

A Strategy for the Growth Natural Permanent Sample Plot Program: A Discussion Paper

Prepared For:

**Forest Analysis and Inventory Branch
BC Ministry of Forests, Lands and Natural Resource Operations
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EXECUTIVE SUMMARY

ES1. This report outlines a proposed 10-year strategy and actions for the Forest Analysis and Inventory Branch (FAIB) Growth Natural Permanent Sample Plot (GN-PSP) Program. Development of this strategy was based on recognition by FAIB that the GN-PSP Program was not sustainable in its current state, given that the current in-house funding levels are inadequate, and there are also other competing forest inventory program priorities. To-date, there are 7,839 plots in the GN-PSP Program, of which approximately 5,427 PSPs are still active or pest-damaged, in Crown land (including national parks and protected areas), and the responsibility of FAIB.

ES2 The proposed strategy is to remeasure a sub-set of about 150 high-value existing GN-PSPs per year, and freeze the establishment of new GN-PSPs, over the next 10 years. This proposed strategy should be revised in the future if more resources become available or when the information needs change.

ES3. The main objective of the GN-PSPs remains that of providing real time-series data province-wide, for re-calibrating existing GY models, and for building new models and conducting special studies, to address emerging issues.

ES4. The high-value GN-PSPs should be selected based on the former Forest Productivity Council's (FPC) matrix and plot rating system, plus consideration of additional factors related to climate change impacts and model calibration to account for Mountain Pine Beetle (MPB) effects. The uniform application of the 10-year remeasurement cycle for the PSPs is inefficient; slow growing plots should be remeasured less often than the fast-growing. A PSP remeasurement cycle based on plot estimated top height growth (say, at every 5-m interval) should be considered instead.

ES5. Methods for monitoring the guidelines developed for protecting the GN-PSPs should be developed. The FAIB should continuously improve the quality and accessibility of the GN-PSP database, and encourage use of the data. For example, analysis of data from the GN-PSPs in the MPB-attack areas could provide pre- and post-attack stand development trends, and natural regeneration following the attack.

ES6. New mechanisms for lobbying for GN-PSP protection and funding, to replace the defunct FPC, should be considered. The value of the GN-PSPs and how they support political decision-making regarding forest resources and their stewardship must be made clear to management. It is also important to document and publish the value of the GN-PSPs and results obtained from their analyses, so as to justify requests for more resources. The GN-PSP program should be marketed as part of FAIB's Stand Development Modeling (SDM) program, to reflect their linkages. This way, also, the GN-PSP program will not stand-out during budget cuts, and it can be more easily justified.

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ABBREVIATIONS AND ACRONYMS

BC	British Columbia
BEC	Biogeoclimatic Ecological Classification
DBH	Diameter at Breast Height (1.3 m)
CMI	Change Monitoring Inventory
EP	Experimental Project
FAIB	Forest Analysis and Inventory Branch
FPC	Forest Productivity Council
GN-PSP	Growth Natural Permanent Sample Plot
GY	Growth and Yield
MFLNRO	Ministry of Forests, Lands and Natural Resource Operations
MPB	Mountain Pine Beetle
PSP	Permanent Sample Plot
SDM	Stand Development Monitoring (FAIB)
SFM	Sustainable Forest Management
SIGY	Southern Interior Growth and Yield Cooperative
TASS	Tree and Stand Simulator
TAC	Technical Advisory Committee
TSR	Timer Supply Review
VDYP7	Variable Density Yield Prediction System
VRI	Vegetation Resources Inventory
YSM	Young Stand Monitoring

1. INTRODUCTION

1. British Columbia has a long history of forest permanent sample plot (PSP) establishment dating back to the establishment of experimental plots in the early 1920's. The Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) Forest Analysis and Inventory Branch (FAIB) legacy "Growth Natural" PSP (GN-PSP) Program was started by the government in 1961 within the Growth and Yield Section of the then-Inventory Division. (See Annex 1 for a brief history of the GN-PSP program.) The main goal of the GN-PSP Program was to provide long-term real time-series data on stand growth, regeneration and mortality. The intended uses of the PSP data at the time were:

- Check the assumptions made in yield projections, which were developed from temporary sample plots.
- Develop a database for growth modeling.
- Provide "ground control" data for a variety of purposes.

2. The GN-PSP Program consists of two sets of PSPs: (1) The growth natural plots that were established since the Program was started in 1961, and (2) The then-Research Division control plots that were established dating back to the 1920's, and were turned over to the Inventory Program in late 1970's. These PSPs are long-term sample plots established in subjectively selected, well-stocked natural stands, in a range of stand conditions. They are periodically remeasured, approximately every 10 years (resources permitting), to provide real time-series data.

3. To-date, there are a total of 7,839 plots in the GN-PSP Program. Of these, approximately 5,427 PSPs are still active or pest-damaged, are in Crown land (including national parks and protected areas), and are the responsibility of FAIB. The remaining PSPs are outside Crown land, or have been dropped, logged or are badly damaged. Of the 5,427 GN-PSPs, about 25% have more than 30 years of remeasurements, 25% have 16-30 years of remeasurement, 25% have 1-15 years of remeasurement, and the remaining 25% have only the establishment measurement.

4. The FAIB has recognized that the GN-PSP Program is not sustainable in its current state, given that the current in-house funding levels are inadequate, and there are other competing program priorities. This was also the conclusion of an independent evaluation of the Program by the consultant (see Annex 2). The FAIB commissioned a project to develop this draft 10-year GN-PSP Strategy discussion paper, to help set priorities on the GN-PSP establishment and remeasurement. Initial ideas by FAIB and this consultant were sent to selected stakeholders at the Canadian Forest Service, forestry consulting community and the academia for comment. Comments from these contacts are incorporated into this draft (Annex 3). This strategy discussion paper shall be sent out for wider review by all key program stakeholders.

2. GN-PSP PROGRAM ISSUES

5. The historical GN-PSP database has been extremely valuable. It has been used to develop growth and yield (GY) models, including VDYP7 and TASS. These models are now routinely used in sustainable forest management (SFM) applications, such as timber supply review (TSR), provincial forest inventory update, Vegetation Resources Inventory Management System (VRIMS), and silvicultural planning. The PSP database has also been used in research and development projects on emerging issues, including climate change studies, stand recovery studies after catastrophic forest health epidemics, and dead tree dynamics.¹ As well, there have been assorted requests for the PSP data from various agencies and consultants for other projects needs (see Example requests given in Annex 4).

6. The establishment and maintenance of PSPs is, however, an expensive business. The total cost of the PSP Program since its establishment in 1961 is unknown, but its replacement value has been estimated at about \$80 million.² Plot establishment and remeasurement costs keep sky-rocketing due to, for example, low contractor availability and high day-rate bids. The average plot establishment or remeasurement cost is currently approximately \$1,250/plot. Furthermore, the budgets for the Program have varied over time, depending on government political will and other priorities. For example, the PSP establishment and remeasurement declined substantially in the 1980's due to the then government's austerity budget cuts; and it surged during the federal-provincial Forest Resources Development Agreement (FRDA) era. The PSPs are long-term by nature, and require stable funding and staffing commitments to be successful.

7. As the Ministry is continually forced to review its programs, the GN-PSP Program is especially vulnerable to budget cut-backs. This is because of its high and significant cost, and the difficulty of justifying the Program to the managers, especially because of its long-term nature and lack of a cost/benefit analysis. Yet, there are currently no suitable alternatives to PSPs for gathering long-term real time-series data. This has been recognized internationally in the literature. For example, PSP data should not be replaced with data from "pseudo" time series from temporary sample plots.

8. The GN-PSP program size is large – a total of 7,839 plots. These are more plots than the FAIB can afford to remeasure. Some plots have not been maintained or re-measured in a decade or more; thus, some are probably no longer salvageable, and some others are at risk of loss if they are not re-visited soon. Some plots are of higher quality than others to retain for the long-term (e.g., larger plot sizes, more remeasurements, and more heights measured). There is also some duplication of GN-

¹ Stone, J., J. Parminster and J. Braz. 2002. Standing dead tree dynamics extracted from growth and yield permanent sample plots in British Columbia. USDA Forest Service Gen. Tech. Rep. PSW-GTR-181.

² https://www.for.gov.bc.ca/hts/vri/pmps/downloads/PSP_Protection_Memo.pdf.

PSPs within some stand types. That is, many of the GN-PSPs overlap in similar stand types. Once the duplication is reduced, the number of potential high-value GN-PSPs should decrease considerably.

9. The GN-PSPs have some design limitations for monitoring and mortality applications. The plots are not representative of the average stand conditions, since they were subjectively located in uniform, “well stocked” stands. Thus, they cannot be used for GY monitoring. As well, the plot sizes are relatively small, and are not ideal for tracking mortality, which was one of the original objectives of the program.

3. PROPOSED PROGRAM STRATEGY

3.1 Overview

10. The legacy GN-PSPs are the only plots in the province with a long history of remeasurements, besides the earlier experimental plots (EPs). Note that, of the FAIB 5,427 GN-PSPs, about 1,357 have more than 30 years of remeasurements. This is a desirable feature for GY modeling and climate change studies. There is, therefore, still a need to maintain at least some of these plots, until sufficient remeasurement data have been accumulated from the GY monitoring programs or other sources (see Section 4). Thus, a strategy is needed on how to sustainably manage the program, i.e., address the issues outlined above. The following section outlines a proposed 10-year strategy for the GN-PSP program.

3.2 Information Needs

11. The mission of the ministry’s Forest Inventory Program is to produce reliable forest inventories and stand growth models so that natural resource management in British Columbia is informed by credible information on forest condition. The core functions of the Inventory Section are:

- i) Collect, manage, and make available forest inventory information for British Columbia.
- ii) Develop and make available stand growth and yield models.

The Inventory Section also has other responsibilities, such as GY monitoring used to check GY predictions and assumptions.

12. The GN-PSP Program contributes time series data as inputs for achieving core function ii) and for other uses. The proposed program strategy is aimed at providing direction for a sustainable program. A provincial PSP strategy report has been prepared in the past by S. Stearns-Smith (2006)³ for the Southern Interior GY Cooperative (SIGY). This report reviewed the business case and plot establishment and remeasurement strategies for the PSP program, and there has been no other formal strategy prepared

³ Stearns-Smith, S. 2006. Provincial PSP remeasurement priorities (BC’s PSP strategy revisited). Contract report prepared for the SIGY.

since then. The current FAIB overall PSP approach is to remeasure all the EPs and a sub-set of the GN-PSPs, and to establish CMI and YSM in MPB-affected and other high priority management units.

3.3 Proposed Approach

13. The proposed 10-year strategy to address the issues raised in Section 2 for an efficient and sustainable GN-PSP Program is to:

Remeasure a sub-set of about 150 high-value existing GN-PSPs to meet changing GY information needs, and freeze the establishment of new GN-PSPs, over the next ten years.

This proposed strategy should be subject to periodic review, and when more resources become available or information priority or needs change. It is elaborated further in the following sections.

3.4 Objective

14. The main objective of the GN-PSPs remains that of providing long-term stand development (real time-series) data province-wide, for re-calibrating existing GY models, and building new models and conducting special studies, to address emerging issues (such as the effects of changing environmental conditions and MPB attack on stand GY).⁴

3.5 New Plot Establishment

15. No new GN-PSPs have been established by the ministry since about seven years ago; the last plots were established in 2007. Ideally, establishing more PSPs should be part of any strategy. However, due to limited resources, the past strategy to freeze the establishment of new GN-PSPs should continue over the next 10 years, unless more resources become available (as has happened in the past), or as high priority needs arise. Resources should be channeled to protecting the investment already made - by remeasuring existing plots.

3.6 Plot remeasurement and Maintenance

16. *Centralized program.* The FAIB should re-establish a centralized provincial GN-PSP program. However, only a sub-set of high-value PSPs, covering the entire province and a broad range of stand types, should be selected for remeasurement and maintenance (check status of tree tags and plot monumentation). These PSPs will be still active or pest-damaged, are in Crown land (including national parks and protected areas), and are the responsibility of FAIB. Some other Canadian jurisdictions have done this in the past, such as the province of Ontario, where in the 1990's the number of

⁴ Note that providing mortality data is not explicitly included in this objective because the plot sizes of almost all of the PSPs are not ideal (too small) for tracking mortality over time; thus, a separate program is needed for this purpose.

historical PSPs was reduced from 4,300 to 1,100, and the remeasurement cycle doubled from 5 to 10 years.⁵

17. *Program cost.* Based on current funding levels, the forest inventory program can support the remeasurement and maintenance of about 150 high-value PSPs per year on a 10-year remeasurement cycle. This would cost a total of approximately \$200,000/year, at a unit cost of \$1,250/plot for plot remeasurement. The total annual cost would be about \$680,000/year for a fully-fledged remeasurement program (all PSPs under the FAIB responsibility).

18. *Selecting high-value (Priority) GN-PSPs.* A subset of about 150 high-value GN-PSPs managed by FAIB should be selected based upon the following considerations and approach (adapted from FAIB, 2015):⁶

- a) *Needs and available resources:* Consider currently available or anticipated budget and other resources, as well as GY modeling strategies and priorities.
- b) *Scope.* Consider all the GN-PSPs that are active or pest-damaged, outside private/IR lands, at least 0.04 ha in individual-plot size, and under the FAIB responsibility. Plots with only the establishment measurement should also be included, as suggested by SIGY.³
- c) *Distribution:* Assign each PSP to a cell within a matrix that most closely approximates the former Forest Productivity Council of B.C.'s (FPC) PSP matrix criteria, to ensure a broad range of stand conditions are represented. These criteria include BEC zone, species (pure, mixed-conifer, mixed-deciduous), age class, density class (density for age 0-20 years, then Wilson's spacing factor), and site index class. This FPC matrix needs to include additional criteria as suggested by SIGY.³
- d) *Rating:* Compute a numeric rating for each PSP within each cell based on the FPC's approved quality rating methodology (Forest Productivity Council TAC, 1994).⁷ The quality rating factors include plot area, number of trees per plot, source of stand age and top height, plot status, presence of stem maps, presence of a buffer, measurement interval, number of height trees, and DBH tagging limit. This FPC quality rating should be modified to assigning a high rating for:
 - i. PSPs needed for re-calibrating TASS and VDYP7 (and other models) to incorporate excessive mortality due to MPB attack.
 - ii. PSPs in areas where studies have indicated significant impacts owing to climate and atmospheric changes, in consultation with the Canadian Forest Service, Victoria, BC.

⁵ Sharma, M., J. Parton, M. Woods, P. Newton, M. Penner, J. Wang, A. Stinson, and F. W. Bell. 2008. Ontario's forest growth and yield modeling program: Advances resulting from the Forestry Research Partnership. For Chron. 84 (5):694-703.

⁶ FAIB (2015). 2015-2018 Sample Plan - Growth Natural PSP Re-measurement. FAIB, Victoria, BC. (Contact: Rene de Jong).

⁷ De Jong, R.J., J. Braz, P. Marshall, G. Nigh and N. Smith. 1994. Quality rating for permanent sample plots. Report to the Forest productivity Councils of BC by the PSP Ranking Sub-Committee of TAC.

- e) *Plot selection*: Sort the PSPs from highest to lowest rating value within each matrix cell, and select highest-value PSP in each cell.
- f) *Periodic review*: The high-priority list should be periodically reviewed to take into consideration of emerging needs and priorities, and available resources.

19. The FAIB had earlier applied this approach (with slightly different criteria), and identified a preliminary list of 1,788 high-value PSPs. This FAIB list should be updated to incorporate other considerations and criteria that have been suggested here. The high-value GN-PSPs should all be stem-mapped, ecologically-classified, all individual-tree heights measured, and the standard tree measurements, including MPB-related attributes, taken.

20. *Remeasurement cycle*. The uniform application of the 10-year remeasurement cycle for the PSPs is inefficient. The PSP remeasurement cycle could be based on estimated plot top height growth (say, every 5-m interval): slow growing plots would be remeasured less often than the fast-growing. For example, a coastal Douglas-fir PSP on site 30 established at breast-height age 25 years, would be remeasured at intervals of 10, 15, 20, and 25 years and so on (estimated from site index curves). This proposed approach sounds like a logistical nightmare; however, with good planning it could be smoothly implemented resulting in reduced remeasurement cost. It is also consistent with the modeling philosophy of some models such as TASS, which is height-driven.

21. *Partnerships*. There is value in responding to stakeholder needs and capitalizing on cost sharing opportunities for PSP re-measurement that target specific issues. However, there is also cost in that special themes or issues for PSP re-measurement take FAIB staff time and resources away from re-establishing a stable provincial PSP program. The FAIB is encouraged to meet these requests, where possible, especially if they include remeasurement of the priority or other GN-PSPs as well.

22. *Lower-priority PSPs*. The lower priority PSPs should be made “dormant” – but not de-activated – for future evaluation and possible measurement should new priority needs or extra resources become available.⁸ However, if they are in conflict with a harvesting plan, then the ministry should be contacted so the PSP program staff can arrange a final re-measurement before the harvest.

23. *Use of GN-PSP data*. The past data from the GN-PSPs should be used to promote or attract potential clients to remeasure these plots, by demonstrating their analytical value. For example, analysis of the existing GN-PSPs in MPB-affected areas should be

⁸ The dilemma here is that the legacy PSPs cannot be replaced once they are lost or discarded, since the spatial/time series link would be broken.

considered. This analysis would, for example, examine the pre- and post-attack stand development, and natural regeneration following the attacks.⁹

3.7 Plot Protection

24. Recent reconnaissance of some PSPs found that many had been harvested without prior consultation with the PSP Program staff. This prompted the Chief Forester to write a memo, dated July 15, 2011, to all the District Managers and Regional Executive Directors, outlining guidelines for protection of PSPs from harvesting.² These guidelines state that harvesting plans should consider if a ministry-managed PSP is in a conflict situation. If a PSP is in conflict with a harvesting plan it is requested that the proponent contacts PSP program staff, who will review that PSP and work with the interested party to determine its relative overall importance and will make a decision whether the PSP should be de-activated or continue to be protected. In the case of de-activation, the plot should be remeasured for the last time. Mechanisms for monitoring these guidelines to ensure compliance should be developed by FAIB.

3.8 Data Management

25. The ministry GN-PSP information has been compiled and entered into a Microsoft Excel format file (csv format), which can be downloaded from the ministry website. Also available are the plot location data and data dictionary. The PSP data are also maintained in a centralized database and can be found on the Land and Resource Data Warehouse - <http://geobc.gov.bc.ca>. Plot summary data are also posted on the FAIB FTP site (ftp://ftp.for.gov.bc.ca/HTS/external!/publish/faib_ground_samples). The FAIB should continuously improve the quality and accessibility of the GN-PSP database. It should continue to do the data cleaning, error checking, and re-compilation, and making the data accessible for review.

3.9 Marketing the Program

26. Promoting the GN-PSP program used to be done through the BC Forest Productivity Council. However, the FPC was disbanded in 2002, for a number of reasons:

- a) Annual administrative cost of running the FPC became fairly high, and government was looking for areas to reduce administration costs.
- b) Both the ministry and industry were reducing their number of dedicated GY staff and so towards the end of the FPC there were few industrial co-operators left to attend and participate on the FPC meetings.
- c) The FPC had completed a lot of planning and strategy work – so it was logical to reduce that planning/strategy effort and move on to implementation.

⁹ The consultant is conducting an exploratory analysis using some of the remeasured MPB-affected GN-PSPs, to examine their potential for tracking stand development before and after attacks and natural regeneration following the attacks.

- d) There was a shift of resources to implementing the new VRI.

27. It is still essential to establish new mechanisms for lobbying for GN-PSP protection and funding, to replace the defunct FPC. The value of the PSPs in the face of changing information needs and how they contribute to political decision-making regarding forest resources and their stewardship must be made clear to management. There is also a need to document and publish the value of the GN-PSPs and results obtained from their analyses, so as to justify requests for more resources. The GN-PSP program should be marketed as part of, and integrated with, the FAIB's Stand Development Modeling (SDM) program. This way, the program will not stand-out during budget cuts, and the program will be easier to justify.

4. LINKAGES TO OTHER FAIB GROUND SAMPLING PROGRAMS

28. There are no direct linkages between the GN-PSP program and other FAIB ground sampling programs, notably Change Monitoring Inventory (CMI), Young stand monitoring (YSM), and VRI Phase II. Of these, the programs that are somewhat similar to the GN-PSP are the CMI and YSM monitoring programs in that they also consist of permanent plots designed to measure growth. The VRI Phase II plots are temporary inventory plots designed to estimate yield, although they are re-locatable and can also be remeasured to estimate change.

29. Ideally, it would have been preferable to review the GN-PSP program together with all these other ground sampling programs under the FAIB, and after an assessment of current and anticipated future information needs. The FAIB current ground sampling programs were reviewed for effectiveness and efficiency by Thrower (2014).¹⁰ The Thrower review included the CMI, VRI Phase II, and YSM programs, but not the GN-PSP program.

30. The CMI program consists of permanent, re-measurable plots systematically located on a provincial 20 km x 20 km uniform fixed grid. Their objective is to support provincial reporting of the status and changes in the forest. The YSM program also consists of permanent, remeasurable plots systematically located within the provincial grid in young stands aged 15-50 years. Their objective is to check the accuracy of GY predictions of key timber attributes in young stands, to support timber supply review (TSR). This monitoring program is expected to provide feedback to timber supply analysts and GY modelers, to identify opportunities for improving timber supply forecasting.

31. The subjectively located GN-PSPs have a relatively long history of

¹⁰ Thrower, J. 2014. Some thoughts on FAIB ground sampling programs. Contract report to the FAIB, Victoria, BC, 15 September 2014.

remeasurements and are useful for calibrating GY modeling and climate change studies. However, they are of limited value for monitoring. The CMI and YSM monitoring initiatives have attractive sampling design features and can serve the dual purposes of monitoring and model calibration. But, they currently have a relatively short history of remeasurements, relatively small number of plots, and limited geographical and stand-type distribution.

32. A mix of Growth Natural PSPs and Monitoring PSPs should be maintained. That is, there is a need to strike a balance between installing new and remeasuring existing unbiased monitoring PSPs, and maintaining the value of GN-PSPs, which lies mostly in their very long-term growth records. For example, re-consider the need to maintain a full complement of GN-PSPs in areas where monitoring plots have already been established (e.g., MPB-affected areas).

5. CONCLUSION

33. This report has outlined a 10-year strategy and actions for the GN-PSP Program. Development of this strategy was driven mainly by the current scarcity of resources for plot remeasurement and maintenance. The proposed strategy is to remeasure a sub-set of about 150 existing high-value GN-PSPs to meet changing GY information needs, and freeze the establishment of new GN-PSPs, over the next ten years. This proposed strategy should be reviewed periodically, and when more resources become available or information priorities or needs change.

ANNEX 1: A BRIEF HISTORY OF THE GROWTH NATURAL PSPs

The following notes are excerpts from an email written by Bob Macdonald, then a Growth and Yield Forester in the Kamloops Forest Region, in January 2006:

“In 1961, the provincial government instituted a permanent sample plot (PSP) program within the Growth and Yield Section of the Inventory Division. The intent of the program was to:

- Check out the assumptions made in yield projections (developed) from temporary sample plots;
- Develop a database for growth modeling; and
- Provide “ground control” data for a variety of purposes.

The PSPs were installed to capture growth information for fully stocked unmanaged natural stands on pre-determined strata which were originally: coast vs. interior, species group, age class, and site class. The main intent of PSPs has always been focused on developing a database covering the full range of conditions needed for calibration of growth models. Thus, PSPs are not representative of average conditions on the landbase and should not be used to develop statistics based on sampling theory. That is the job of inventory samples.

Between 1961 and 1978 over 2000 “Growth Natural” PSPs were established. In 1979 the program was regionalized with dedicated staff assigned to look after plot measurements. A further 730 Research Division (now Branch) PSPs were turned over to the (then) Inventory Division to maintain. Of those original plots, approximately 245 are still being remeasured and provide connected trend data going back to the 1920’s. A number of TFL’s also actively established PSPs to include: MacMillan Bloedel (2,000+ plots), Western Forest Products (700+ plots), and lesser numbers on BC and Canadian Forest Products and Canadian Pacific’s private holdings. Fewer TFL’s established plots in the interior with Westar (250+) being a noted exception.

In the mid 1980’s, the government established the Forest Productivity Committee that largely dealt with experimental installations. This committee later evolved into the Forest Productivity Council (FPC) that was very active in promoting PSP work until its demise in 2001. The FPC developed provincial PSP strategies to promote further PSP establishment as well as coordinate activities between government, TFL’s and other PSP practitioners. During this time (1987-2001) another 3500 samples were established and the government undertook purchasing plot data from TFL’s. Various PC-level software was developed to support this program to include:

- An FPC matrix that grouped plots by species/site type, and rank (relative value of the plot*);
- Digital field recorders to replace field sheets; and

- Support databases and sample compilers.

The FPC matrix was also used to guide the installation of new PSPs in designated stand types and fill gaps in the matrix. It was last updated in 2002 and should no longer be considered reliable. I have attached an example of a matrix report (view with notepad) which shows the distribution of samples in the various stratification cells. The stratification was by BEC zone, species (pure, mixed conifer, mixed deciduous), age class, density class (density for age 0-20 then Wilson's spacing factor), site index class. The FPC recommended establishing samples at all levels of stocking but only the last few years of plot establishment reflect this.”

ANNEX 2: SUMMARY OF INITIAL COMMENTS ON A GN-PSP PROGRAM STRATEGY

The following comments are summarized from the inputs from selected stakeholders, from the Canadian Forest Service (CFS), the forest consulting community and academia. Most of the selected stakeholders had been involved in earlier discussions with FAIB on this subject. The initial thoughts on the strategy that were circulated are stated, followed by a summary of reviewers' comments is given.

Initial thoughts on a GN-PSP program strategy

The main strategic issue is how to make the PSP program sustainable, given the government budget and other resource limitations; there are more PSPs than FAIB can afford to remeasure and maintain under current conditions. Initial thoughts on a province-wide ministry Growth Natural PSP Program:

1. The main goal of the Growth Natural PSPs remains that of providing a set of long-term stand development (real time-series data) data province-wide, for recalibrating existing GY models, and for building new models to address emerging concerns/variables as they arise in the future (e.g., climate change).
2. Freeze new Growth Natural PSP establishment.
3. Remeasurement of a subset of existing high quality Growth Natural PSPs (approximately 150 plots/year, selected using the former Forest Productivity Council's matrix and rating scheme).
4. Explore opportunities for potential uses of the surplus PSPs, e.g., analyses related to Mountain Pine Beetle (MPB) attacks.
5. Vary the remeasurement cycle depending on PSP height growth, rather than a uniform 10-year cycle for all PSPs.
6. Establish lobbying mechanisms for PSP protection and funding.
7. Invest more resources into the establishment and remeasurement of randomly-selected monitoring PSPs (CMI/YSM, with short remeasurement history) versus the subjectively-selected Growth Natural PSPs with long remeasurement history.

Summary of stakeholder key comments:

- Climate change impacts are not considered in the strategy.
- Consider selecting legacy PSPs in those areas in which we expect to see big climate changes, to check hypotheses and model forecasts.
- Existing GY models, in their current forms, are not responsive to climate change – there is an urgent need to also develop new models that address climate change impacts and to support these models with PSP measurements.
- Continue to document the value of these plots and the results obtained from their analyses so as to justify the requests for more resources in the future.
- The current number of PSPs is inadequate given the forecasts for shifts in climatic envelopes and their ramifications for tree growth in BC.

- More resources for PSPs in recent years have been moved from the Legacy PSPs to the CMI program.
- Primary interests in the PSPs should be: (1) optimization of FVS-like models of tree growth and mortality that are sensitive to environmental change, and (2) direct time series analysis of trends in PAI, growth, and mortality. To achieve these, a possible sampling matrix could be: SPECIES x SITE QUALITY x AGE x REGION x CLIMATE x TIME.
- The proposed 150 plots/year sampling intensity for pre-existing plots is not adequate.
- In developing a strategy, it would be preferable to start with an assessment of the types of information needed to address current problems and some thoughtful speculation about information requirements in the future. Such an assessment should encompass all the Ministry's plot measurement programs, (e.g., EPs, Growth Natural, CMI, NFI, YSM, and others).
- Consider interviewing users. It seems prudent to consider whether some of those information needs might be better met by one of the other PSP programs at some point in the future.
- Consider other important information needs, e.g., the effect of forest health agents that affect young stands. For an assessment of the types of information needed, the following general categories are offered (this is not an exhaustive list):
 - i. Data to improve our understanding of climate change and monitor effects.
 - ii. Data to improve growth and yield projections for whole forest planning and evaluation of silvicultural options.
 - iii. Data to demonstrate sustainability (due diligence checks on our forest management).
- The FAIB should assess the quality of the data in the PSP database.
- The legacy PSPs cannot be re-established once they are harvested, since the spatio-temporal link would be broken. These have been the basis for many questions over the years, and will be the basis for many more that we cannot imagine.
- Long term measurements over time provided by the legacy plots are needed and they cannot be replaced by new ground plots being established now.
- All PSPs should be kept; they should not be sacrificed for some other objectives. Legacy plots should be the highest priority, and then all others can be debated.

ANNEX 3: EVALUATION OF THE GROWTH NATURAL PSP PROGRAM

INTRODUCTION

EV1. This is an evaluation report of the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) Forest Analysis and Inventory Branch (FAIB) legacy “Growth Natural” Permanent Sample Plot (PSP) Program. This evaluation is being done as part of the overall PSP Strategy Project, whose objective is to develop a strategy for the PSP Program. The overall purpose of the evaluation is to validate the program goals and approach, identify specific good practices, and assess the potential for improvement.

EV2. This report was prepared on contract by A.Y. Omule, Forestry Consultant. It outlines the PSP Program status, the results of the evaluation analysis, and some recommendations. The report will provide background support for the development of the Growth Natural PSP strategy.

PSP PROGRAM CONTEXT AND STATUS

EV3. The PSP Program was started by the government in 1961 within the Growth and Yield Section of the then Inventory Division. Please see Annex I for a brief history of the PSP Program. The main goal of the PSP Program is to provide long-term real time-series data on stand growth, regeneration and mortality. These data are intended to be used for:¹¹

- a) Developing and maintaining GY models (e.g., VDYP7 and TASS), which are used in sustainable forest management (SFM) applications, such as timber supply review (TSR), inventory update, and silvicultural planning.
- b) Conducting research and development special projects on emerging issues, such as climate change impacts, and stand recovery after catastrophic forest health epidemics.

EV4. The growth natural PSP Program consists of two sets of PSPs: (1) “G” sample type¹² - the growth natural plots that were established since the Program was started in 1961, and (2) “R” sample type – The then Research Division control plots that were established dating back to the 1920’s, and were turned over to the Inventory Program in late 1970’s. These PSPs are long-term sample plots established in subjectively selected, well-stocked natural stands.¹³ They are established in a range of stand conditions, based on a matrix built on specific criteria such as BGC zone, leading species, stand age, site index and stand density. The PSPs range in size from 0.01-0.41 ha, with most (97%) being at least 0.04 ha, which is the minimum plot size recommended by the now

¹¹ Please refer to FAIB website: GY Website: <https://www.for.gov.bc.ca/hts/vri/psps/psp.html>.

¹² These letter designations are from the PSP database.

¹³ These plots specifically exclude the permanent sample plots from the Intensive Forestry Program and the Silviculturally-treated Program, both of which have been discontinued.

defunct Forest Productivity Council (FPC). The PSPs are periodically remeasured, approximately every 10 years (resources permitting), to provide real time-series data on stand dynamics, including rates of growth and mortality.

EV5. To-date, there are a total of 7,839 growth natural PSPs in the PSP Program. Of these, approximately 5,427 PSPs are still active or pest-damaged,¹⁴ are in Crown land and are the responsibility of FAIB. The remaining PSPs are outside Crown land, or have been dropped, logged or are badly damaged. Of the FAIB still active or pest damaged plots, 4,154 are “G” sample type with a total of up to 6 measurements per plot, and 1,273 are “R” sample type with up to 12 measurements.

ANALYSIS BY EVALUATION CRITERIA

Overview

EV6. This evaluation of the PSP Program considered the standard criteria normally used in project/program evaluation: Relevance, Effectiveness, Efficiency, Impact and Sustainability.¹⁵ These criteria are defined within this context as follows:

- a) Relevance – the extent to which the PSPs are suited for the ministry’s priorities, and the validity of the current program.
- b) Effectiveness – a measure of the achievement of the PSP program objectives, and factors affecting achievement of these objectives.
- c) Efficiency – the cost-effectiveness and timeliness of the PSPs to provide information to meet the ministry priorities.
- d) Impact – influence of the PSPs on the ministry activities, such as timber supply review.
- e) Sustainability – whether the PSP program can be maintained into the future in its current form, and under what conditions.

Relevance

EV7. The PSP Program is highly relevant for sustainable forest management. The Program has provided real time-series data for the calibration of GY models, in particular TASS and VDYP7. These models are now routinely used in TSR. The PSP data are used in model calibration as follows:

- TASS - The data from about 2,265 growth natural PSPs were pooled with data from other sources, and used to define the upper and lower limits within which the TASS model is permitted to forecast yield.
- VDYP7 – The data from almost all the growth natural PSPs (except the plots where there was high historic mortality or where too many trees had broken tops), and from unknown sources, were used to develop relationships for predicting the growth over time of some of the model’s key attributes, namely,

¹⁴ Pest-damaged PSPs are now continued to be remeasured because of the need for data on the effects of MPB infestation over the past few years.

¹⁵ These criteria are normally used by many international organizations, such as the UN Food and Agriculture Organization (FAO), for evaluation their programs and projects.

basal area/ha and trees/ha. The predicted estimates of these attributes, along with predicted stand height, were then used to estimate future volume yield.

EV8. The expectation was that the PSP data would continue to be needed for regular re-calibration of these two (and other) models using PSP data updated with new remeasurements. This has, however, not been done as often as would be desirable, apparently due to lack of time and additional staff resources (TASS), and is seen as not necessary (VDYP7). If the PSP data are not being used for re-calibration, then why continue remeasuring the PSPs? Anyhow, new TASS spruce yield tables are planned to be released soon. As well, an improved version of VDYP7 for stands with excessive pine mortality (such as, the MPB-attacked stands) is planned; thus, the growth natural PSP data (and data from remeasured VRI Phase II plots) will be vital for incorporating that improvement in VDYP7.

Effectiveness

EV9. The PSP Program effectiveness in achieving its intended goal has been satisfactory. It has provided real time-series data on stand growth, regeneration and mortality that have been used to calibrate TASS and VDYP7 models. The PSP program also acts as some sort of insurance against future emerging or unexpected SFM issues that require long-term time-series data. However, some shortcomings have affected the effectiveness of the Program:

- a) Sampling design - The subjective location of the PSPs in fully stocked stands reduced their application. This is because these PSPs are not representative of the provincial forest landbase; they represent, to some extent, only the fully-stocked portion of the landbase. This then necessitates model forecast reductions for so-called "Operational Adjustment Factors" or "%stockable" attributes, to reflect future operational stand conditions. Plot locations should have been randomly or systematically located within a defined population or stratum, as recommended by Curtis (1983),¹⁶ and as is now done in the Young Stand Monitoring (YSM) program.
- b) Mortality and plot size – Most of the plots meet the FPC 0.04-ha minimum threshold – so as to contain a sufficient number of stems to provide approximately 50 crop trees per plot at culmination age. This minimum is suitable for measuring stand growth and regeneration. However, this relatively small plot size is not particularly suitable for collecting data for modeling mortality, especially if the plots are not stem mapped. Larger (≥ 0.1 ha), stem-mapped plots are more desirable for tracking mortality. Note that only about 25% of the growth natural PSPs under ministry control are at least 0.1 ha in size.

¹⁶ Curtis, R.O. 1983. Procedures for establishing and maintaining permanent sample plots for silvicultural and yield research. USDA Forest Service Pacific Northwest For and Range Exp. Stn. Gen Tech. Rep. PNW-155.

- c) MPB-attack regeneration – The methods for tallying natural regeneration are being revamped, to be able to capture seedling data (trees < 0.3m tall) after the MPB attack. This had not been anticipated in the past.
- d) Program size (total number of PSPs) – The total number of plots in the PSP program is relatively low. This has forced the GY modelers to look elsewhere for additional PSP data. For example, for TASS modeling, additional data have been obtained from a host of other sources, including the forest industry, Canadian Forest Service, US Forest Service, and GY co-operatives (such as the Stand Management Cooperative). Out of a total of approximately 15,000 PSPs in the TASS modeling database, only about 15% come from the provincial PSP Program. While the idea of embellishing the PSP database with outside data sources for GY modeling purposes was creative and cost-effective, there is a risk of a lack of data updates from new remeasurements from some sources, such as some forest industry companies that no longer exists or got out of GY business entirely.

EV10. Despite some of these shortcomings, these legacy PSPs have real value in terms of having been observed over several decades. Thus, maintaining the existing provincial PSP Program, with some modifications or integrated with other FAIB ground sampling programs, would be wise.

Efficiency

EV11. Establishment and maintenance of PSPs is an expensive, but necessary business. The total cost of the PSP Program since its establishment is unknown, but its replacement value has been estimated at about \$80 million.¹⁷ The budget for the Program has varied over time, depending on political good will and government priorities. For example, the PSP establishment and remeasurement declined in the 1980's due to the then government's deep budget cuts, and it surged during the period of the federal-provincial Forest Resources Development Agreement (FRDA). Plot establishment and remeasurement costs keep sky-rocketing because of low contractor availability and high day-rate bids. Yet, there are currently no suitable alternatives to PSPs for gathering long-term real time-series data.

EV12. More efficient ways to reduce cost of PSP maintenance need to be explored. The PSP Program has already started doing this by freezing the establishment of new PSPs; and ranking the existing PSPs based on specific criteria and prioritizing the most valuable ones for remeasurement.¹⁸ Another suggestion for consideration is to adjust the remeasurement cycle. Insistence on uniform application of the 10-year remeasurement cycle for all the PSPs (or even just the priority ones) is not efficient. The remeasurement cycle could, for example, be based on height growth: slow growing plots would be

¹⁷ https://www.for.gov.bc.ca/hts/vri/pmps/downloads/PSP_Protection_Memo.pdf.

¹⁸ Please see the preliminary guiding principles for establishment and remeasurement of Growth Natural PSPs developed by FAIB ("Rough Draft #2, July 22 – Guidance for the PSP program").

remeasured less often than the fast-growing. This proposed approach sounds like a logistical nightmare, but with good planning it could be implemented.

Impact

EV13. The PSP Program has had a significant impact on SFM. It has contributed to the development and enhancement of the TASS and VDYP7 models, which are now used to forecast timber yields for TSR, update timber inventories, and silvicultural planning (TASS).

EV14. The PSP data have also contributed to helping Canada meet its international reporting obligations on climate change, by indirectly supporting the development of the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3). This model is a stand-level modeling framework that simulates the dynamics of forest carbon stocks required under the Kyoto Protocol.

Sustainability

EV15. Overall results of the assessment of sustainability of the PSP Program are mixed. There are several factors that tend to support the sustainability of the Program while many others mitigate continuity. Factors that promote sustainability include:

- a) Explicit linkage - The long-term data collection is being explicitly linked to model development, e.g., for specific situations such as the MPB-attacked stands.
- b) Institutional arrangements – The TASS and VDYP7 modelers and PSP Program staff are now under one Section within FAIB. This seems to have fostered better communication between the stakeholders (modelers) and those responsible for planning PSP data collection.
- c) Plot protection – Recent reconnaissance of the PSPs found that several had been harvested without prior consultation with the PSP Program staff. The Chief Forester's memo,⁷ dated July 15, 2011, which was addressed to all the District Managers and Regional Executive Directors and outlining guidelines for protection of PSPs from harvesting, if followed, should help to alleviate this problem.

EV16. Sustainability is still doubtful because of:

- a) Program budget - Budget reductions continually force the government to review the establishment and re-measurement of PSPs. The PSP Program is especially vulnerable to budget cutbacks because its cost is high and significant ("it stands out"). The PSP budget should be included explicitly as part of the Stand Development Modeling budget.
- b) Justification – The benefits of the PSPs are long-term and indirect, and, therefore, difficult to justify to decision-makers, through a regular cost-benefit analysis.
- c) Lobbying – There is now no united government-industry body to lobby for the funding, protection and maintenance of PSPs since the abolition of the provincial Forest Productivity Council.

- d) Competing initiatives – New initiatives that involve PSP establishment and remeasurement have emerged and threaten the existence of the growth natural PSP Program. In particular, the YSM initiative – where PSPs are systematically located in a target population - is believed by some GY experts as a suitable replacement, or supplement, of the PSP Program. The issue is that the legacy PSPs have a long history of remeasurements (desirable for modeling purposes), but has some limitations; and the YSM has attractive sampling design features, but has a relatively short history of remeasurements and number of plots.

EV17. Sustainability of the legacy growth natural PSP Program shall depend on how effectively the negative issues identified above are addressed.

CONCLUSIONS AND RECOMMENDATIONS

EV18. The overall conclusion of this evaluation is that, despite its design and budget limitations, the growth natural PSP Program has been implemented continuously with improvements over time; and the Program goal is being achieved to a satisfactory extent. The Program has continued to produce real time-series data that have been used to develop GY models, which are now routinely used for SFM decision-making. However, continuation of the PSP Program in its current state is not sustainable; modifications to make the Program more efficient have to be made.

EV19. The main recommendation is that the Growth Natural PSP strategy that is currently under development should consider the suggestions and issues raised in this evaluation. These suggestions and issues are specifically related to the Program design, efficiency and sustainability.

ANNEX 4: PSP DATA REQUESTS FULFILLED BY FAIB (2013-2015)

<i>Request</i>		<i>No. PSPs</i>	<i>Intended Use of Data</i>
<i>No.</i>	<i>Date</i>		
1	1-Mar-2013	1759	Development of a new non parametric index for describing similarities and differences in plot and stand level diameter distributions. The goal is ultimately to provide an integration of this index with Reineke's (1933) Stand Density Index (SDI). The results of this work are to be presented at the 2013 Western Mensurationists Meeting in Leavenworth WA (June 23-25) and the second IUFRO meeting on Complex Forest Ecosystems in New Orleans, LA (Oct 7 - 9).
2	15-Apr-2013	256	To examine the hemlock PSP data to estimate volume of trees less than 12.0 cm DBH.
3	15-Apr-2013	103	To create representative stand/stock tables for stands in the ungulate winter range habitat classes (various categories of habitat/BEC types, etc.) as part of the Type 4 Silviculture Analysis. To spatially join to polygons of interest, and perhaps correlate plot data trends with some of the UWR-type attributes.
4	18-Apr-2013	83	Species at risk recovery strategy development for Env. Canada. Data to be used to identify known locations, density, and other attributes, with respect to whitebark pine in BC. It will also be used to identify where data gaps exist.
5	12-Apr-2013	152	Determination of growth rates within traditional operating areas and sites
6	17-Apr-2013	649	To provide supporting ground data as part of joint Lidar program with Western Forest Products
7	15-May-2013	118	To develop location-specific Ht-DBH models to apply to LiDAR data that is collected.
8	24-May-2012	80	To check on growth/mortality.
9	10-Jun-2013	1328	To test understory regen models in TASS.
10	10-Jun-2013	507	To calibrate & validate models projecting levels of bark beetle-caused mortality and respective stand/volume trajectories in boreal forests, under different stand conditions, landscape contexts, and climate change scenarios.
11	10-Jun-2013	1852	To compare against MSYT's developed as part of Type 4 silviculture strategies in Prince George and Robson Valley TSA's, completed by Forest Ecosystem Solutions Ltd.
12	15-jul-	1174	For quantifying old-growth attributes

Request		No. PSPs	Intended Use of Data
No.	Date		
	2013		
13	11-Sep-2013	165	To compute MAI, PAI for dry-belt Fdi managed under a selection harvest system.
14	27-Sep-2013	8961	To fit stand level volume-to-biomass conversion equations.
15	2-Dec-2013	569	To aid in the design of geophysical designs and other oil and gas activities.
16	16-Dec-013	171	Biodiversity project for 'Teck Coal'
17	5-Feb-2014	8961	Climate change studies
18	01-Jan-2014	502	For updating their timber supply analyses for all 3 of their tenures
19	02-Feb-2014	570	To provide MOF-purchased (from MB) PSP compilation summaries for PSPs falling within ITL private land holdings.
20	02-Feb-2014	41	Forest Health and Economics analysis (project for RPB)
21	05-Mar-2014	599	For climate change research projects
22	08-May-2014	988	Fire hazard prediction model, and exploring interaction with TASS.
23	15-May-2014	19	For biodiversity indicators analysis, request filling in data gaps
24	3-Jul-2014	689	To examine relationships and trends between the volume in trees between 4.0 and 12.5 cm DBH and those > 12.5cm DBH. This will be for a specific type of PL stands - focusing on high density mid-aged stands.
25	14-Jul-2014	388	
26	5-Dec-2014	2283	For a study on LIDAR – based estimates of timber volume in Tolko operating areas
27	5-Dec-2014	141	Research and modeling of mixed species (AT/SX) stands
28	23-Jan-2015		For development of survival probability and tree growth models for boreal, montane and supalpine forests of Canada and Alaska, to be implemented in the mixedwood growth model (MGM) and published.