbreak of the size and growth rate similar to the current infestation in BC. Invariably, the size of these events allowed systematic or random ground sampling as means of establishing outbreak calibration points for detection and mapping. Examples include correlation of field sampling and multi-source satellite imagery for MPB outbreak mapping in Yellowstone National Park, aerial photography and sketch mapping calibrated by field surveys in Alaska, Minnesota, Michigan, Indiana, California, Sweden, Russia and China. The size and dynamics of the current BC outbreak requires innovative monitoring methods due to its unique characteristics and scale.

10. Applied research of predictive methods for defining infestation risk areas is required. Results should be tied to pilot projects as means of targeting data collection in discrete areas. Predictive mapping, including some of the Predictive Ecosystem Mapping work in BC, is moving towards raster analysis of input layers with DEM derivatives supplying as much as 80 percent of the input (other inputs are satellite and ortho-imagery, digitized geology maps and soil maps and

vegetation classification where appropriate)[4]. A similar procedure used to map the risk of MPB infestation is required.

11. Historical and current multi-temporal datasets will be analyzed to detect image changes indicative of the outbreak's history. This information, in conjunction with the knowledge of the infested stand's shelf life, is very important in decision making on salvage harvest scheduling. British Columbia has a vast archive of historical Landsat imagery and can capitalize on applied research done at the Pacific Forestry Centre on this topic.

[4] Personal communication - Keith Jones with Bob MacMillan, LandMapper Environmental Solutions Inc., Edmonton

3. Business Requirements through to Entities and Attributes

The business and decision-making responsibilities for land-based resource management operates in an environment where no single agency or organization has control over the collective resources. As a result, effective delivery of resource information depends on a collaborative and coordinated approach involving government ministries and industry. The Resource Information Branch of MSRM plays an important role in facilitating and coordinating various transactions between stakeholders from across the resource information business area.

Information needs on the location and extent of MPB-infested stands and new outbreaks are shared by different Provincial Ministries, Federal Government agencies and the private sector. Integration of these needs in a set of procedures designed to improve our capabilities to detect, map and manage MPB-affected areas in B.C. will better enable mitigation and minimization of the MPB infestation effects. The information used in this summarization of business requirements is based upon feedback, primarily written responses, to the Challenge Paper, the results from the two workshops and a summary of the business requirements from the Quesnel TSA planning group.

Establishment of new standards, procedures, administrative and funding mechanisms is needed to accomplish this task. Strategic level business decisions on a new approach include decisions on information needs for the entire province and on effective ways of collecting, managing and sharing this information at the Provincial level, the Region level, the TSA level, the District level and the operator/licensee level. Changing existing inventory procedures, or establishing new forest health mapping programs, entails a wide range of decision-making on a tactical level, but within the strategic framework and plans set at the region, TSA and District levels. Determining optimal data acquisition procedures (imagery, maps, sketches), interpretation and mapping guidelines and incorporating acquired information into existing processes also falls into the operational level.

Table 1 ranks the top priority business areas from a list of 21 identified business areas affected by the Mountain Pine Beetle infestation. The top five priority areas were selected for further analysis by the participants. Five table groups, one for each of the five top priority business areas, were asked to identify the high-level business information requirements and develop a series of inventory/monitoring questions describing those requirements. The questions were then used to identify the information entities and attributes needed to answer each question.

Table 1: Initial Composite List of High Level Business Drivers and Priority Ratings

Ranking	High Level Business Area	# Votes
1	**Timber Supply (AAC)**	20
2	**Timber Harvest Scheduling (Allocation); Salvage (Shelf Life)**	18
3	**Silviculture, Regeneration, Succession/Stand Dynamics, Silviculture Policy**	12
4	**Forest Health**	11
5	**Declining Asset Value**	9
6	Socio-economics / Health, Community Planning / Stability (House Insurance, Particulates)	5
7	Fish / Wildlife Habitat (Land Use Planning?)	3
8	Water – Hydrology, Quantity, Quality	2
9	Forest Protection, Fire Risk (Fuel Management)	2
10	Product / Mill Capacity & Planning (Economic)	1
11	Leading Edge Management	1
12	Biodiversity	1
13	Infrastructure – Roads	1
14	Landscape Analysis (& Visual)	1
15	Agriculture/Forage, Dominant Range	0
16	Non-Timber Forest Products (Botanicals), Other Forest Uses (Guiding, Trapping)	0
17	Climate Change (National/International Obligations – Kyoto), Species Migration	0
18	Treaties/First Nations Interests	0
19	Recreation, Tourism, Eco-tourism	0
20	Broad-Level Reporting (State of…)	0
21	Certification	0

Most resource-based business areas share the need for timely, cost effective and efficiently distributed data and information on the location, extent and severity of MPB infestations. Integration of this information will form the basis for informed decisions on how to recover the greatest value from dead timber, how to foster new and emerging forest-based activities and how to conserve the long-term forest values identified in land use plans.

Timber Supply

The discussion on timber supply issues identified a temporal dimension to the business issues. First, there is the AAC uplift work which is required to be completed over the next five years, but which needs information this year. Second, there is the regular timber supply review process which is scheduled out to 2010 and beyond, but needs new and improved information two years from now.

One major point identified by the group was the need for improved information on non-MPB affected stands. All of these points were also listed in the Quesnel TSA Business Drivers for Updated Inventory Information report (Appendix 6). More detail, a finer level of inventory, on the non-pine types are also required as these will be the future AAC basis while the pine types recover from the MPB infestation effects.

The following key business questions were developed:

1. Location, extent, severity, timing Information 1a. Where is the current MPB infestation (last 2 years green/red/grey attack, extent, severity)? 1b. Where are the past MPB infested areas (extent, severity, date, for last 5 years)? 1c. Where is the MPB likely to be found next (where is it going)? 1d. How long will the infestation last (10 more years/ 20 more years)?
2. Depletion Information 2a. How much volume has been killed? 2b. How much volume has been salvaged? 2c. How much volume can be salvaged and for what products (shelf life)? 2d. How much green volume will be removed with salvage? How much green volume will be left?
3. Allocation / Calculation Base 3a. What administrative unit should the uplift calculations be based on (TSA, district)? 3b. Should uplift be based on THLB or total landbase in the management unit?
4. Depletion Update 4a. How frequently does the AAC uplift need to be reviewed / recalculated?
5. Impact on Existing Inventory, Databases, IT Systems 5a. What is the impact of these new information requirements on the supporting databases, inventory systems, IT structures?
6. Growth & Yield 6a. How do we model growth of affected stands?

Timber Harvest Scheduling (Allocation) & Salvage (Shelf Life)

Harvest scheduling focuses on very short-term information needs. Questions about where to log; what timber should be taken and what timber should be left, which stands are better left for other resources uses, are critical to harvest scheduling decisions. The resource information needs essentially boil down to the question of where the MPB-killed timber is located, how long will we have financially expedient access to this affected (dead) timber, how does this unplanned for mortality affect the whole range of forest resource uses and what are the resulting impacts on harvest scheduling.

Most of this information needs to be updated annually so organizations can update harvesting plans annually. It was assumed by the group that we are targeting those stands of timber that have been most impacted by the MPB.

The following key timber harvest and salvage questions were identified:

1. What is the current inventory of merchantable timber in stands, by species?	Need to know: annually
2. What is the level of pine mortality for the district?	Need to know: annually
3. Where is the mortality occurring?	Need to know: annually
4. What was the year of main mortality in merchantable stands for the district (when did the clock start ticking)? Need to know: annually	
5. What is the rate at which affected stands will deteriorate?	Need to know: once
6. When will affected stands be unmerchantable?	Need to know: annually
7. Which affected stands are better left for other resource uses?	Need to know: annually

Silviculture, Regeneration, Succession & Stand Dynamics, Silviculture Policy

It was assumed that this business area is focused on looking for silviculture investment opportunities in both harvested and non-harvested portions of MPB affected stands for (a) mitigating allowable annual cut falldown, and (b) future wildlife requirements. Five possible silviculture opportunity conditions were identified.

- Stands that are not harvested that have no regeneration.
- Stands that are not harvested that have natural regeneration.
- Mixed stands that are not harvested with or without a pine component.
- Young managed and unmanaged stands that are killed.
- Stands in which harvesting has occurred.

The questions focused on the general question: what are the silviculture investment decisions that inventory information can assist? For example this information can be used for site preparation and rehabilitation; planting and advanced regeneration; stand tending, including brushing; spacing and fertilization; and silviculture planning.

The group assumed that issues in logged and treated areas would be covered by the timber harvest business area questions - both areas are closely linked.

The following key silviculture questions/information requirements were identified:

1. Where are the areas that have been killed by the MPB? What is the location and extent of the non-harvested MPB killed stands?
2. What is the presence and condition of the understorey; of the young stand?
3. Is there regeneration present? And if so how much is present? (Presence/condition of understorey / young stand)
4. What is the residual volume?
5. What is the site productivity potential; is it worth treating? (Residual volumes / site productivity) What is the management objective for the stand?
6. What is the growth potential of existing regeneration and of residuals? What is the regeneration delay; when will we get regeneration (artificial vs. natural)?
7. What are the characteristics (species) of the future regeneration?[5]
8. Do we have adequate models? Do we have data for modelling? What model building data is required?

Forest Health

[Note: there were no forest health experts at the Vancouver workshop due to a parallel forest pathogen workshop being held in Victoria.]

It was assumed there would be interest in trying to control the leading edge of the infestation. If so, then forest health inventory information is needed about the leading edge conditions. This requirement leads to a whole set of MPB biology-related questions (as opposed to harvesting) regarding green attack, red attack, grey attack, etc.

If you cannot control or manage the infestation, then you want the information to serve more as "a knowledge bank" which moves into the area of monitoring and the need for monitoring forest health trends. This information is particularly important in the non-beetle areas because that is the remaining forest which must support the future harvest while the MPB affected areas recover.

It was recognized that the forest health questions may change, but if the monitoring approach is sufficiently robust, then hopefully the system can answer these new questions. So we are thinking here of an ideal, long-term monitoring system. A link to the National Forest Inventory (grid) and system was seen as possible national network that could be used to advantage.

The links between forest health and inventory are very important and the MPB challenge is an opportunity to break down some of those barriers and link them together.

The following key forest health questions were identified:

1. Which pathogen?	*5. When did the infestation occur?*
2. Which species is the pathogen affecting?	*6. What is the rate of spread of the infestation (both within and between stands)?*
3. What is the severity of the infestation?	*7. What are the characteristics of the infestation / spread? (Immediate + periodic updates, 3-5 yrs)*
4. Where is the infestation?	

[5] Does not include forest health issues

Declining Asset Value

This business area was identified as focusing on managing the forest resource base from an "asset-management" point of view. A number of factors were identified which are beginning to affect industry and government business decisions. These include:

- The ability of the industry to attract financing (licensees) - MPB losses affect the book value of tenures.
- There are implications to timber pricing in terms of changes in the quality of the wood and in terms of the large supply of MPB-wood; both will affect the value of the asset to the people of BC.
- There will be a reduction in timber supply with attendant affects on government revenue (reduced value to the public in terms of stumpage revenue and potentially reduced future harvest rates for a time).
- There is a question about the long-term productivity of the land base in terms of how these stands will respond (we are assuming they will come back and grow the way they grew before, but it may not happen quickly or may require further intervention and costs to achieve. These factors could affect the ability to provide revenue and to support economic activity in the future.
- There is a potentially large public silviculture liability/cost related to rehabilitation of these stands.
- "Oversupply" of beetle-killed wood could lead to product price reduction in our markets, creating further impacts on resource allocation strategies and more pressure and difficulties in balancing immediate utilization to minimize losses against impacts on government revenue and market prices.

The following key asset value questions were identified:

1. How do we determine the pre-MPB forest asset value?
2. How do we determined and describe the dynamics of the value decline?
3. How we determine the post MPB forest asset value?

4. Strategy Framework

The strategy framework is based upon feedback from the Challenge Paper (approximately 40 written responses were received), feedback from the two workshops (Prince George on March 11th and Richmond on March 29-30th) and discussion with knowledgeable and experienced government and industry experts. Additionally, the strategy is designed to fit within the current Provincial Mountain Pine Beetle Action Plan.

The new inventory and monitoring strategy must achieve significant gains in three dimensions in order to enable the responsible ministries, industry and the affected communities to minimize the effects of the MPB infestation.

- First, the strategy must enable the development and implementation of an inventory and monitoring system(s) which can provide detailed, within-stand data for purposes of harvest scheduling and silvicultural planning.

- Secondly, the system must be capable of providing updated stand-level forest resource data on both living and dead trees for the entire MPB-infestation area on at least an annual update basis.

- Third, the entire system must be "Strategically Resilient" and sustainable within the available resources of the ministries and the forest industry; i.e., the system must be flexible, affordable and operationally functional. The objective is to devise a system contains sufficient flexibility in the key design components to make it easily adapted to new business requirements as they arise. Directly recognizing the need for strategic resilience, implies that the system will be continually changing and renewed to reflect changing business requirements. This has significant implications on both the design and the technological components of the system --- in other words this is not expected to be a "once-built" system, but rather a strategy of approaches for collecting, managing and reporting out data necessary to manage dynamic, natural resources which will be continually changing.

The Framework is formatted to follow from the results of the Vancouver workshop and is focused on addressing key business requirements for the five, priority high-level business areas, as identified by the participants at the workshop. These priority business areas are::

- **Timber Supply Analysis** - setting of short-term, mid-term and long-tern harvest levels taking into consideration the effects of the MPB epidemic.

- **Harvest Scheduling** - establishment of harvest schedules which maximize both the recovery of salvageable material from post-leading edge stands and, where appropriate, use "Leading Edge" harvesting approaches to capture pockets of MPB-infested trees and slow the rate of spread.

- **Silviculture** - development and implementation of appropriate silvicultural strategies and practices which minimize the impact of the MPB epidemic on local ecosystems and merchantable fibre supplies.

- **Forest Health** - identification of MPB-infested areas, location of new infestations - monitoring the rate of spread, monitoring the mortality rate within infested stands and

monitoring the deterioration rate of MPB-killed trees. Attention must also be paid to the presence and abundance of other forest pests.

- **Declining Asset Value** - recognition and determination of the economic and financial impacts of the MPB infestation on the forested landbase, including effects on tenure values, short-term and mid-term harvest levels, socio-economic conditions and non-timber resource values. The intent is to value the impacts and mitigation efforts from an asset-management viewpoint.

Each of the five business areas was analyzed and discussed by a working table and reviewed by the workshop group. For each business area, key questions were identified. Inventory, growth and yield and monitoring data requirements necessary to answer each of the questions were defined, as well as timing requirements. All of this information was collated and organized into the following three types of table:

- **Tables 2.1** to **2.5** list the key questions as defined by the working group for each business area, followed by a listing of the data entity, attributes and attribute characteristics needed to satisfy all of the key questions. These tables include a "How?" column indicating the generic data acquisition method for each type of parameter.

- **Table 3** synthesizes all the entities and attributes into one consolidated set which will answer all the business requirements (key questions) across all five priority business areas.

- **Table 4** provides an overview of the key questions, timing and approaches for acquiring data and information to answer the questions, by each of the five highest priority business areas.

Note that the "Approaches" identified in Table 4 can be considered as:

- ***Inventory***: fresh inventory, involving remote sensing (aerial photography), photo-interpretation, ground truthing and ground survey work.

- ***Monitoring***: periodic capture of data to detect change.

- ***Update***: update of inventory information.

- ***Modelling***: use of inventory and/or monitoring data to forecast conditions.

Table 2: Strategy Framework - Priority Business Areas, Key Questions, Information Characteristics and Methods

Note: Imagery refers to airborne or satellite-borne sensors
Imagery HiRes = resolution > 1m
Imagery MedRes = 1m < resolution < 5m
Imagery LowRes = 5m < resolution < 30m
AirSurv = Aerial surveys (e.g., sketch surveys)
Ground = Field surveys

2.1 TIMBER SUPPLY UPLIFT (AAC + TSR)	
Key Questions	
1. Location, extent, severity, timing Information	
1a. Where is the current MPB infestation (last 2 years green/red attack, extent, severity)?	1c. Where is the MPB likely to be found next (where is it going)?
1b. Where are the past MPB infested areas (extent, severity, date, for last 5 years)?	1d. How long will the infestation last (10 more years/ 20 more years)?
2. Depletion Information	
2a. How much volume has been killed?	2c. How much volume can be salvaged and for what products (shelf life)?
2b. How much volume has been salvaged?	2d. How much green volume will be removed with salvage?
3. Allocation / Calculation Base	
3a. What administrative unit should the uplift calculations be based on (TSA, district)?	3b. Should uplift be based on THLB or total landbase in the management unit?
4. Depletion Update	
4a. How frequently does the AAC uplift need to be reviewed / recalculated?	
5. Impact on Existing Inventory, Databases, IT Systems	
5a. What is the impact of these new information requirements on the supporting databases, inventory systems, IT structures?	
6. Growth & Yield	
6a. How do we model growth of affected stands?	
Entities and Attributes which can Provide the Information Needed	

2.1 TIMBER SUPPLY UPLIFT (AAC + TSR)											
Entity	Attribute	VRI or other standards in place?	Update frequency	Needed immediately?	Need to monitor?	Monitoring timescale	Compilation Precision	Reporting Precision	Desired accuracy	Desired precision	How?
Stand (= polygon)	Species mix (%) Stand Average	Yes	Annual	Yes	Yes	3-5 years	Polygon	Polygon	High	Med	Imagery HiRes
	Stand Location	Yes		Yes	No		Polygon	Polygon	High	High	GIS
	Parameters: Stems/ha Average Dbh Top ht/Site ht Volume/ha Basal area/ha	Yes		Yes	Yes	3-5 years	Polygon	Polygon	High	Med	Ground
	Mortality (Severity class)	No	Annual	Yes	Yes	3-5 years	Polygon	Polygon	Med	Med	Imagery MedRes
	Year of mortality	No		Yes			Polygon	Polygon	High	Med	Imagery MedRes
	Dead volume by species (%)	Yes		Yes	Yes	3-5 years	Polygon	Polygon	High	Med	Ground
	Environmental restrictions	Yes		Yes			Polygon	Polygon	High	High	GIS
Growth Model	Stand average model - handles mixed species plus forecasts live and dead volume & BA	No	3-5 years	Yes	Yes	3-5 years	Polygon	Polygon	Med	Med	R & D GY PSPs
Shelf Life Model	Under development		3-5 years	Yes	Yes	3-5 years	Polygon	Polygon	High	Med	R & D

2.2 HARVEST SCHEDULING	
Key Questions	
1. What is the current inventory of merchantable timber in stands, by species?	Need to know: annually
2. What is the level of pine mortality for the district?	Need to know: annually
3. Where is the mortality occurring?	Need to know: annually
4. What was the year of main mortality in merchantable stands for the district (when did the clock start ticking)?	Kneed to know: annually
5. What is the rate at which affected stands will deteriorate?	Need to know: once
6. When will affected stands be unmerchantable?	Need to know: annually
7. Which affected stands are better left for other resource uses?	Need to know: annually

Entities and Attributes which can provide the information needed

Entity	Attribute	VRI or other standards in place?	Needed immediately?	Need to monitor?	Update frequency	Monitoring timescale	Compilation Precision	Reporting Precision	Desired accuracy	Desired precision	How?
Stand-table within stand by diameter class	Stand Structure by species, tree class-live, attack class (green, red, grey), dead, by diameter class: Volume/ha, (merch and total), stems/ha, BA/ha, Merch ht, total ht, #Logs by dib & grade, check, rot, etc.	Yes, operational cruise	Yes	Yes	Annual	15 years on 3-5yr cycle	Stand-table within Polygon	Stand-table within Polygon	High	High	Ground
Stand average	Crown closure	Yes	Yes	Yes	Annual	15 years on 3-5yr cycle	Stand Average	Stand Average	Med	Med	Imagery MedRes
Stand-table	Snags: #, size, species, condition class	Yes	Yes	Yes	Annual	15 years on 3-5yr cycle	Stand-table	Stand-table	High	Med	Imagery HiRes Ground
Stand Average	Mortality (severity class)	Ad-hoc / No	Yes	Yes	Annual	15 years on 3-5yr cycle	Stand Average	Stand Average	Med	High	Imagery MedRes
Stand Average	Mortality volume by year by spp	Yes	Yes	Yes	Annual	15 years on 3-5yr cycle	Stand Average	Stand Average	High	High	Imagery LowRes

2.2 HARVEST SCHEDULING											
Stand	Location relative to other spatially identified values	Yes	Yes	Yes	Annual	Short to mid-term	Stand Average	Stand Average	Med	Med	Imagery MedRes GIS
Stand	Presence & Severity of Other pathogens	Yes	Yes	Yes	Annual	15 years on 3-5yr cycle	Stand Average	Stand Average	High	Med	Ground

2.3 SILVICULTURE / REGENERATION											
Key Questions											
1. Where are the areas that have been killed by the MPB? What is the location and extent of the non-harvested MPB killed stands?											
2. What is the presence and condition of the understorey; of the young stand?											
3. Is there regeneration present? And if so how much is present? (Presence/condition of understorey / young stand)											
4. What is the residual volume?											
5. What is the site productivity potential; is it worth treating? (Residual volumes / site productivity)											
6. What is the growth potential of existing regeneration and of residuals? What is the regeneration delay; when will we get regeneration (artificial vs. natural)?											
7. What are the characteristics (species) of the future regeneration?[6]											
8. Do we have adequate models? Do we have data for modelling? What model building data is required?											
Entities and Attributes which can provide the information needed											
Entity	Attribute	VRI or other standards in place?	Update frequency	Needed immediately ?	Need to monitor?	Monitoring timescale	Compilation Precision	Reporting Precision	Desired accuracy	Desired precision	How?
Tree											
	Canopy position, crown length (plus usual inventory parameters – stand structure info below)	Yes	3-5 year cycle	Yes	3-5 year cycle for normal stands, annually for MPB	Captured as part of stand structure	Stand-table within polygon	Stand-table within polygon	High	High	Imagery HiRes, AirSurv, Ground
	Tree condition class plus other factors (wildlife tree, MPB, rot ...)	Yes	3-5 year cycle for normal stands, annually for MPB	Yes	3-5 year cycle for normal stands, annually for MPB	Captured as part of stand structure	Stand-table within polygon	Stand-table within polygon	Med	Med	Imagery HiRes, AirSurv, Ground
Stand											
Stand	Spatial features	Yes	Once	Yes	Once	5 years	Stand	Stand	High	Med - High	Imagery MedRes, AirSurv

[6] Does not include forest health issues

2.3 SILVICULTURE / REGENERATION											
Stand-table within Polygon	Structure by species, tree class: live, attack class (green, red, grey), dead, diameter class: Volume/ha # stems/ha BA/ha	Yes, operational cruise	3-5 year cycle for normal stands, annually for MPB	Yes	3-5 year cycle for normal stands, annually for MPB	3-5 year cycle	Stand-table within polygon	Stand-table within polygon	High	High	AirSurv Ground
Stand	Stand structure - \vertical complexity	Yes	3-5 year cycle for normal stands, annually for MPB		3-5 year cycle for normal stands, annually for MPB	3-5 year cycle	Stand	Stand	High	High	Imagery HiRes, AirSurv, Ground
Stand	Stand structure – horizontal complexity - Uniform or clumped	Yes	3-5 year cycle for normal stands, annually for MPB		3-5 year cycle for normal stands, annually for MPB	3-5 year cycle	Stand	Stand	High	High	Imagery HiRes, AirSurv, Ground
Stand	Age (average)	Yes	Once, except for MPB		3-5 year cycle for normal stands, annually for MPB	3-5 year cycle	Stand	Stand	Med	Med	Imagery MedRes, Ground
Stand (site height)	Height (average)	Yes	3-5 year cycle for normal stands, annually for MPB		3-5 year cycle for normal stands, annually for MPB	3-5 year cycle	Stand	Stand	Med	Med	Imagery MedRes, Ground
Stand	Site index – derived or field estimate	Yes	Once, except for MPB		5 year cycle	5 year cycle	Stand	Stand	High	High	Ground, modelled

2.3 SILVICULTURE / REGENERATION											
Stand	Competitive vegetation (brush, grass, etc.)	Yes	3-5 year cycle for normal stands, annually for MPB		3-5 year cycle for normal stands, annually for MPB	3-5 year cycle	Stand	Stand	Med	Med	Imagery HiRes, AirSurv, Ground
Stand	History	Yes	Annually		?		Stand	Stand	High	Med-High	GIS, Inventory
Site											
	Series – BEC	Yes	Once only		Once	Once	Series polygon	Series polygon	High	Med	GIS, Ground
	Soil depth & classification	Yes	Once only		Once	Once	Series polygon	Series polygon	Low	Low	Ground
	Site Condition		3-5 year cycle for normal stands, annually for MPB		3-5 year cycle for normal stands, annually for MPB	3-5 year cycle	Series polygon	Series polygon	Med	Med	Imagery HiRes, AirSurv, Ground

2.4 FOREST HEALTH	
Key Questions	
1. Which pathogen?	*5. When did the infestation occur?*
2. Which species is the pathogen affecting?	*6. What is the rate of spread of the infestation (both within and between stands)?*
3. What is the severity of the infestation?	*7. What are the characteristics of the infestation / spread? (Immediate + periodic updates, 3-5 yrs)*
4. Where is the infestation?	

Entities and Attributes which can provide the information needed

Entity	Attribute	VRI or other standards in place?	Update frequency	Needed immediately?	Need to monitor?	Monitoring timescale	Compilation Precision	Reporting Precision	Desired accuracy	Desired precision	How?
Stand											
Stand	Location of stand	Yes	Annual	Yes	Yes	3-15 years	Stand	Stand	High	High	Imagery MedRes, AirSurv
Stand	Presence & abundance of pathogens	Presence –Yes Abundance - No	Annual	Yes	Yes	3-15 years	Stand	Stand	High	High	Imagery HiRes + Ground
Stand	Affected tree species	Yes	Annual	Yes	Yes	3-15 years	Stand	Stand	High	High	Imagery HiRes + Ground
Stand	Time of first infestation	Yes (red attack only)	Annual	Yes	Yes	3-15 years	Stand	Stand	High	High	Imagery LowRes
Stand	Mortality (severity class)	Ad-hoc / No	Annual	Yes	Yes	3-15 years	Stand	Stand	Med	Med	Imagery HiRes, AirSurv
Stand	DBH, height, # of trees killed	Yes	Annual	Yes	Yes	3-15 years	Stand	Stand	High	High	Imagery HiRes, Air Surv, Ground
Stand	Mortality volume by year of death and species	Yes	Annual	Yes	Yes	3-15 years	Stand	Stand	High	High	Inventory + Ground

2.5 DECLINING ASSET VALUE											
Key Questions											
1. How do we determine the pre-MPB forest asset value?							3. How we determine the post MPB forest asset value?				
2. How do we determined and describe the dynamics of the value decline?											
Entities and Attributes which can provide the information needed											
Entity	Attribute	VRI or other standards in place?	Update frequency	Needed immediately?	Need to monitor?	Monitoring timescale	Compilation Precision	Reporting Precision	Desired accuracy	Desired precision	How?
Stand											
Stand	Spatial location	Yes	Annual	Yes	No	3-15 years	Stand	Stand	N/A	Med	Imagery MedRes ,GIS
Stand Average	Species Mix(%) , Stand inventory information by Species Mix, Site Index, Age	Yes	Annual	Yes	Yes	3-15 years	Stand Average	Stand Average	Med	Med	Inventory
Stand	Year of first infestation	Yes (red attack only)	Annual	Yes	No	N/A	Stand	Stand	Med	Med	Imagery LowRes
Stand	Mortality – (severity class) & 1st yr of attack	Ad-hoc / No	Annual	Yes	Yes	3-15 years	Stand	Stand	Med	Med	Imagery MedRes, Air Surv
Stand	Mortality volume by year of death and species	Yes	Annual	Yes	Yes	3-15 years	Stand	Stand, mortality volume & % recovery	Med	Med	Inventory + Imagery
Stand	BEC, slope, aspect, soil moisture class	Yes	N/A	Yes	N/A	N/A	Stand	Stand	Med	Med	Imagery MedRes, GIS + Inventory

Table 3: Strategy Framework - Composite Attribute Table

ENTITY	ATTRIBUTE	BUSINESS AREA						
		Timber Supply		Harvest Scheduling		Silviculture / Regeneration	Forest Health	Declining Asset Value
		Leading Edge	Salvage	Leading Edge	Salvage			
Stand								
Stand- table Detail - by diameter class, distance-independent	Stand Structure by species, tree class: live, attack class (green, red, grey), dead, diameter class: Volume/ha (merch & total), stems/ha, BA/ha, Total ht, Merch ht, #Logs by dib & grade, rot, checking, etc.			●		●	●	●
Stand Average	Crown closure					●		
Stand Average	Stand structure - \vertical complexity					●	●	
Stand Average	Stand structure – horizontal complexity -Uniform or clumped					●	●	
Stand Average	Site index – derived or field estimate			●		●	●	●
Stand Average	Competitive vegetation (brush, grass, etc.)					●	●	
Stand	History			●	●	●	●	
Stand Average	Snags: #, size, species, condition class	●		●	●	●		
Stand Average	Mortality (severity class)	●	●	●	●	●	●	●
Stand	Year of first infestation by pathogen	●	●	●	●		●	
Stand Average	Mortality volume by year by species by pathogen	●	●	●	●		●	●
Stand	Spatial location	●	●	●	●	●	●	

ENTITY	ATTRIBUTE	BUSINESS AREA						
		Timber Supply		Harvest Scheduling		Silviculture / Regeneration	Forest Health	Declining Asset Value
		Leading Edge	Salvage	Leading Edge	Salvage			
Stand	Location relative to other spatially identified values	●	●	●	●	●		
Stand	Presence & Severity of Other pathogens	●	●	●	●	●	●	●
Stand	Affected tree species – pathogen	●	●	●	●	●	●	●
Stand	Mortality (severity class) by pathogen	●	●	●	●	●	●	●
Stand	DBH, height, no of trees killed by pathogen			●	●	●	●	●
Stand	BEC, slope, aspect, soil moisture class	●	●	●	●	●	●	
Stand	Environmental restrictions / concerns	●	●	●	●	●		●
Growth Model: Stand Average								
	Stand average model - handles mixed species plus forecasts live and dead volume & BA	●	●	●	●	?		●
Growth Model: Tree List – Stand Table Projection								
	Tree List or Stand Table Projection growth model - handles mixed species, multi-storied, multi-aged stands (distance-independent)	? Depends on length of planning horizon for harvest schedules	? Depends on length of planning horizon for harvest schedules	Only if have to predict detailed wildlife habitat characteristics	Only if have to predict detailed wildlife habitat characteristics	●		
Shelf Life Model								
	Under development	●	●	●	●		●	●
Other Resource Management Requirements								
Stand	Spatial location and extents required for: habitat parameters, riparian buffer zones, aesthetics	●	●	●	●	●		●

Table 4: Strategy Framework - Overview

BUSINESS AREA	TIMEFRAME			APPROACH			
Key Questions	Immediate	Medium	Long	Inventory	Monitoring	Update	Modelling
Timber Supply (AAC Uplift)							
1. Location, extent, severity, timing Information							
1a. Where is the current MPB infestation (last 2 years green/red attack, extent, severity)?	●	●		●	Imagery + Ground	●	
1b. Where are the past MPB infested areas (extent, severity, date, for last 5 years)?	●	●	●	●	Imagery + Ground	●	●
1c. Where is the MPB likely to be found next (where is it going)?		●	●	●			●
1d. How long will the infestation last (10 more years/ 20 more years)?	●	●	●				●
2. Depletion Information							
2a. How much volume has been killed?	●	●	●	●	Imagery + Ground	●	
2b. How much volume has been salvaged?	●	●	●	●	Imagery + Ground	●	
2c. How much volume can be salvaged and for what products (shelf life)?	●	●	●	●			●
2d. How much green volume will be removed with salvage?	●	●		●	Ground	●	
3. Allocation / Calculation Base							
3a. What administrative unit should the uplift calculations be based on (TSA, district)?	●	●	●	●			●
3b. Should uplift be based on THLB or total landbase in the management unit?	●	●	●	●			●
4. Depletion Update							
4a. How frequently does the AAC uplift need to be reviewed / recalculated?	●	●	●	●	●	●	
5. Impact on Existing Inventory, Databases, IT Systems							
5a. What is the impact of these new information requirements on the supporting databases, inventory systems, IT structures?	●			●	●	●	●
6. Growth & Yield							
6a. How do we model growth of affected stands?		●	●	●			●

BUSINESS AREA	TIMEFRAME			APPROACH			
Key Questions	Immediate	Medium	Long	Inventory	Monitoring	Update	Modelling
Harvest Scheduling							
1. What is the current inventory of merchantable timber in stands, by species?	●	●		●	●	●	
2. What is the level of pine mortality for the district?	●	●	●	●	●	●	
3. Where is the mortality occurring?	●	●		●	●	●	
4. What was the year of main mortality in merchantable stands for the district (when did the clock start ticking)?	●	●		●	●	●	
5. What is the rate at which affected stands will deteriorate?	●	●		●	●	●	●
6. When will affected stands be unmerchantable?	●	●		●	●	●	●
Silviculture/Regeneration							
1. Where are the areas that have been killed by the MPB? What is the location and extent of the non-harvested MPB killed stands?	●	●	●	●	●	●	
2. What is the presence and condition of the understorey; of the young stand?	●	●	●	●	●	●	
3. Is there regeneration present? And if so how much is present? (Presence/condition of understorey / young stand)	●	●	●	●	●	●	
4. What is the residual volume?	●	●	●	●			
5. What is the site productivity potential; is it worth treating? (Residual volumes / site productivity)	●	●	●	●			●
6. What is the growth potential of existing regeneration and of residuals? What is the regeneration delay; when will we get regeneration (artificial vs. natural)?	●	●	●	●	●		●
7. What are the characteristics (species) of the future regeneration?[7]	●	●	●				●
8. Do we have adequate models?	●	●	●				●
9. Do we have data for modelling? What model building data is required?	●	●	●				●

[7] Does not include forest health issues

BUSINESS AREA	TIMEFRAME			APPROACH			
Key Questions	Immediate	Medium	Long	Inventory	Monitoring	Update	Modelling
Forest Health							
1. Which pathogen?	●	●	●	●	●	●	
2. Which species is the pathogen affecting?	●	●	●	●	●	●	
3. What is the severity of the infestation?	●	●	●	●	●	●	
4. Where is the infestation?	●	●	●	●	●	●	
5. When did the infestation occur?	●	●	●	●	●	●	
6. What is the rate of spread of the infestation (both within and between stands)?	●	●	●	●	●	●	●
7. What are the characteristics of the infestation / spread? (Immediate + periodic updates, 3-5 yrs)	●	●	●	●	●	●	
Declining Asset Value							
1. How do we determine the pre-MPB forest asset value?	●	●		●			●
2. How do we determine and describe the dynamics of the value decline?	●	●		●			●
3. How we determine the post-MPB forest asset value?	●	●		●			●

Resource Information Themes

In addition to looking at the data from a business requirements point of view, it is also useful to view the data requirements from a resource information themes viewpoint. Tables 2 and 4 provide a list of key questions for each of the five priority business areas as defined during the Richmond workshop. Many of the key questions found in each business area can be aggregated to form resource information themes to help answer the same question or theme of questions for each business area. The themes can assist in defining data priorities and in determining the task teams that will complete the next steps (Steps 5 and 6 of the ***Workshop and Workbook "road map"***) of the strategy development process, as depicted in Figure 1. These task teams should also be responsible for identifying and assessing technical alternatives and feasible options for operational testing of different components of the "MPB Resource Information System".

Table 5 identifies four potential resource information themes or categories that share key questions for the five business areas. Following each question in Table 5 is a one or two-letter code combined with a number in parentheses identifying the business area and key question within that business area. For example, a code "S-1" refers to the first key Silviculture business area question identified during the Richmond Workshop.

The four main themes are:

- **Location and Extent**
- **Volume and Value**
- **Corporate Decision**
- **Technical Consideration**

Location and Extent Theme

This theme aggregates similar questions where clear evidence of MPB attack and the time of attack occurrence is necessary to answer the question. The theme of questions is further subdivided into a) current (inventory) and b) where the infestation will spread in the future.

For the current (inventory) sub-theme, a set of standard forest/vegetation attributes, including information on regeneration and productivity, are ascribed to current infested or MPB-killed areas. Non-conventional data on dead forest conditions including date of death is required. Stand attribute data required by existing or yet to be developed forecasting models that will guide forest management strategies also needs to be collected as well as tree species other than pine and pathogens that may affect these tree species.

The information and method to collect this information is required immediately at an operational scale for planning salvage operations, silviculture activities, harvest rates and harvest schedules for both the leading edge and salvage of MPB-infested areas. Identifying the backlog of MPB-infested areas (location and extent) is the priority followed by the development of an update procedure.

The identification of current MPB infested areas including date of death combined with the inventory-monitoring update system and existing or yet to be developed prediction models are important for developing near-term and mid-term forest management strategies. To be effective, these strategies require integrating the prediction of future spread and extent of MPB infestations.

Volume and Value Theme

The questions aggregated for this theme apply to both dead and live MPB-affected stands. This theme relies upon information from the ***location and extent*** theme and expands the data required in order to determine stand volume and value. This theme is also subdivided into a) current and b) future stand volume and values. Shelf life or rate of deterioration is an important consideration of this theme and is critical and is required immediately for managing salvage operations of MPB-killed stands and developing a MPB silvicultural strategy.

Corporate Decisions Theme

The aggregate of questions in this theme require corporate management decisions and frequently rely on technical information and data summarization.

Technical Considerations Theme

Although not specific, the questions in this theme identify general technical questions that need to be considered to identify required attributes and develop options for different methods and approaches to answer the questions in the other three resource information themes. Of particular importance are the questions on growth and yield modelling as such modelling is a key component of all harvest and silvicultural planning exercises.

In summary, based on the four resource information themes, the "MPB Resource Information System" has three basic components. These components include:

(i) **an inventory** that defines location and extent of MPB infested areas and other forest stands and provides attributes describing both dead and live stands that can also be used for operational activities, planning and modelling;

(ii) **an update procedure with a monitoring aspect** (e.g. growth and yield) to keep the inventory attributes current or provide data for modelling; and

(iii) **a modelling component** to predict derived attributes, future spread of infestation, rate of deterioration, and future changes in inventory attributes.

The mapping scale and update frequency of different attributes needs to be considered in each component as well as other resource information (e.g. BGC, TRIM) required for the modelling component. Task teams may require subtask committees to address more complex and specific questions within each theme. The teams and committees should be based upon a combination of the four resource information themes and 3 components above and the complexity of each question in Table 5 or new questions arising during the process.

Table 5: Strategy Framework - Resource Information Themes based on Common Questions across Business Areas

Resource Information Theme		Business Area Questions
1. Location and Extent	Current	1. Where is the current MPB infestation (green, red and grey attack) (TS-1a, FH-4)
		2. What is the severity and extent of the infestation within the stand? (TS-1a, S-1, FH-3
		3. Where are the past MPB infested areas (extent, severity, date, for last 5 years)? (TS-1b, HS-3)
		4. When did the infestation occur based on main mortality of merchantable volume in stand? (HS-4, FH – 5)
		5. Where is the mortality occurring (HS – 3)
		6. What is the current inventory of merchantable timber in stands, by species (HS-1)
		7. What is the presence and condition of the understorey; of the young stand? (S-2)
		8. Is there regeneration present? How much is present (Presence/condition of understorey / young stand)? (S-3)
		9. What is the residual volume? (S-4)
		10. What is the site productivity potential (S-5)
		11. Which species are pathogens affecting? Where? (FH -1, FH-2)
	Future (Modelling)	1. Where is the MPB likely to be found next (where is it going)? (TS-1c)
		2. How long will the infestations last (10 more years/ 20 more years)? (TS-1d)
		3. What is the rate of spread of the infestation (both within and between stands)? (FH-6)
		4. What are the characteristics of the infestation / spread? (Immediate + periodic updates, 3-5 yrs) (FH-7)
2. Volume and Value	Current	1. How much volume has been killed in the stand? In the District? (TS-2a, HS-2)
		2. How much volume has been salvaged? (TS-2b)
		3. How much volume can be salvaged and for what products (shelf life)(TS-2c)
		4. How much green volume will be removed with salvage (TS-2d)
		5. When will affected stands be unmerchantable? (HS-6)
		6. What is the rate at which affected stands will deteriorate? (HS-5)
		7. How do we determine the pre-MPB forest asset value? (DAV – 1)
		8. How do we determine the post MPB forest asset value (DAV – 3)
	Future (Modelling)	1. How do we model growth of affected stands? (TS-6a)
		2. How do we determine and describe the dynamics of the value decline? (DAV-2)
		3. What is the growth potential of existing regeneration and of residuals? (S-6)
		4. What is the regeneration delay; when will we get regeneration (artificial vs. natural)? (S-6)
		5. What are the characteristics (species) of the future regeneration? (S-7)
3. Corporate Decisions		1. What administrative unit should the uplift calculations be based on (TSA, district)? (TS-3a)
		2. Should uplift be based on THLB or total landbase in the management unit? (TS-3b)
		3. How frequently does the AAC uplift need to be reviewed / recalculated? (TS-4)
		4. Which pathogen should we monitor or manage? (FH-1)
		5. What MPB stands are they worth treating silviculturally (Residual volumes / site productivity)? (S-5)
4. Technical Considerations		1. What is the impact of these requirements on the supporting databases, systems, IT structures? (TS-5a)
		2. Do we have adequate models? (S-8)
		3. Do we have data for modelling? (S-9)
		4. What model building data is required? (S-9)

Table 6 identifies the primary data entities and attributes to be captured for two of the Resource Information Themes. The Location and Extent theme focuses on spatial and associated temporal data. This can be tested and implemented in a very different timeframe and context than can the second theme, Volume and Value, which will require some form of detailed ground sampled data for some components.

Table 6: Strategy Framework - Composite Attribute Table for Resource Information Themes

ENTITY	ATTRIBUTE	RESOURCE INFORMATION THEMES			
		Location and Extent		Volume and Value	
		Current	Future	Current	Future
Stand					
Stand-table by diameter class, Distance-independent	Stand Structure by species, tree class: live, attack class (green, red, grey), dead, diameter class Volume/ha, # stems/ha, BA/ha, Total ht, Merch ht, # logs by dib & grade, bole checking, rot, height to base of live crown, etc.			●	●
Stand	Crown closure				
Stand	Stand structure - \vertical complexity			●	●
Stand	Stand structure – horizontal complexity -Uniform or clumped			●	●
Stand	Site index – derived or field estimate			●	●
Stand	Competitive vegetation (brush, grass, etc.)			●	●
Stand	History			●	●
Stand	Snags: #, size, species, condition class			●	●
Stand	Mortality (severity class)	●	●	●	●
Stand	Year of first infestation by pathogen	●	●	●	●
Stand	Mortality volume by year by species by pathogen	●	●	●	●
Stand	Spatial location	●	●	●	●
Stand	Location relative to other spatially identified values	●	●	●	●
Stand	Presence & Severity of Other pathogens	●	●	●	●
Stand	Affected tree species – pathogen	●	●	●	●
Stand	Mortality (severity class) by pathogen	●	●	●	●
Stand	DBH, height, no of trees killed by pathogen			●	●
Stand	BEC, slope, aspect, soil moisture class	●	●	●	●
Stand	Environmental restrictions / concerns	●	●	●	●
Growth Model: Stand Average					
Stand	Stand average model - handles mixed species plus forecasts live and dead volume & BA			●	●
Growth Model: Tree List – Stand Table Projection					
Tree	Tree List or Stand Table Projection growth model - handles mixed species, multi-storied, multi-aged stands (distance-independent)			Inventory data or model-generated	Model-generated detail
Shelf Life Model					
Tree/Stand	Under development			●	●
Other Resource Management Requirements					
Stand	Spatial location and extents required for: habitat parameters, riparian buffer zones, aesthetics	●	●	●	●

Discussion

As can be seen, most of the business areas require the same or very similar data. However, resolution and timing requirements vary considerably.

The most detailed data and up-to-date data are required by Harvest Scheduling and by Silviculture; which is to be expected as these business areas are dealing primarily with short-term, detailed planning and site-specific land management activities. However, not all of the area affected by the MPB infestation needs to be covered and maintained to this degree of detail, continuously. The landbase coverage where these business needs dominate data requirements can be characterized as "the last five years of harvesting plus the areas planned for the next five years of harvesting". Based upon the other key business requirements, stand-average data should be sufficient on the rest of the affected landbase - although these data must also be updated annually due to the sensitivity of salvage and utilization to time since death.

The variation in timing and resolution of the data requirements provides significant opportunities to use a range of data sources and methodologies to generate the necessary information - as can be seen from the "How" columns in Table 2 and the Resource Information Themes in Tables 5 and 6, a variety of data sources and technologies can be used to collect the data and information needed.

This opportunity - use of a variety of methodologies and data sources - is critical to the timely development, implementation and maintenance of the enhanced forest resource inventory and monitoring strategy. In other words, it is essential to the success of the strategy to design into the system the use of a variety of methodologies and techniques for acquiring data. This is a key element in giving the strategy strategic resilience.

General levels of resolution for data collection are indicated in the Tables. However, details, both in terms of costs and time to acquire, will have to be worked out via field/operational tests this summer and fall (2005). Similarly, suggested re-measurement cycle times are indicated for monitoring and inventory updates. These cycle times are based upon field experience in normal forest inventory and growth and yield work, and are designed to enable efficient capture of changes in tree and stand parameters which are measurable. However, testing and refinement will be required in order to ensure that re-measurement/monitoring cycles and data resolution are sufficient to meet the defined business requirements relative to the MPB infestation.

Selection of appropriate data acquisition and technical alternatives for addressing the combination of business requirements must consider a number of factors, including:

- existing inventory and monitoring systems;
- multi-sourced data information factors;
- transactional spatial database factors;
- multi-scale and multi-temporal factors;
- forest estate and harvest scheduling modelling factors;
- data reliability factors.

These factors must be considered in combination in the form of a comparative evaluation of feasible technical alternatives.

Starting with the evaluation of technical alternatives, the next step in strategy development is to consider non-technical factors such as:

- costs and resources, business and decision factors including alternatives and trade-offs, timeliness, flexibility and agility;
- organizational factors regarding governance and coordination;
- available government, industry and private sector capacities and skills;
- and lastly, training and infrastructure requirements and business and organizational cultural considerations.

Consideration of the technical and non-technical factors will lead to the identification of several feasible options.

Preliminary feasibility analysis identified gaps in both data acquisition and technological implementation which must be field tested and validated prior to the development of a full implementation plan.

The recommended action plan (Chapter 6) identifies the next steps necessary to resolve these issues.

5. Conclusions and Implications

Conclusions

1. During the course of this project it became clear that many projects, initiatives and technologies are being applied to address a wide range of issues related to the mountain pine beetle epidemic. In order for any strategy to work efficiently and effectively, some form of coordination/oversight/feedback function has to be put in place as soon as possible. This will enable rapid adoption of common data requirements and provide quick and widespread feedback on what works and doesn't work.
2. Urgency is the primary driver. If we are to maximize recovery of value from the affected trees and landscapes and if we are to minimize the impacts, we must be able to initiate a new, coordinated approach to collection, storage, utilization and update of inventory and monitoring data within the next 9-12 months.
3. Meeting the business requirements will require an inventory/monitoring system capable of being updated on at least a yearly cycle.
4. The responses to the Challenge Paper and the feedback from the Challenge Dialog workshops identified the underlying data needed to meet business requirements across a wide range of interests and issues. While the timing and degree of precision differed, basic vegetation inventory and landform data were identified as the primary data components for all identified business needs. These data are commonly collected in forest/vegetation inventory and survey work, but to meet MPB requirements much more emphasis on the dead and dying trees is needed.
5. The new inventory system must focus on collecting and maintaining data to provide answers to key business drivers, not on collecting and maintaining data to a single, specified standard. Existing datasets to specific standards must be maintained, but the system must also allow for data from different sampling plans at different standards to be collected and managed.
6. Collecting and maintaining data from many different datasets with differing sample designs and standards is feasible, providing the data is geo-referenced. This enables the use of GIS-based (spatial position and extent) queries to be used by decision-makers. However, decision-makers must also be aware of the different qualities of data which could be included within a given query. The intelligent use of such data will require training of users.
7. Utilizing a "Resource Information Categories" approach is a useful way to organize the framework needed to meet the identified business requirements. The four suggested categories can serve as effective ways of organizing the data, the issues, developing task lists, assigning project teams and establishing priorities. For example, work on the "Spatial Location and Extent" theme tasks, which obviously focus on spatial location information, can be done in parallel with work on the "Volume and Value" theme. Each theme can have its own set of priorities and its own set of tasks - all defined around meeting business requirements.
8. All data within the system must be available to all users. Owners of the data which are placed in the system are responsible for its accuracy and currency. Accordingly, all data must be date and time stamped as of the last date of update. Obviously users must be knowledgeable about the data in the system and its limitations, but there should be no barriers to legitimate data access.

Summary Strategy Statement

By utilizing a "Resource Information Categories" approach and adopting a more open policy on data which will be included in the system (data which is geo-referenced with a sampling plan – meeting business needs versus meeting a specified standard), rapid and effective progress can be made on developing a new approach to the collection and maintenance of resource inventory and monitoring data to meet the business requirements of the mountain pine beetle epidemic.

Significant gains in useable information can be created for relatively low cost every time a dataset is made useful to another group of users or another business area.

Implications

There are a number of obvious implications arising from the adoption of the recommended strategy. There are probably many implications which are currently unknown. It is our expectation that most of the effects will be borne by the data collection, data storage, data maintenance and data retrieval functions within MSRM.

It is recognized that the suggested strategy will have significant implications on the IT systems used for those purposes, both for attributes as well as the location, GIS/geo-referencing and remote sensing aspects of forest resource data. This is a huge change from the current practice of maintaining separate datasets to strict standards for specific purposes. While we recognize that it is essential to keep datasets such as the VRI and NFI inventories separate and maintained to their appropriate standards, it is equally essential that we find ways of using the VRI/NFI data in combination with many other datasets to assist in decision-making for all of the priority business areas.

By adopting an open policy on data collection and maintenance, new sources of data can be made available to the system and to a wider range of users. One good example is operational cruise data. A second example is the FIA inventory data being collected by various licensees. A third is the EFS data being collected and submitted electronically for harvest and silvicultural activities. These data are being collected to various standards and with differing sampling plans, but all of these programs are collecting data which can be geo-referenced and all are based upon a sampling plan or, in the case of the EFS data, a provincial data collection standard. As a result they can be used to provide additional information to aid in decision-making for geographic areas within which these data have been collected.

Under the present system, the managers of the data have accepted *de facto* responsibility for data quality, accuracy and currency. Under an open data policy, responsibility for the quality, accuracy and currency of the data would reside directly with the data suppliers. The data manager is only responsible to see that the data gets properly loaded into the system. Users of the system must have a way acquire sufficient knowledge about the various datasets they are using with their queries so that they can use them appropriately for supporting decisions. Metadata describing each of the various datasets is an essential part of this process. Additionally, when queries are run, each parameter of interest should carry with it the basic statistical properties (mean estimate, variance, standard error of the mean, etc.) attributed to that parameter as part of that query, as well as basic information on the numbers of samples used from each dataset.

6. Recommended Action Plan

Next Steps

The actions recommended below are based on business needs reflected in the Strategic Framework section and on guiding principles emerging from the Challenge Dialogue process. The urgent nature of the needs requires rapid decisions and implementation of action items. Most of the recommended action items can proceed in parallel and save time.

Guiding Principles for Action

1	***Establish a dialogue with industry***	A Technical-Business Advisory Group would ensure effective communication with industry and academia. The Group would share the results and recommendations of this strategy with industry, coordinate action items with industry initiatives, and feed Strategy results (e.g. from pilot projects) to stakeholders.
2	***Streamline existing programs and activities***	Establish mechanisms to coordinate current inventory and monitoring programs within MoF, MSRM and WLAP and reduce duplication. Take advantage of existing tools for rapid and effective mapping of existing and new outbreaks.
3	***Use best available science and information***	Use the best available science and technology along with local and indigenous knowledge.
4	***Utilize Geo-referencing and GIS technology to enable capture and utilization of a wide range of available data***	Establish mechanisms to coordinate the capture, storage and utilization of data from a wide range of activities; e.g., operational cruises, remote sensing, licensee inventory related survey projects and research projects.
5	***Verify methods for meeting identified MPB information needs by pilot projects***	Pilot and verify data and information acquisition methods for meeting the information needs identified in the Strategy Framework. Document their costs, benefits and operational feasibility via pilot project results.
6	***Mobilize new resources***	New resources will be needed to complement and enhance current mapping of existing and new outbreaks and compile and maintain the required updated datasets.
7	***Track progress and success***	Monitor all MPB inventory projects for effectiveness. Share the results in order to facilitate uptake and adaptive implementation.

Recommended Action Plan: Walk-Through

1. Implement Strategy Framework (Phase I outcome)

Present this report to key MoF and MSRM clients. Resolve any client concerns. Validate the findings and action steps. Coordinate with the MPB Action Plan.

Create high-level governance and coordination group to guide implementation of the strategy. Assign overall executive responsibility for implementation to one individual, backed up by an oversight committee. Develop implementation performance measures. Develop an evaluation and reporting process to assess the progress and success of the implementation plan.

2. Form a Technical and Business Advisory Group

Establish a Technical and Business Advisory Group by contacting technical experts (government, industry, academia) and business leaders. Develop ToR for the group. Form the group.

May also want to consider the establishment of one or more technical working committees to assist in specialty areas.

3. Compile a catalogue of MPB-related inventory and monitoring projects

Initiate and compile a list of relevant projects, either completed, or currently underway. Access FIA funded projects via FIRS (http://www.fialicensees.com/Login/login.asp), projects managed by the PFC (see their website), licensees and other agencies. Summarize outcomes and "lessons learned". Identify MPB information acquisition gaps in relation to Strategy Framework needs.

4. Prepare workplan for Strategy Phase 2

Reference other work, see catalogue above. Reference the business drivers and themes identified in this report.

Build on the Phase 1 outputs to prepare workplan for Strategy Phase 2. (Workshop Workbook Sessions 5 and 6 would provide a good outline to start on this process).

5. Formalize the Strategy Framework

Verify business requirements identified in the Strategy Framework with industry and other key stakeholders who were not able participate in Challenge Paper and Workshops. Use the technical and business advisory committee. Review the action steps and build a comprehensive plan to implement them (Strategy Phase 2). Confirm the priorities and arrange in projects and tasks. Assign projects and tasks to individuals for implementation.

6. Proceed with pilot projects needed to establish optimal methods and procedures for efficient and timely acquisition of information identified in the Strategy Framework

Time pressures for implementation require acquisition of data through pilot projects this summer and fall season (July - September 2005). Two to three pilot areas should be selected to represent conditions typical of the central Interior. Pilot projects should be carried out in an operational mode, simulating reality as much as possible, including

administration and coordination logistics. Use the technical and business advisory committee to select/design the projects. Acquire imagery, conduct aerial and ground surveys. Compare the information acquired with the information needs identified in the Strategy Framework and the factors noted in Boxes 1 and 2.

Recommended Action Plan: At-a-Glance

No.	Action	Lead Agency	Timeframe	Milestones	Dependencies / Relationships
1	***Create governance and coordination group for strategy implementation***	MoF/MSRM	Immediate	• ToR • Group establishment • Executive responsibility assigned	Coordinate with MPB Action Plan, COFI
2	***Form technical & business advisory group*** ***(possibly establish some specialty technical committees)***	MoF/MSRM	Immediate	• ToR • Proposed list of members • Advisory Group formed • Establishment of technical working committees.	Coordinate with MPB Action Plan, COFI
3	***Develop catalogue of all MPB-inventory and monitoring-related projects, & carry out gap analysis***	MoF/MSRM	Immediate	• Reports: - FIA funded projects - Federal projects - Industry • Other	(2), (3)
4	***Prepare workplan for Strategy Phase 2***	MoF/MSRM	Immediate	• Workplan based on using resource information themes + business requirements	(1)
5	***Verify business requirements with industry and other key stakeholders***	MoF/MSRM	Immediate	• Formalized Strategy Framework and Action Plan approved by key stakeholder groups	(2), (3)
6	***Do Pilot projects***	MoF/MSRM	Immediate (July-Oct window)	• Outline pilot project plans based on information gaps • Approve pilot project plans • Commission pilot projects • Monitor pilot projects	Depends on gaps identified in (5)

Box 1: Factors to Consider for Next Steps

Evaluation of Optimal Detection and Mapping Methodologies

Integration of remotely sensed imagery and other sources, both conventional (ground sampling), and non-conventional (e.g. change detection, multi-source data integration), should be evaluated as an entire package. Pilot projects over 2-3 areas of known outbreak are recommended using (but not restricted to) the data sources listed in the Strategy Framework tables. As many data sources as possible should be obtained for each test site (which presumably will already have been mapped by either "measle mapping", sketch survey, or another mapping method). Each site should be analyzed at the:

- Landscape (reconnaissance level) using multi-temporal Landsat imagery
- Stand level, using either newly acquired, or recent aerial photography.
- Tree level, by sampling.

Each dataset should be evaluated as to its red-attack and dieback detection threshold, mapping precision, accuracy, and operational availability.

Data acquisition logistics should be addressed in detail, describing availability limitations, copyright and licensing limitations, weather conditions, and other factors affecting data quality and costs.

Coordination of Mapping Activities

A task force for administration of data ordering, quality control, information extraction and distribution should be established. This implies inter-Ministry and Branch jurisdiction of the task force. Optimal priorities and streamlined decision making will be among attributes assigned to the task force's operation.

Modelling Infestation Risk

Areas with various levels of infestation risk should be determined prior to new data acquisition. Existing models should be used, or improved, to determine discrete risk areas by integration and analysis of multi-source spatial data.

Monitoring

Reduction in cost and improved availability make acquisition of images at regular intervals during the year an attractive option for operations and compliance monitoring purposes. A further direct benefit is getting the information faster and as a contiguous digital file, hence mapping exercises can be completed in a fraction of the time required to work with individual photographs.

Optimally, multiple data sources should be ordered since weather conditions may not allow data acquisition within the specified time frame for a single source.

Box 2: Factors to Consider for Data Collection, Storage and Utilization

Utilization of Geo-referencing and GIS technology

Integration of widely diverse datasets can be accommodated by geo-referencing the sample data and storing each dataset in its own GIS coverage. Each dataset must be capable of being geo-referenced and must be based upon some type of sample design. Metadata descriptions would need to be developed and stored along with each dataset so potential users know the reliability and precision of the datasets available.

The utility of a particular dataset for a specific purpose would be based upon its geographic location(s), parameters measured and the specifics of the design and measurement standards used.

This approach enables data with differing sample designs and differing levels of precision to be combined to answer a geo-referenced query without violating the integrity of individual studies or programs. Queries can be answered without the need to have the same degree of resolution across the entire landbase.

For example, this approach enables FIA-sponsored forest inventory projects, operational cruise projects and measle-mapping data to be used together with the applicable NFI/VRI data for a given area to derive improved estimates of inventory information on live and dead trees, information which may not be readily available from any single data source.

As stated in Box 1, the objective is to utilize all data, both ground sampled and remotely sensed, as part of the complete, composite dataset available to users. The capability of reviewing the extent and quality of available data on a geo-referenced basis enables immediate gains in decision-making power and leads to improved efficiencies in identification of data gaps, as well as efficiencies in the collection, storage and utilization of data for all business requirements.

APPENDIX 1: MPB Epidemic Expansion Rate

Epidemic Expansion Facts

The mountain pine bark beetle population has seen an unprecedented explosion, growing from less than 100,000 cubic metres volume of attacked timber in 1994, to 173.5 million cubic metres of cumulative grey, red and green attack in the working forest alone by the end of 2003. The volume is now about 3½ times the interior's annual harvest level.

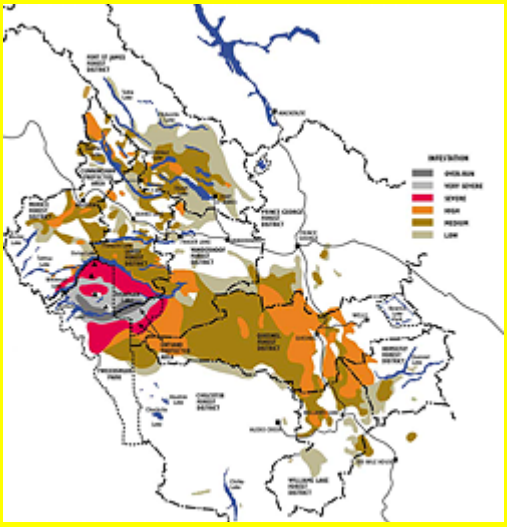
This is by far the largest insect epidemic in Canada's history.

The table below shows the rapid spread beyond endemic levels over the past decade.

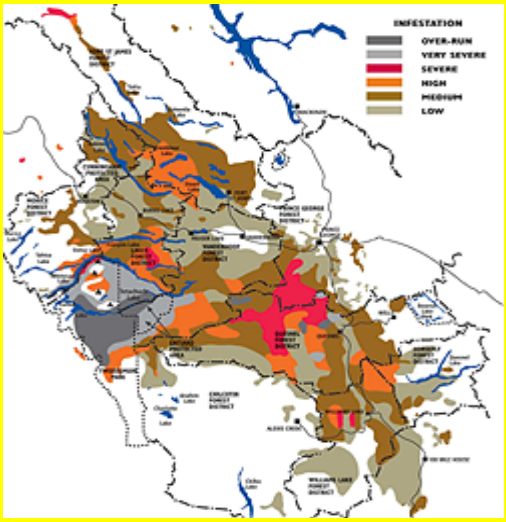
Year	Geographical Location of Spread	Area of spread (km^2)	Volume (million m^3)*
1994	Tweedsmuir/Ootsa	25	0.1
1995	Tweedsmuir/Ootsa	50	0.2
1996	Tweedsmuir/Ootsa	75	0.3
1997	Tweedsmuir/Ootsa	225	0.5
1998	Houston to Entiako	1,225	2.5
1999	Houston to Quesnel	3,225	6.0
2000	Takla Lake/Houston to Williams Lake	57,000	41.1
2001	Takla Lake/Smithers to 100 Mile	80,000	71.8
2002	Takla Lake/Smithers to Cranbrook	89,000	107.7
2003	Williston Lake/Smithers to Cranbrook	101,000	173.5

Source: COFI Mountain Pine Beetle Task Force annual survey.
*Cumulative volume of dead timber.

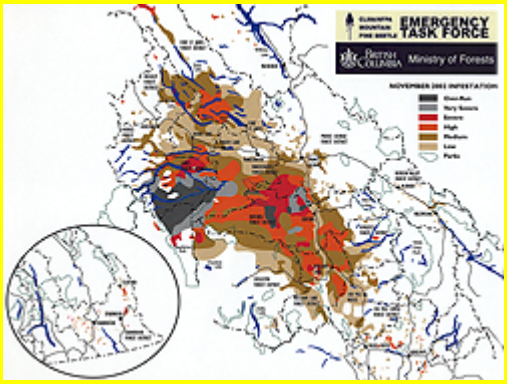
Fall 2000



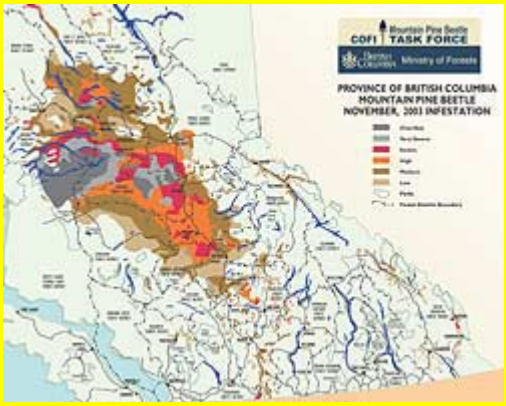
Fall 2001



Fall 2002



Fall 2003



Source: COFI Mountain Pine Beetle Task Force annual survey.
Note: Within the mapped infestation perimeters, there are varying degrees of attack as indicated:

Low: 1-3 percent

Medium: 4-20 percent

High: 21–40 percent

Severe: 41–60 percent

Very severe: 61–80 percent

Overrun: 61–80 percent

As of Fall, 2003:

- Ranging from 1% to 90% attack the epidemic is 1,150 km long and 550 km wide at its widest point, over three quarters the size of Sweden.
- Volume infested by fall 2003: 173.5 million m^3 spread over 10.1 million ha (in the working forest; this does not include volumes in parks and protected areas which are estimated to exceed 30 million m3).
- Volume infested 2002: 107.7 million m^3 spread over 8.9 million ha.
- Volume infested 2001: 71.8 million m^3 spread over 8.0 million ha.
  Provincial Allowable Annual Cut (AAC) in BC: approximately 74 million m^3 (source Ministry of Forests).
- Value of lumber products that can be produced from 173.5 million m^3 of timber is just under $18 billion (based on average lumber price December 5, 2003 $CDN 415/Mfbm).
- Stumpage value to the province is in excess of $2.7 billion (approximate average interior stumpage 2003 $16.00/$m^3$).
- 173 million cubic metres of wood will produce 43 billion board feet of lumber, nearly 1.4 times Canada's total annual softwood lumber production.
- 43 billion board feet of lumber is enough lumber to build 5.2 million homes.
  US housing starts total 1.7 million per year on average.
- Harvesting directed at the beetle in 2003/2004 is expected to be 26 million m^3, up from the 23 million m^3 achieved in the 2002/2003 harvest season. This is over 80% of available harvest capacity.

APPENDIX 2: Mountain Pine Beetle: Latest Predictions

Provincial Level Projection of the Current Mountain Pine Beetle Outbreak: An Overview of the Model (BCMPB) and Draft Results of Year 1 of the Project, Marvin Eng, April 2004.

Website: http://www.for.gov.bc.ca/hre/bcmpb/

Figure 7 illustrates the effect of the mountain pine beetle outbreak and associated management activities on pine volume within the timber harvesting landbase. As a worst case scenario, we project that less than 20% of the total pine volume in the province will remain living after 20 years. That is, only the non-susceptible pine will remain living. A significant proportion of the remainder will be harvested, either as green volume or as salvage, but almost half the volume will become "non-recovered" losses.

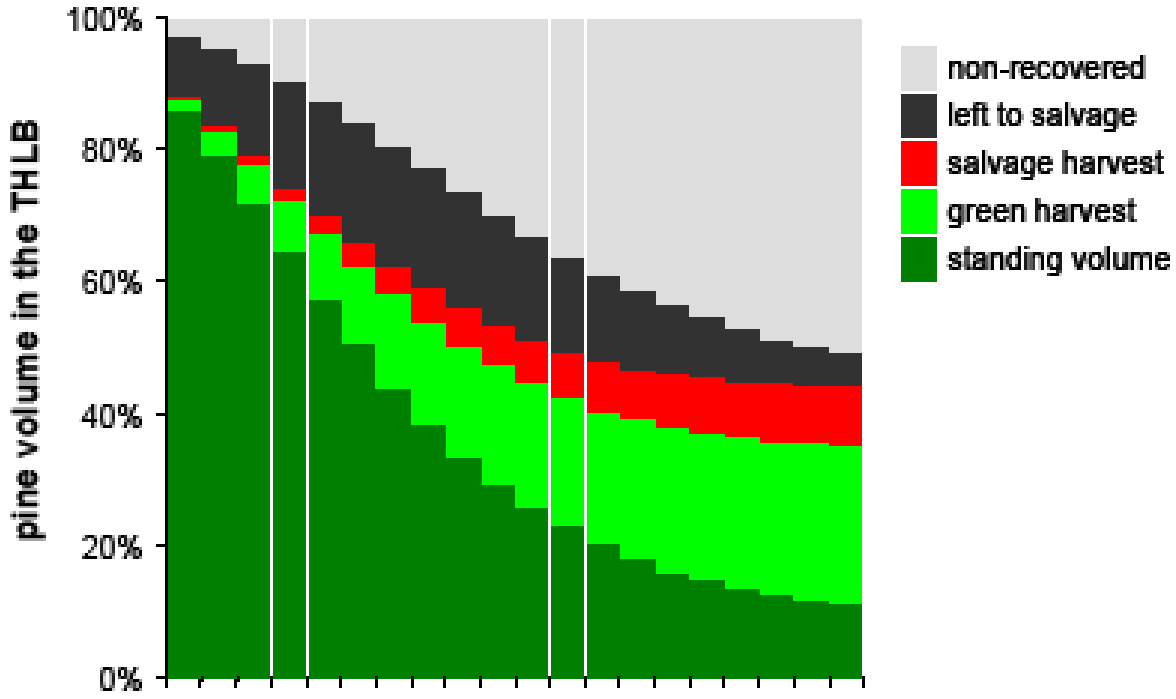
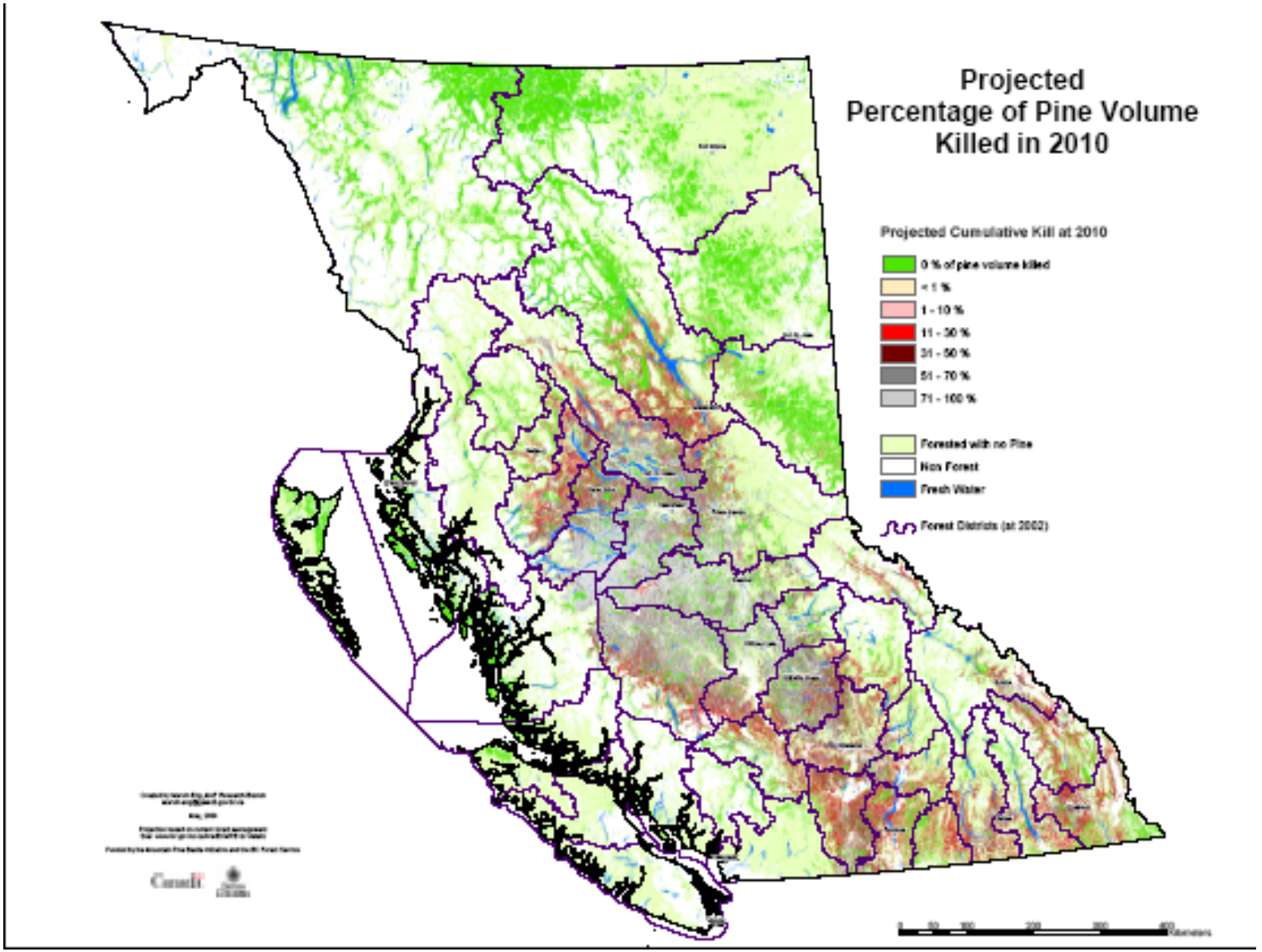


Figure 7. Projected proportion of pine volume on the timber harvesting landbase in various categories under the Reference Scenario

Map: Projected Percentage of Pine Volume Killed in 2010 (overleaf)


Projected
Percentage of Pine Volume
Killed in 2010
Projected Cumulative Kill at 2010
0 % of pine volume killed
< 1 %
1 - 10 %
11 - 30 %
31 - 50 %
51 - 70 %
71 - 100 %
Forested with no Pine
Non Forest
Fresh Water
Forest Districts (at 2002)

APPENDIX 3: Prince George Workshop Participants

NAME		POSITION / ROLE	AFFILIATION	LOCATION
Boyce	Melanie	A/Director Forest Analysis Branch	Forest Analysis Branch, MoF	Victoria
Cullen	Heather		MSRM	
Dobbins	Barry		MoF - NIFR	
Eng	Warren	Forest Inventory Specialist	Atticus Spatial Information Management Ltd.	Vancouver
Hebb	Kathleen		MoF	Vanderhoof
Langin	Herb		MSRM	
Lodin	Michal	Remote Sensing Specialist	GeoSpatial International Inc.	Victoria
Mainer	Dave		MoF	Vanderhoof
Nakatsu	Dick		MSRM	Prince George
Reimer	Don	President	D.R. systems inc.	Nanaimo
Schultz	Fern	Director	Resource Information Branch, MSRM	Victoria
Stace-Smith	John		Tolko Industries Ltd.	

APPENDIX 4: Vancouver (Richmond) Workshop Participants

NAME		POSITION / ROLE	AFFILIATION	LOCATION
Affleck	Peter	VP Forestry	Council of Forest Industries	
Albricht	Rob	Consultant	Earthimaging Technology	
Baker	Rick	Manager Forest Cover Update	Vegetation Resource Inventory, MSRM	
Bowdige	Laurence	VRI Monitoring Program Coordinator	Vegetation Resource Inventory, MSRM	
Boyce	Melanie	A/Director Forest Analysis Branch	Forest Analysis Branch, MoF	Victoria
Eng	Warren	Forest Inventory Specialist	Atticus Spatial Information Management Ltd.	Vancouver
Fletcher	Christine	Manager, Policy and Development	Forest Analysis Branch, MoF	Victoria
Grace	Jim	Regional Inventory Forester	Kamloops Service Contact Centre, MSRM	Kamloops
Harrison	Dave	Chief Implementation Officer, Mountain Pine Beetle Initiative	NRCan	
Heath	Jamie	Consultant	Terrasaurus	Vancouver / Williams Lake
Iles	Kim	Consultant - Forest Inventory Specialist	Kim Isles & Associates	
Johansen	Gary	VRI Audit Coordinator	Vegetation Resource Inventory, MSRM	
Jones	Keith	Principal	R. Keith Jones & Associates	Victoria
Lodin	Michal	Remote Sensing Specialist	GeoSpatial International Inc.	Victoria
MacDonald	Bob	Growth & Yield Forester	Kamloops Service Contact Centre, MSRM	Kamloops
MacMillan	Bob	Consultant	LandMapper Environmental Solutions Inc.	Edmonton
Mainer	Dave	Field Operations Supervisor	MoF	Vanderhoof
Makar	Matt	Resource Information Specialist-Forestry	Kamloops Service Contact Centre, MSRM	Kamloops
Morrison	Ann	Senior Vegetation Update Forester	Forest Cover Update, MSRM	
Mueller	Helmuth	Operations Manager	Alexis Creek, MoF	Alexis Creek
Nakatsu	Dick	Resource Information Forestry Growth and Yield (Prince George)	Prince George Contact Centre, MSRM	Prince George
Niemann	Olaf	Professor	Geography Department, University of Victoria	Victoria
Nussbaum	Albert	Senior Analysis Forester-TSA	Forest Analysis Branch, MoF	
Omule		Biometrician - NFI	Canadian Forest Service, NRCan	
Otukol	Sam	Biometrician	Vegetation Resource Inventory, MSRM	
Pelcat	Mike	Stewardship Officer	Quesnel, MoF	Quesnel
Ramsay	James	Forest Resource Management Specialist, Director	AeroLight Imaging Inc.	Victoria
Reimer	Don	President	D.R. systems inc.	Nanaimo

Schultz	Fern	Director	Resource Information Branch, MSRM	Victoria
Sharma	Rajeev	Remote Sensing Scientist	Canadian Forest Service, PFC, NRCan	Victoria
Spring	Al	Head, Airborne Remote Sensing	Base Mapping and Geomatic Services, MSRM	
Stearns-Smith	Steve	General Manager	Southern Interior Growth and Yield Co-op	
Tautz	Art	Manager, Research & Development	Biodiversity Branch, MWLAP	
Vivian	Jon	Manager, Vegetation Resource Inventory	Resource Information Branch, MSRM	
Waddell	Dave	Systems Forester	Dev & Policy Section, MoF	
Wakelin	John	Mountain Pine Beetle "File"	MSRM	
Wood	Colene	Biodiversity Forester	Ecosystem Planning Section, MWLAP	
Wulder	Mike	Research Scientist	Canadian Forest Service, NRCan	
Yuan	Xiaoping	Forest Statistics Officer	Resource Information Branch, MSRM	

Appendix 5: FIA-funded Forest Health Mapping and Monitoring Initiatives (2004-2005)

A total of 26 forest health projects have been completed or are underway under FIA funding for 2004-2005:

Total number of aerial survey projects:	27	Cost:	*0.675M
Aerial survey projects:	13		
Heli GPS surveys:	3		
GPS Aerial surveys	1		
Other aerial surveys:	10		
Ground Survey Projects:	32	Cost:	*1.710M

*Costs are approximate.

Comparative example of costs *versus* resolution and temporal availability of different available data sources:

Data	Resolution (m)*	Detectable objects	Stereo available	Revisit cycle (days)	Cost/sq. km (in $ Cdn)
LANDSAT 7	15	Major roads, major cutblocks	N	16	0.02
IRS-C	5.8	Minor roads, minor cutblocks	N	5	0.50
IRS-D	5.8	Minor roads, minor cutblocks	N	3	0.50
SPOT 5	2.5 m	Trees (mature)	Yes	5	1.00
EROS	1.8	Trees (immature)	N	7	15.00
IKONOS	1.0	Trees (immature)	Yes	3	45.00
Quickbird	0.61	Trees, shrubs	Yes	1-3.5	45.00
Aerial photography,* 1:40,000	0.6	Stand (texture), roads, cutblocks	Yes		7.00
Aerial photography, 1:15,000	0.23	Trees, shrubs, coarse woody debris	Yes		10.00
Sketch surveys (heli- or aircraft-based)	varies	Tree clusters	N		TBD

* Scanning resolution is assumed 15 microns

** Cost for aerial photography acquisition is based on a sample coverage of a 300,000 ha block, and does not include scanning

Appendix 6: Quesnel TSA Business Requirements for Inventory

May 12, 2005

Quesnel TSA - Business Drivers for Updated Inventory Information

The Quesnel TSA has suffered extensive losses and damage due the effects of mountain pine beetle. It is projected that there will be substantial long-term impacts on timber supply and other forest values. Major forest licensees and the Ministry of Forests recognize that efforts must be undertaken to reduce or mitigate short-, mid- and long-term effects of the epidemic. We also recognize that there are major gaps in land-base information that is needed for planning purposes. The Quesnel group volunteered to participate in a pilot project that is, so far, undefined. The notes provide below are derived from recent discussions about business drivers and needs as we see the situation in Quesnel. Participants and contributors to the points provided below come from staff in government ministries and major licensees in Quesnel.

At the Provincial level, a project is underway to try and come up with an inventory strategy that addresses post-epidemic conditions. This project addresses timber and non-timber values. The pilot project being contemplated in Quesnel may serve to develop and refine the processes.

In the discussions in Quesnel, we recognized that there are other forest values other than timber that have been and are being affected by the epidemic. We generally limited our point of view to timber values, as that is what we have expertise in. Anything that we can do to mitigate the timber impacts will also have a beneficial effect on the community.

A. BUSINESS DRIVERS

1. Harvest Planning and Scheduling

1.1. Salvage value and minimize economic losses from attacked pine

1.2. Minimize rate of losses of pine to decay

1.3. Balancing salvage planning (i.e. to avoid 'taking the best and losing the rest')

1.4. Identifying areas to abandon with respect to sawlog harvesting opportunity

Inventory Needs

- Improve shelf-life estimates, including how it may differ in different BEC sub-zones and variants
- Derive estimates of timelines for development of factors which affect decline of wood quality, such as checking, drying, loss of bark
- Stratification of dead stands, damaged stands and green stands
- Ground sampling to quantify residual live volumes. .
- Determine areas where there is least value for timber and greater non-timber values, such as habitat or biodiversity, to support abandonment choices
- Updated photography or other imagery with a resolution useable for broad stratification and sampling, and for mapping OGMAs, MDWR, WHAs, or other biodiversity and habitat features.

2. Mitigation of short- and mid-term losses of timber supply

2.1. Bring mid-rotation stands to merchantable size in time to coincide with projected timber supply 'falldown'.

2.2. Improve estimates of growth potential on managed and unmanaged stands

2.3. Leave partially attacked stands for future harvesting opportunities

Inventory needs or information gaps

- Growth response of fertilizing in mid- or late-rotation stands, and when would fertilized stands reach merchantability, as compared to unfertilized stands.
- Stand selection criteria for mid- or late-rotation fertilizing
- Ground sampling to quantify ages and volumes of live residual trees in partially attacked stands
- Ground sampling to quantify understorey coniferous density and growth rates in the various BEC sub-zones and variants (possibly to site series level)
    - Require species, densities, ages, heights, site index estimates
- Feedback mechanism to confirm or modify data derived from ground sampling.
- Photography or other imagery with a resolution useable for broad stratification and sampling.

(A PEM project for the Quesnel TSA will be completed in 2006; a site index project will be undertaken once the PEM is completed. Any adjustments to site index will be incorporated into the next TSR. This project supports item 2.2.)

3. Rehabilitation for long-term timber supply

3.1. Prepare a rehabilitation strategy that would identify what can be done, where and what results would be expected.

3.2. Determine the potential to reclaim marginal or abandoned agricultural land as forest land.

B. NON-TIMBER CONSIDERATIONS

4. Habitat or Biodiversity Mitigation

4.1. What are potential stand manipulation measures that may help create wildlife habitat?

4.2. What are the implications of the recent 'biodiversity uplift' in BEC sub-zones and landscape units.

4.3. What is the impact of pine mortality on terrestrial lichens in northern caribou habitat?

4.4. What is the condition of OGMAs, WTPs, RMAs or other biodiversity and habitat features after the MPB epidemic

4.5. How are 'indicator species' reacting to habitat changes resulting from the MPB epidemic?

4.6. Should we re-evaluate how biodiversity can be measured in pine-leading areas, post-MPB epidemic

Needs

- Participation of WLAP in planning.
- New photography or imagery to assist in planning, ground sampling, and project work undertaken by government ministries and licensees related to both timber and non-timber values.

Appendix 7: Image Primer

Image Primer June 9, 2005

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When determining what imagery will meet specific business needs, business areas need to determine where information is needed, when it will be needed and how soon it can be provided, what is the required currency of information, how large is the area of interest or the area of the target population, and what level of information detail is needed. The following diagram is used to illustrate these concepts.

The information provided below should guide acquisitions of new image data. Acquisitions should consider the specific risks and cost benefits associated with the different image datasets for each business area use and specific location. The net benefit of one data source over another for a given use will vary due to the risks and the local situation. As a best practice, information compiled from source images should have the source identified as an attribute within feature metadata records.

Applications and Optimal Image Use

Extent of forest mortality caused by pests and/or disease at the stand level:

1. Multi-temporal multispectral Landsat images for use from strategic down to operational planning levels e.g. Mountain Pine Beetle red attack. These data are suitable for mapping the extent and monitoring over time. These data should provide the 90% answer for the extent and location of forest mortality.
2. Multi-temporal SPOT 5 MSS is not currently available over large areas of the province. There are higher costs and increased time involved in mapping the extent and monitoring over time with these data.
3. Annual coverages of colour aerial photography/orthophotos are rarely available over large areas of the province due to costs. These are used for more detailed information such as mapped classes of mortality severity.

Year of forest mortality caused by pests and/or disease at the stand level:

1. Multi-temporal Landsat multispectral images for use from strategic down to operational planning levels. These data combined with other GIS information should provide the 90% answer for year of forest mortality.

Small scale salvage:

1. Multi-temporal multispectral Landsat images for use from strategic down to operational planning levels. These data are suitable for mapping the extent, location, area, and monitoring small scale salvage over time. These data should provide the 90% answer for the extent, location, and area of small scale salvage openings down to 0.25 hectares.
2. Multi-temporal SPOT 5 MSS is not currently available over large areas of the province. Tasking this satellite for acquisitions for multi-temporal coverages should be based on the risks and cost benefits.
3. If higher resolution current imagery is available (SPOT 5, aerial photography/orthophoto), these data should be used based on the risks and cost benefit.

Forest fire boundary extent and year of fire:

1. Current and multi-date multispectral Landsat images for use from strategic down to operational planning levels. These data are suitable for mapping the extent of forest fires and monitoring over time. These data should provide the 90% answer for the extent and location of forest fires.
2. If higher resolution current colour imagery is available (SPOT 5 MSS, aerial photography/orthophoto), these data should be used based on the risks and cost benefit.

Forest cover (VRI) update of harvest openings and results audit:

1. Multispectral Landsat multi-date images for use from strategic down to operational planning levels. These data are suitable for mapping the extent, location, area, and monitoring over time.
2. If higher resolution current colour imagery is available (SPOT 5 MSS, aerial photography/orthophoto), these data should be used based on the risks and cost benefit.

Emergency response:

1. Current multispectral Landsat images for use from strategic down to operational planning levels. These data are suitable for locating new roads and landings that may not be available from other sources in planning response strategies e.g. forest fires.
2. Fires having greater risk such as interface fires will require more current and higher resolution imagery.
3. Radar satellite data can be used effectively to respond to large scale flooding emergencies and monitoring.

Forests compliance & enforcement:

1. Current multispectral Landsat images for use from strategic down to operational planning levels. These data are suitable for identifying likely areas of forest harvest trespass prior to field survey confirmation.

Silviculture survey planning:

1. Current colour orthophotos are the preferred image data source for Silviculture Survey planning. These data are suitable for identifying all road and transport features, vegetation patterns, and tree patches within cut blocks.
2. Current SPOT 5 MSS and/or SPOT black and white (panchromatic) merged with current Landsat multispectral. These data are likely to achieve results similar to those from orthophoto but with less detail and precision.
3. Current Landsat images can be used for this application with a further reduction in detail and precision.

Timber sales operational planning:

1. Current colour orthophotos are the preferred image data source for Timber Sales operational planning. These data are suitable for identifying all road and transport features, vegetation patterns and current cut block openings.
2. Current SPOT 5 MSS and/or SPOT black and white (panchromatic) merged with current Landsat multispectral. These data are likely to achieve results similar to those from orthophoto but with less detail and precision.
3. Current Landsat images can be used for this application with a further reduction in detail and precision.

Cost Comparisons (prices in $ CDN)

LANDSAT 5	30 Multi, Therm	**$0.03**	no copyright
LANDSAT 7 *	15 Pan, 30 Multi, Therm	**$0.03**	no copyright
SPOT 2 & 4	10 Pan, 20 MSS	**$0.77**	unrestricted within BC Govt
IRS	5.8 Pan, 23.5 MSS	**$0.92**	unrestricted within BC Govt
SPOT 5	5 Pan, 10 MSS	**$1.33**	unrestricted within BC Govt
SPOT 5	2.5 Pan	**$2.00**	unrestricted within BC Govt
IKONOS	1 Pan, 4 MSS	**$24.75**	unrestricted within BC Govt
QUICKBIRD	0.6 Pan, 2.5 MSS	**$27.25**	unrestricted within BC Govt
1:30,000 Ortho	B/W 0.5 or 1	**$18.00**	BC Govt owns copyright
1:30,000 Ortho	Colour 0.5 or 1	**$19.00**	BC Govt owns copyright
1:15,000 Ortho	B/W 0.25 or 0.5	**$30.70**	BC Govt owns copyright
1:15,000 Ortho	Colour 0.25 or 0.5	**$32.70**	BC Govt owns copyright

Aerial Photography to Orthophoto Cost Comparisons

Photo Scale	Aerial Photo Acquisition and Scanning cost/sq km	Aerial Triangulation cost/sq km	Orthophoto cost/sq km	Total
1:15,000 B/W	$21.00	$7.50	$2.20	$30.70
1:15,000 Colour	$23.00	$7.50	$2.20	$32.70
1:30,000 B/W	$14.00	$2.67	$1.33	$18.00
1:30,000 Colour	$15.00	$2.67	$1.33	$19.00

* Landsat 7 suffered a permanent malfunction on May 31, 2003. Quality full scene data has not been available from Landsat 7 since this date.

Satellite data costs are based on orthorectified GIS-ready products.

Aerial photography costs are based on recent block flying programs from the Base Mapping and Geomatic Services Branch, Air Photo Operations.

Aerial photography acquisition costs are related to; remoteness of the area of interest, size of the area of interest, season, start up costs and the availability of air crews and equipment. Price of aviation fuel!

Aerial Triangulation and Orthophoto costs per hectare from the Base Mapping and Geomatic Services Branch 1:20,000 map tile costs, converted to cost per sq km.

Orthophoto costs include photo acquisition, scanning, and aerial triangulation.

Satellite Earth Observation (EO) Systems

(pixel size in metres, swath width in kilometres)

satellite	pixel size	swath width
LANDSAT 5	30 m	180 km
LANDSAT 7	15 and 30 m	180 km
SPOT 2 and 4	10 and 20 m	60 km
IRS-1C and 1D	5.8 and 23 m	70 km
SPOT 5	5 and 10 m	120 km
SPOT 5	2.5 m	60 km
Radarsat-1	10 to 100 m	50 to 500 km
Radarsat-2	3 to 100 m	50 to 500 km
IKONOS	1 and 4 m	11 km
ORBVIEW-3	1 and 4 m	8 km
EROS-1A	1.8 m	13 km
QUICKBIRD	0.6 and 2.5 m	16.5 km

Appendix 8: Methods of Data Capture Supplement

MPB Inventory Activities
May 13, 2005

Broad Scale (Multiple Management Units)		Medium Scale (Management Unit, District, TFL)		Specific (Sub-units, Sub-populations)	
Activity	**Target / Outcome**	**Activity**	**Target / Outcome**	**Activity**	**Target / Outcome**
Photo Interpretation • Generalized live / dead polygon delineation from satellite imagery (minimum polygon size would likely be about 5 ha)	• Updated file to provide a better indication of where live trees (no species) are located; identifies broad areas of infested / killed stands	*Photo Interpretation* • Photo interpretation at management unit level post beetle attack; may aid in determination of advance regen areas	• Complete coverage of unit; requires aerial photo acquisition in most units	*Photo Interpretation* • None supported	
Image Acquisition • Satellite, small-scale photography (1:40,000 – 1:70,000)	• Identifies broad areas of beetle impact from remote sensing, allows for TRIM updates	*Image Acquisition* • Medium-scale photography (1:10,000 – 1:20,000; B&W and colour) • Medium-scale photography (1:30,000)	• Used for VRI photo interpretation; allows for determination of sub-polygon information • Sub-polygon level information of marginal quality	*Image Acquisition* • Large-scale photography (1:500 – 1:5,000).	Tree-level information

Broad Scale (Multiple Management Units)		Medium Scale (Management Unit, District, TFL)		Specific (Sub-units, Sub-populations)	
Activity	**Target / Outcome**	**Activity**	**Target / Outcome**	**Activity**	**Target / Outcome**
Ground Sampling • Possible re-visitation of pre-beetle VRI ground samples in areas such as Vanderhoof	• Provides insight into results of infestation; will require determination of desired attributes to measure	*Ground Sampling* • Ground sampling of larger populations; stratification where necessary	• Statistically valid answer for unit; may be reported using strata-based results	*Ground Sampling* • Not supported without better determination of business drivers	• Projects may be approved but collected data may not be stored and utilized corporately
Monitoring • NFI	• Broad reporting over multiple units or province	*Monitoring* • Supported but not required of licensees	• Business drivers unclear at this point	*Monitoring* • Not supported	
Growth and Yield • PSP	• Re-measure existing long term samples to capture yield, mortality, regeneration, stand dynamics in MPB stands	*Growth and Yield* • PSP	• Establish new PSPs to fill gaps in database • Re-measure existing long term samples	*Growth and Yield* • PSP	• Establish new PSPs to fill gaps in database