Adaptive Management in Experimental Watersheds Research Design

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Prepared for the EBM WG

By

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Executive Summary and Major Findings

Implementation of Ecosystem Based Management (EBM) on the coast is intended to include adaptive management (AM). We discuss why AM is a necessary part of thoughtful, informed and responsive management. In this report we outline a research framework in five broad areas; 1) aquatic ecosystems 2) terrestrial ecosystems, 3) single species, 4) climate change and 5) carbon. First steps in developing a system for knowledge acquisition are identified with specific steps for a set of priority questions. Implementation monitoring of the plan was not specifically addressed in this report but there are efficiencies to be made linking research projects and plan implementation, plus and over time information from monitoring should inform development of research priorities just as research is expected to inform on longer term monitoring. The report presumes an independent EBM research team will be created to work with an EBM management team to further develop research on knowledge gaps and uncertainties and that there will be an identifiable EBM research program.

Identifying Key Questions? A knowledge summary has been developed (Price, Tyler, Daust and Soto 2009) to shed light on key knowledge gaps in relation to effective implementation of EBM. Their process identified existing knowledge gaps with resolvable uncertainty, and where the values of concern are potentially at risk with current approaches to management. The highest priority research questions from that work were summarized (Price and Daust 2008) and were modified by a broader look at factors affecting EBM implementation on the coast. Research projects linked to those priority research questions are developed in this report.

For each of the key questions we identify: a) a four phase plan to move towards gaining useful knowledge, and b) a GIS identification of watersheds and watershed units which may be appropriate to locate study sites for analysis within the framework.

Developing Key Questions: The priority research questions identified focus on improving understanding of potential impacts and risks to ecosystems from land use within the context of EBM. The research studies proposed here focus on: 1) hydroriparian ecosystems, 2) older forest ecosystems and 3) specific focal species. Ecosystem vulnerability from climate change and carbon cycling are included because they are also are key to future forest management decisions.

With each of the three focus areas, are a number of specific questions of interest:

1a) Hydroriparian: Different levels of buffering around active fluvial units, specifically:
- What are the impacts on the morphology of Active Fluvial Units (AFUs) of removing forest from floodplains and fans and adjacent riparian forest buffers?

1b) Hydroriparian: Unstable terrain and soil movement and stream morphology, specifically:
- What are the impacts on the morphology of streams from different levels of forest development on unstable terrain and near steep streams susceptible to debris torrents?

1c) Hydroriparian: Harvest adjacent to smaller streams and karst ecosystems, specifically:
- What are the impacts on the biodiversity and productivity of hydroriparian ecosystems of harvesting the riparian areas of small upland streams (> 6% gradients such as S4, S5 and S6s)? A similar study can be used to address impacts to karsts.

2a) Old forest retention: A range of stand structure retention levels (15% plus) within landscapes with a range of landscape level reserves, specifically:
- Are there combinations of stand level and landscape level retention levels that pose high risk to species populations within watersheds/ landscapes?

2b) Old forest: Biodiversity values within old (180 – 300 year old stands) and very old or ancient stands (500 years plus), specifically:

- Are old forests at the 'young end' of the defined age range (e.g. 180 – 300 years) biologically equivalent to much older stand and less frequently disturbed ecosystems?

3) Study of single species focuses on critical habitat and dispersal or movement within the species' natural range. Focal species are identified in the LUOs, but a broader context is needed to determine whether other species should also be prioritised for research and management. We propose applying the Ministry of Environment Conservation Framework as a means to narrow and prioritize single species studies in the absence of alternate direction. This process has not yet been implemented by MoE (so its efficacy is hard to assess yet), but theoretically it provides an approach to identify not only currently 'at risk' species, but those of potential future concern.

- For priority species /ecosystems what is critical habitat and what level of stewardship will result in low risk management?

4) There is a need to look for trends associated with climate change for a variety of indicators. Baseline ecosystem data is generally lacking and since climate change is affecting all ecosystems and species it is an added complication for interpretation of all research and experiments. A review of existing monitoring and coordination with on-going provincial initiatives is recommended in the initial phase of research in this area. Of particular interest are; a) natural disturbance shifts as these relate to ecosystem integrity and vulnerabilities, and b) identification of thresholds where trends may result in significant risk to ecological integrity (e.g. temperature trends and cold water fish populations). Key research questions developed are;

- What are the observed climate trends for the coast?
- What ecosystems/species are most vulnerable to climate change?
- What adaptation can be undertaken?

5) Carbon cycling relates to climate change and is included here since we expect carbon to play a future role in management decisions. This research should be relevant both in terms of management decisions around mitigation of future climate change through direct carbon storage, and provide more specific information relating to sequestration and carbon offsets markets. A key research question developed is;

- How much carbon is stored and cycled in different forest ecosystems in different seral stages?

A framework for research: There are many interested parties (e.g. provincial and First Nations governments, ENGOs, industry, local stakeholders) who must work together for efficient implementation and adaptation. We propose a four phased approach to help bring the areas of uncertainty and risk into focus and prevent a commitment to research in the absence of agreement to apply the findings. These research phases presume that there is an independent research group supported by the interested parties managing EBM implementation and that the independent research group will take direction from the interested parties to improve knowledge on priority EBM questions.

Phase 1: Successful adaptive management is much more than 'finding answers to key questions'. Identifying upfront when knowledge will be considered sufficient to change management is also a key requirement. Existing information can be ignored for many reasons (lack of certainty among stakeholders, prioritization of conflicting values, lack of implementation opportunity etc.). Without upfront discussion of such factors much money and effort can be needlessly wasted. Phase 1 involves a process where stakeholders, decision-makers and the research team[1] determine the level of evidence sought on specific questions before management will be expected to respond. Understanding what types of indicator responses will be considered no longer 'low risk' is also an important *a priori* step as it sets a benchmark for the research. Climate change may also result in the need to change existing low risk designations.

Phase 2: In the context of Phase 1, undertake a detailed review of current knowledge specific to the research question and confirm whether there is a need for additional research in light of what is known. This phase is expected to involve a robust meta-analysis of existing work, and include assessment of uncertainties and whether coastal systems can be expected to be more or less sensitive than other areas where information exists already. Examples of literature specific to some research questions such as buffers and integrity was begun in Appendices C and D, but a full literature review should be undertaken for all questions prior to new field sampling. Phase 2 may suggest an immediate change in policy and implementation if existing information contradicts existing policy. Phase 2 may also result in a fine-tuning of research questions as more specific knowledge gaps are identified.

Phase 3: Undertake retrospective studies to seek evidence through random sampling of existing harvested areas and compare this to baseline information from unimpacted areas. Although retrospective studies tend to lack statistical power, they have the benefit of informing on questions where watersheds and landscapes may take decades to respond to forestry and development impacts. They are also cheaper and potentially provide information in a relatively short timeframe, compared with 'before/ after' experimental studies.

Phase 4: Initiate this only after phase 3 demonstrates that the evidence available from retrospectives studies is shown to be, or likely to be insufficient or inconclusive based on power analyses. At this stage, a research team designs Active Adaptive Management and prescribes treatments. Licensees implement the research design followed by a period (possibly decades) of monitoring and analysis.

Time Frames: We recommend that the research for each topic area consider the entire plan area and history of harvest as the source from which learning is possible. We have placed emphasis on learning initially from the historic development footprint because longer term cumulative effects of development begun many decades ago may only be becoming evident now. In the next 1 to 2 years there needs to be an emphasis in Phases 1 and 2. These phases are principally office and GIS supported efforts for the research team to become very familiar with watersheds and landscapes and test the limits of current inventory, remote sensing to identify experimental units. Field sampling can be done during this period but it is recommended that is limited to testing protocols and establishing variance in population that will inform on sample size for the level of confidence agreed as necessary for management. Phase 3 research may take anywhere from a year to a number of years to identify potential effects from past harvesting. The level of investment placed into research, combined with management direction on acceptable risk, the variation in natural ecosystems and the variation of practices in the managed ecosystems will affect the required sampling size and the timeframe. Phase 4 can be expected to take many years, if not decades, to produce useable results for anything other than very focused / specific questions.

What makes Adaptive Management Research Successful? The final section of the report discusses a number of logistical and social issues related to successful implementation of EBM research. These include issues with: short and long term funding support, cost-sharing between

[1] It is assumed throughout this document that a 'research team' will exist in order to carry out further implementation of this program.

EBM groups to support long-term research goals, governance and decision making, accountability and cooperation. Partnerships with research institutions (universities and colleges) can result in access to researchers and support towards field research facilities. Managing longer term research and monitoring is likely most effective when partnering with local residents to manage data collection and maintain field facilities. Current adaptive management is linked to Forest Stewardship Plans and cost recovery for Active Adaptive Management experiments (Phase 4) may only be possible through access to additional timber. Cost recovery through "research stumpage" may need to be explored to ensure participation is feasible. Multi licensee agreement on priorities and cooperation on plan-wide priorities could, coupled with research stumpage allowances, provide an alternate means to defer experimental costs associated with Phase 4 studies. Experience with other AM approaches indicate that AM and AAM persists only as long as there is support from the powerful interest groups managing the process and that failure is often due to intransigence by powerful interest groups. The report closes with a brief discussion on decision making and how to structure independent research findings and inform on risk to ecological integrity. These processes of assessment and reporting may be more assured if linked to periodic government obligated processes such as Timber Supply Review and Forest Stewardship Plan preparation and approvals.

GIS-Assisted Watershed Analysis: A significant part of this project was to begin identification of potential watersheds where work could begin on the priority questions. We recommend using watersheds units as they provide an appropriate scale for study of forestry activities and they include stands which have been subject to differing degrees of cumulative impacts over varying periods of time. Each research question requires different specific benchmarks and treatment unit comparisons so no single watershed data layer is suitable for all study questions. Questions of harvest of unstable terrain, for example requires identification of unstable slopes in harvested and unharvested conditions. The watershed units available provide a set of potential candidates that could be randomly sampled.

The watersheds identified here are called 'candidate experimental watersheds' because they will be used to select sample sites and ease GIS summaries and comparisons of multi-stand areas more effectively. The experimental watersheds are the starting point to randomize sampling sites for retrospective studies (Phase 3). Watersheds were digitized for the EBM WG as an aid to EBM implementation. Watersheds are also digitized for the Watershed Atlas which was undergoing refinements to identify a greater number of smaller watersheds than currently identified. By manipulating the EBM Watersheds data we identify that there are 1940 potential candidate experimental watershed units between 1,000 and 5000 ha in size. Of these, 792 had fish observations and 840 are partly or wholly within Parks and Protected areas. The approach to sample sites for each research question is provided in Appendix A.

Summary Recommendations:

1. Engage an independent research team to overview future implementation of EBM. Although this and various other EBM working group projects have attempted to lay the path to AM implementation, actual implementation will be dependent on the individuals holding the reins in the future.
2. Use the key questions and the phases outlined to begin the research projects. The projects identified are considered to support information needed to answer the highest priority questions. Use the experimental design provided here to begin to implement research on the specific questions.
3. Use robust existing information to assess current policy. Phase 1 of the process is intended to aid in this process of applying research to policy by getting agreement on use of robust information. It is meant to avoid spending money without agreement to use the information in decision-making.

4. Consider the entire area as an experiment that began with the first harvesting and initially focus research on the key questions through retrospective studies (Phase 3) by looking for treatment units and evidence already available through sampling from within the area. Test research design and pilot field studies initially by sampling that compares natural forest ecosystem baselines to ecosystems where the impacts if development are highest. If the sample design cannot detect differences in response variables in these ecosystems then review approach and possible next steps.
5. Use GIS as a major support tool to find sample sites and to randomize sampling. We do not recommend at this time focusing research on a small number of permanent 'research watersheds'. Instead, the report recommends using watershed units to find benchmark sites and treatment units for sampling and comparison purposes specific to each research question. After a period of familiarization with research studies and a number of watershed databases it may become apparent that some specific watersheds do provide many of the features needed for sampling. At that time it may be appropriate to establish some long- term research watersheds. However, we are unable to make such as recommendation at this preliminary stage.
6. Assess and report risk based on existing knowledge within the context of uncertainties. The research will provide insight into risk and loss of ecosystem integrity. Assessment and reporting on risk is more likely assured if linked to periodic government obligated processes such as Timber Supply Review and Forest Stewardship Plan preparation and approvals.
7. Acknowledge that a research program in temperature rainforest will deliberately explore the question of natural capital and living off nature's interest. This is central to maintaining both sustainable communities and ecosystem integrity, and in avoiding "boom and bust" cycles. Maintaining natural capital is consistent with EBM vision for understanding what low risk ecosystem means and adapting management to that.

Glossary of abbreviations

AAM Active Adaptive Management
AFU Active Fluvial Units
AM Adaptive Management
BCTS British Columbia Timber Sales
BEC Biogeoclimatic Classification
CDC Conservation Data Centre
CF Conservation Framework
CFCI Coast Forest Conservation Initiative
CIT Coast Information Team
EBM Ecosystem Based Management
ECA Equivalent Clear Cut Area
ECOCAT Ecological Catalogue (a web site maintained by government)
ENGO Environmental Non Government Organization
FFEI Future Forest Ecosystem Initiative
FN First Nations
FSW Fisheries Sensitive Watersheds
FPB Forest Practices Board
FREP Forest and Range Evaluation Program
FRF Functional Riparian Forest
FRPA Forest Range Practices Act
FORREX Forest Research Extension
GAR Government Actions Regulation
HPG Hydroriparian Planning Guide
LRDW Land Resources Data Warehouse
LUO Land Use Objectives
LWD Large Woody Debris
MOE Ministry of Environment.
MOFR Ministry of Forest and Range
PEM Predictive Ecosystem Mapping
RIC Resources Inventory Committee
RICS Resources Inventory Committee Standards
SPOT High Resolution Satellite Images
SSS Sites Series Surrogates
TEM Thematic Ecosystem Mapping
TSR Timber Supply Review
TU Treatment Units
USFS United States Forest Service
UWR Ungulate Winter Ranges
VRI Vegetation Resources Inventory
WHA Wildlife Habitat Areas
WS Watersheds

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Section 1: Background and Context

Project Objectives

Research to support Ecosystem Based Management (EBM) is integral to the new "Vision for Coastal BC" announced in 2006 (see box below). Recently steps have been taken to formally link research with EBM through an Adaptive Management Framework (Tyler et al. 2009), which aims to support a range of small and large research projects, addressing both ecological and human well being questions. This "experimental watershed project" describes a structured approach for tackling some of the bigger more difficult questions related to ecological integrity. The terms of reference for this report were to: 1) provide a rationale undertaking adaptive management within EBM, 2) identify key ecological questions requiring multiscale (in space and time) scientific experimentation/study to support implementation of EBM, 3) provide a research design for answering key ecological questions, 4) develop a method to identify experimental units for key questions, and 5) provide insights into logistic and social issues that must be evaluated prior to research implementation.

Definitions of EBM and ecosystem integrity

The two boxes below sets a broad context for EBM implementation, and specifically for future research teams providing information for implementation. They identify a risk management framework and the need for independence of science as implementation moves ahead.

EBM: A New Vision for Coastal B.C.[2]

The new vision for the coast provides: ***A unique framework called Ecosystem Based Management (EBM) ….. which set the stage for a collaborative model to fully implement EBM in these areas by 2009.***

Conservation measures ….. seek to achieve a low level of ecological risk overall in the Central and North Coast, over time,

Definitions of "low level of ecological risk" are found in the Coast Information Team EBM Handbook; however the ecological indicators are subject to change through consideration of other information, further research and adaptive management.

Implementation of EBM beyond 2009 will include a) a system for monitoring and evaluating ecological integrity and human well-being; b) an independent research and inventory and data management system; and c) a decision support/analysis system

The box below provides definitions of EBM and the expectation that there will be overall low risk management. It is anticipated that the collaborative EBM research initiative described in this report will assist EBM implementation by increasing understanding of risk to specific elements of ecological integrity associated with land use, as well as confounding factors such as climate change. Research can provide evidence of changes to ecosystems from forestry and development but the definition of risk and acceptable low risk is a management decision though informed by research is never-the-less a social decision. In order to implement low risk practices, a decision support tool for quantifying, tracking and reporting on risk may be needed to balance high risk site level activities with lower risk activities across watersheds and landscapes. It is anticipated that the research team and the projects in this report are central to establishing understanding of ecosystems and risk.

[2] http://www2.news.gov.bc.ca/news_releases_2005-2009/2006AL0002-000066.htm

Definitions of EBM (April 2001) and risk

…an adaptive approach to managing human activities that seeks to ensure the coexistence of healthy, fully functioning ecosystems and human communities. The intent is to maintain those spatial and temporal characteristics of ecosystems such that component species and ecological processes can be sustained, and human wellbeing supported and improved.

Low risk means that management has a high probability of maintaining the ecological value or function[3].

Section 2. Why support "EBM research"?

Taylor, Kremsater and Ellis 1999 define adaptive management (AM) as

> "*a systematic approach to improving management and accommodating change by learning from the outcomes of management interventions. Not only are objectives and policies adjusted in response to new information, but management policies are deliberately designed to enhance the rate of improvement:*
> - *by providing reliable feedback about which policies, plans, or practices are effective and which are not; and*
> - *by increasing understanding about ecosystem function, and identifying thresholds in ecosystem response*."

The interested groups involved with the land use plan and subsequent agreements share a common challenge of making decisions at a variety of scales while staying within the new vision.

A collaborative research/AM program provides interested groups with: 1) a focus on areas of greatest uncertainty across the planning area, 2) support for common research priorities and 3) access to multi-disciplinary research scientists to assist in implementation (Tyler et al. 2009). Having a common research agenda between First Nations, Provincial and Federal governments, forest licensees and environmental non government organizations means collaboration on data collection, data management and sharing, assessments to support implementation direction and increased capacity for all. Though there is different research and data needs among plan signatories, collaboration will be mutually beneficial and provide spin-off benefits to each group. Multi-disciplinary research speeds learning and confidence in results when based on commonly shared data and commonly understood issues of data quality. Shared understanding supports multi-party decision-making and increases the overall likelihood of success in a project.

Data sharing also increases confidence in strategic assessments such as the anticipated vulnerability assessments linked to climate change, additional assessment to focus on study of key questions, plan implementation, forest stewardship planning, forest certification, monitoring as well as facilitation of communications on best practices and standard operating procedures. Based on experience with other AM programs across agencies and cultures, one of the biggest benefits however has been the relationships and trust that built through collaboration to solve common problems over a sustained period[4],[5].

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[3] EBM Planning Handbook

[4] http://www.fs.fed.us/emc/rig/lucid/index.shtml/ **Forest-scale Sustainability Monitoring Project is a USFS lead Local Unit Criteria and Indicators Development (LUCID).** The intent of the LUCID Project was to work with personnel at six test sites and thereby expand the science-based evaluation of the development of forest-scale monitoring programs for sustainable social, economic, and ecological systems.

In addition, having multi-party commitments in place it will be possible for an EBM research group to pursue funding and funding arrangements with research groups in academia and increase capacity through various partnerships. We assume "independent" research means independent of control but not outside of taking consensus direction from all groups. Independence also is understood to mean a degree of independence to report without having findings fettered. Appendix B provides additional rationale for adaptive management research in support of EBM.

Section 3. A context for experimental watersheds

Why watersheds?

Watersheds (WS) are a useful ecological unit to help build a research design. Watershed provide the multi-stand context needed to understand impacts to terrestrial and aquatic ecosystems. Impacts to ecosystems through harvesting and roads may be many decades before becoming apparent and may only be apparent if there is monitoring or study of information to detect cumulative impacts. Watersheds create natural ecological boundaries: movement of terrestrial and aquatic organisms occurs more easily within than between watersheds and watersheds are appropriate for cumulative impact study. Geomorphic processes impact aquatic ecosystems within watersheds allowing comparison between watersheds as a means to understanding cumulative impacts. Dramatic shifts in species occur at the stand level after disturbance, followed by recovery through time – but stand-level impacts accumulate at the watershed scale. Such accumulations at the watershed scale are less easily detected but are the signals for loss of integrity through cumulative stresses on ecosystems. It is these less well tracked and understood response variables that experimental watersheds can illuminate. Fenger and Wheatley 2007 refer to undeveloped watersheds as nature's blueprints and the benchmarks from which to measure ecosystem baselines needed to understand risk, impact and uncertainty linked to development. Lertzman and Mackinnon 2009 provide insights into watersheds as good units for conserving forest ecosystems.

Defining Experimental Watersheds

WS units defined for the EBM area were used to create Figure 1 which shows potential candidate watersheds available within the plan area. These are called candidate experimental watersheds as they are needed to select sample sites for specific research questions. Each research question requires a different context so a single set of WS units defined at a set scale will not be suitable for all questions. For example changes in floodplains and bank stability are questions that require comparison be made between WS with comparable hydrologic characteristics, whereas harvest of unstable slopes require portions of watersheds. Figure 1 was created after sorting all EBM WS into size groups and removing the largest and smallest WS. The histograms of size distribution are shown in Appendix A.

Figure 1 shows there are 1940 potential candidate experimental watersheds between 1,000 and 5000 ha in size. Of these, 792 had fish observations and 840 are partly or wholly within Parks and Protected areas. The distribution of harvest over the last 100 years is shown in Appendix A when summarized within WS units provides a means to understand where longer term cumulative impacts may be evident. Appendix A provides greater detail on use of GIS assessments specific to key research questions.

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[5] http://www.cof.orst.edu/research/safefor/ Applegate Watersheds Simulation Project is an Oregon State University lead project with an overall goal to combine sound scientific methods with community involvement and technical advice from the federal US agencies to develop a model which will reveal the outcomes of various management strategies relative to achievement of resource management goals.

This preliminary GIS assessment provides a decision support tool which under Phase 3 needs to be supplemented by air photos, remote sensed data and site data interpreted by experts from a number of disciplines to confirm sample units. The goal of this preliminary stratification is to reduce natural variation within the sampling sites so comparison of indicators linked to specific research questions can be mostly directly attributed to differences in development, rather than ecological variability.

This report does not recommend a few watersheds be set aside as "research watersheds". Instead, the report recommends using multiple watershed units to find benchmark sites and treatment units for sampling and comparison purposes specific to each research question. After a period of familiarization with research studies (Phase 3) it may be that some specific watersheds do provide many of the features needed and it may be at that time appropriate to establish specific watersheds in which to concentrate a number of research studies and maintain infrastructure. However, we are unable to make such as recommendation at this preliminary stage.

Defining Research, Monitoring and Inventory

Research is a systematic investigation with a practical goal to "establish facts" – which we believe to be 'true' or 'reflect reality'. Research involves collecting information about a subject from a variety of sources including books, journals, inventories, and the internet or carrying out experiments or talking to people and analyzing this new information. Research can use the scientific method (which uses observation and theory to test hypotheses) but does not need to. The basic steps of the scientific method are to:

- Ask a Question
- Do Background Research
- Construct a Hypothesis
- Test the Hypothesis by doing an experiment
- Analyze and interpret the data and draw a conclusion
- Communicate the results

AM Research especially for understanding natural ecosystems can broadly include both inventory and monitoring. Monitoring generally means becoming aware (e.g., by observation or measurement) of the state of a system and in the case of ecological integrity research this means becoming aware of the state and trends within an ecosystem. By some definitions, monitoring includes collecting data and tracking response variables needed as part of a specific experimental research question.

There are different types of monitoring:

1) Compliance monitoring (is it legal?),
2) Implementation monitoring (is the plan being followed?),
3) Effectiveness monitoring (is the plan/practice/objective doing what we thought it would?) and
4) Validation monitoring (are the assumptions used to model and support decisions factually correct?).[6]

The EBM research program outlined in this report has a focus on effectiveness and validation monitoring. Monitoring the implementation of the plan is not specifically addressed in the research priorities. We expect that there will be on going evaluation and monitoring of plan implementation which should feed back and focus the research projects through time.

[6] http://www.for.gov.bc.ca/hfp/frep/about/types.htm .

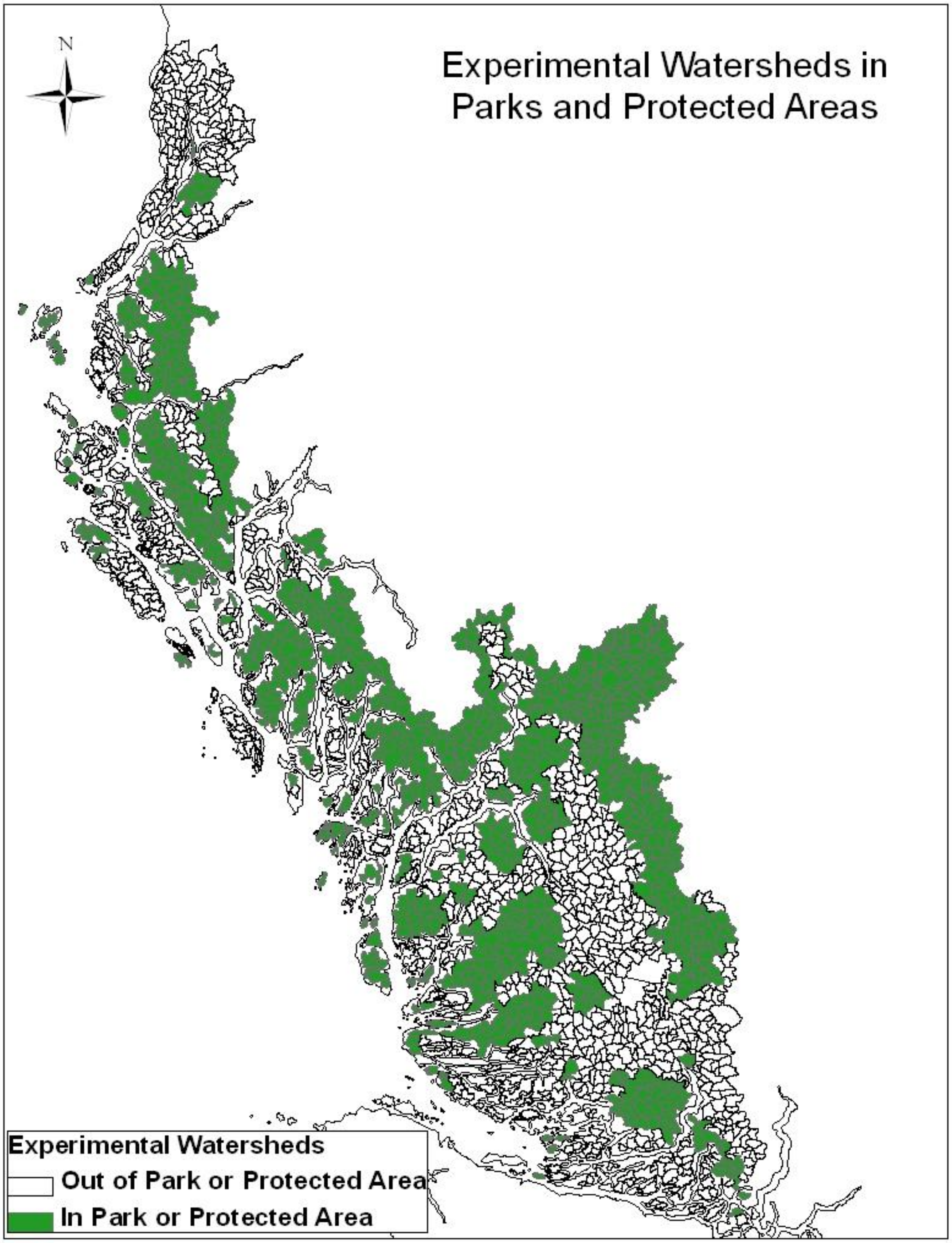

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Figure 1. Potential candidate Experimental watersheds within and outside of Parks and Protected areas.

Research Development: A Phased Approach

We suggest a four phase framework within which to implement a research program intended to support EBM implementation. Phase 1 and 2 are "start-up" and entail an investigation into what level of evidence already exists around a key question, and whether that evidence is sufficient to change practice already (i.e. are management strategies inconsistent with existing current knowledge). Reviewing existing information and deciding whether it already provides enough evidence to change existing practise (if the answer is 'no') creates an opportunity to ask 'what information would be sufficient'? If this type of discussion can occur with a broad enough group of interested parties beforehand, then it is more likely resources can be used efficiently.

Phase 3 involves retrospective observational study and seeks to increase knowledge based on existing forest harvesting and cumulative effects to date. This is a GIS supported assessment to characterize relative risk and measure actual outcomes; it includes identification of benchmarks and treatment units for sampling response variables. This phase is based solely on assessment of past practices. Retrospective analyses are typically lower power, and their design is dogged by difficulties of confounding variables and an inability to assign causes to particular outcomes. Yet, if well designed they have the potential to provide timely answers, and to reflect cumulative effects of impacts over time. We therefore prioritize this approach over immediate experimental research.

However, if there is insufficient evidence from Phase 3 (or insufficient sampling power to attempt it) to change plans and practices then a Phase 4 experiment is recommended. Phase 4 is Active AM (AAM) and considered as a last choice only after there is agreement that there is insufficient evidence from existing research and retrospective studies. This is considered the last option as it is likely the most expensive and timing consuming and is unlikely to provide results in the short term. AAM means licensees may need to amend FSP to include "science prescribed" treatments randomly assigned within the population of experimental watersheds. Some experiments may require the AM provisions now enabled in LUO, some may require special permission, however many are expected to be within LUO scope (e.g. high stand level retention levels).

PHASE 1. Experimental watershed research start-up and key questions

Phase 1 is a consultation with stakeholders, decision-makers and the research team to determine the level of risk and evidence sought on specific questions. Understanding what constitutes 'sufficient evidence' to change management, and the specifics of 'low risk to ecosystem integrity' should be determined for any specific value before commitments to research are made. A low tolerance for errors will mean a more rigorous, but more costly study design may be warranted (e.g., more sampling or an experiment).

Phase 1 also includes establishing an oversight steering committee, technical support team (the research team), funding, work plan, field sampling protocols, training, infra structure and scheduling on the next steps related to each key questions. The structure of AM and independent research capacity has also been discussed (Tyler et al 2008).

It is recommended that the consultation include a review of the adequacy of decision support tools currently used to clarify environmental risk, current distribution of risk to ecosystems and how, who and when risk assessments and tradeoffs will be handled. Assessment and reporting on risk may be more assured if linked to government obligated processes such as Timber Supply Review and Forest Stewardship Plan preparation and approvals. It is likely the envisaged EBM research team can assist in the amendment and development of decision support tools in obligated processes.

At the strategic level it is proposed that GIS assessments be used to help determine distribution of relative risk and assist tradeoffs decisions at strategic scales and simultaneously report on environmental indicator conditions as well as the current timber supply forecast. The current TSR decision support tool is discussed in Appendix B and the last section of the report. It is expected that the research team can assist in amendment and development of decision support tools such as strategic period assessment. At a tactical planning level such as Forest Stewardship Plan approvals more explicit quantification on risk and risk trade offs may also need to be developed suitable for understanding by interested parties. At an operational level assessments and best management practices and training may also become a focus for the research team to assist in accounting for and managing risk.

PHASE 2. Key questions. Do we know enough now to take a decision and adapt?
Before investing in additional research a more thorough review of information specific to any key question is warranted. The intention is to assess available information and determine whether it answers part of all of a key question, whether available information is relevant to the ecosystems of the coast and if not, whether there is any reason to assume coastal ecosystems may be more or less tolerant in relation to an observed trend. We expect such a review to consider published and grey literature, and should explicitly consider both what is published as 'known' and what is unknown as a result of uncertainties. The review should take the form of a meta-analysis (e.g. Huggard 2006 on stand structure) and should help to clarify holes in the system (e.g. are objectives sufficiently stated that they can be tested? We would expect each review to take a significant period of time (in the order of 20 days, depending on information availability?). Appendix C and D provide some additional recent literature on buffers and ecological integrity, however this is provided as a very preliminary list of the types of information available on these questions.

PHASE 3. Retrospective GIS assisted assessments. Relative risk and where to focus sampling.
The entire planning areas has had a history of forest development so before spending funds on new research related to key questions a thorough review of what can be learned from past harvesting is proposed. This means all past harvesting can be considered as treatments. Retrospective studies greatly shorten time between the inception of the study and the presentation of results and can reduce costs (Smith 1998)[7], plus in many cases managers cannot afford to wait for results from the perfect experiment. Retrospective studies may provide sufficient evidence to change a LUO, plan implementation, forest stewardship plans and results and strategies, change standard operating procedures and training without the large investment usually required to undertake experimental studies. Retrospective studies also provide a means to look at natural phenomena such as windthrow and landslides that cannot easily be created for the purposes of a study.

Well implemented retrospective studies can provide a great deal of useful information rapidly and can guide future information gathering and management decision making processes. Random sampling is essential to virtually all statistical methods whether studies are retrospective or the research design has control over the treatment units (Sit and Taylor 1998).

Retrospective studies rely heavily on GIS and manipulation of GIS data to sort watersheds and find suitable treatment units to sample and compare. GIS data layers and decision support tools are expected to provide added benefit for forestry operations and possible spin offs for support of FSPs R&S development ,as well as being helpful for forest certification. The search for sample

[7] In: Sit, V and B. Taylor 1998. Statistical Method for Adaptive Management Studies Chapter 4 Retrospective Studies

sites relies on expertise with access to a number of data sources such as stand level information in the government and industry site level tracking system RESULTS. The research group will need access to air photos and high resolution satellite data such as SPOT which could be made available by government at no cost. The research group will also require access to VRI data and other data linked to Tree Farm Licenses. Access to data by agencies and between interested groups under EBM requires data sharing agreements that enable access to the best available data. Based on the experience gained during this projects improvements are needed with regard to access to data bases and this is the subject of a report that was prepared concurrent with this project Horn 2009.

This retrospective approach (Phase 3) typically requires a larger sample population to achieve statistical power needed to compare differences in response variables than traditional 'experiments (before/after studies) suggested under (Phase 4). Phase 4 requires experimental harvesting which allows for a stronger statistical design because the treatments are repeated and so help to assign 'cause' to any effect observed. This makes detecting changes for example to stream morphology easier but requires a long term commitment (such as Carnation Creek on Vancouver Island). This three decades long "before/after" study has experienced problems with sustained funding and more recently with changes in tenure potentially affecting the unharvested experimental controls (P. Tschaplinski, personal. communication.). Retrospective studies typically require a shorter timeframe of commitment and much less funding.

Whether there are a sufficient number of study sites available from the harvest history needs to be assessed for the entire plan area and this search for existing comparable treatment units and controls relies on an initial GIS assessment specific to each question. Appendix A provides some examples of the challenges of using GIS to find sampling sites.

Retrospective studies can help to focus further research. Zielke, Bancroft and Crockfield, 2008 note that there have been 16 AM projects assisting with implementation of EBM plans and that "*it may be useful to go beyond the pilot areas and be able to identify all the cut blocks, watersheds or sub-watershed units with EBM hydroriparian features or other special habitats of interest".*

It is proposed should the decision be taken to proceed with a Phase 3 retrospective studies that there be a pilot study to test protocols and complete some samples to determine variability. This follows advice on sample size determination. More information on statistics and sampling is available at the C.J. Schwarz Statistical Course notes[8] under section 10.1.14 which states,

> *Sample size determination*
>
> *A common problem in survey design is the choice of sample size. This is an important question because the sample size is the primary determinant of the costs of the survey and of precision. The sample size should be chosen so that the final estimates have a precision that is adequate for the management question. Paradoxically, in order to determine the proper sample size, some estimate of the population values needs to be known before the survey is conducted! Historical data can sometimes be used. In some cases, pilot studies will be needed to obtain preliminary estimates of the population values to plan the main survey. [Pilot studies are also useful to test the protocol - refer to the conclusion for more advice on pilot studies]. Unfortunately, sometimes even pilot studies cannot be done because of difficulty in sampling or because the phenomena is one-time event. If there are multiple objectives it may also be difficult to reconcile the sample size requirements for each objective.*

[8] http://www.stat.sfu.ca/~cschwarz/CourseNotes

It is suggested that the use of qualified statistician is needed to achieve sampling efficiencies. The use of power analysis is also recommended as part of Phase 3. Steidel et al. (1997) indicate that use of statistical power analysis increases the efficiency of research efforts and reduces the probability that inappropriate conclusions are drawn from research findings. A qualified statistician is also needed to assess how well a Bayesian statistical approach can be applied to Phase 3 retrospectives studies. We recommend that a Bayesian approach be fully explored and the benefits of this approach are discussion in the Phase 4 but can be applied in Phase 3.[9]

PHASE 4. Active Adaptive Management.

Completing Phases 1 to 3 should identify where additional information is needed, and how best to spend AAM research funds. At this time decisions will need to be made on experimental design and where there will be AAM through harvest design. There are number of statistical approaches that can be considered at this point of embarking on AAM. One approach to experimental design is to use the traditional frequentist statistical approach and another is to other uses a Bayesian approach.

The traditional statistical approach is based on testing a hypothesis by gathering evidence to disprove the hypothesis (Sit and Taylor 1998). Evidence against the Null hypothesis[10] is assembled and may result in dismissal of the hypothesis based on the strength of the evidence against it. However, in this kind of biological sampling in particular (since there is often such high natural variability and the effect size may be relatively small in comparison) there is always the danger misinterpreting based on both Type 1 and Type 2 errors[11]. The sample size needed at specified confidence levels depends on the variation in the population being sampled.[12] High variation in the population requires a larger sample size. The level of confidence sought requires discussion with management as to their willingness to accept risk. Acceptance of risk is a management decision. Some response variables may provide data fairly quickly but others can take decades so serious consideration is needed before frequentist statistical approaches are used.

Use of a Bayesian statistical approach may be more appropriate to EBM research and adaptive management (Nyberg et al 2006; Bergerud and Reed 1998) Phase 3 and 4. While the focus in traditional frequentist statistical approach is to gather evidence to reject the null hypothesis, by contrast, Bayesian statistics uses evidence or observations to update or to infer the probability that a hypothesis may be true. This means that there is greater potential to incrementally add to knowledge without having to wait long periods before drawing conclusions[13]. A Bayesian statistical approach is also more amenable to supporting models used in decision support.

As a general recommendation, we are suggesting that a Bayesian approach seems to be more likely to use additional information to incrementally improve management than a traditional approach in Phase 3 and 4. However, this decision must be made on an individual basis as a retrospective or experimental approach is developed. A qualified statistician familiar with application of both approaches should be a central member of future research teams.

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[9] http://www.for.gov.bc.ca/hfp/amhome/Publications/index.htm

[10] **Null hypothesis:** A statistical hypothesis that states that there is "no difference" between the true value of a parameter and the hypothesized value, or that there is "no effect" of a treatment.

[11] **Type I error:** The error of rejecting a null hypothesis that is true.
Type II error: The error of not rejecting a null hypothesis that is false.

[12] www.stat.sfu.ca/~cschwarz/CourseNotes/ Course Notes for Beginning and Intermediate Statistics C.J. Schwarz

[13] For a quick summary of the philosophical differences see: http://www.rasmusen.org/x/2007/09/25/bayesian-vs-frequentist-statistical-theory/

AAM needs to include properly designed experiments, with pre and post harvest data collection, analysis and reporting. Results need to be placed in the context of pre-existing knowledge, assessed for management relevance and then acted upon by managers. This requires a research team, including statisticians, to ensure data collected can be used to draw conclusions. AAM may require cooperation from a number of licensees in order to apply a variety of treatments and expand the capacity of treatments over what a single licensee could or should be expected to undertake (one of the purposes of the proposed Adaptive Management Framework is to coordinate collaborative projects). This also would provide flexibility in a randomized treatment approach as a large number of operating areas can be included in the experimental design. It is at this point when cost offsets (e.g., "research stumpage rates") may need to be seriously considered.

Section 4. Key Ecological Integrity Research Areas

Methods: Determining Research Priorities

A number of 'priority key research questions' have been identified in this project. This work has been based primarily on the reports *Adaptive Management Framework for the Central and North Coast of British Columbia: Knowledge Summary: Information Used for Estimating Probability of Success and Uncertainty for EBM Strategies* (Price,Tyler, Daust and Soto 2009 and *High priority research questions related to ecological integrity in the Central and North Coast* **(**Price, Daust and Tyler 2009) as well as additional documents - coast Land Use Objectives[14], CIT reports[15], and a review of long-term Adaptive Management Projects[16]. The Price,Tyler, Daust and Soto 2009 knowledge summary uses a structured approach to determining where knowledge that is key to EBM implementation is missing, and when the lack of the knowledge poses a significant risk to the potential ecological outcome. This draft set of priorities outlined by Price et al 2009 were further refined within this project, and the top 7 ecosystem topics highlighted and projects broadly developed.

In addition, climate change and carbon cycling were identified by the project team as areas to build knowledge specific to coastal forests as both topic areas potentially affect ecological integrity and will likely be important aspects of EBM implementation into the future.

Table 1 lists the key research questions, treatment units, and response variables. Treatment units in Table 1 are the portions of the ecosystems affected by harvesting and roads associated with floodplains, riparian forests, unstable terrain, functional riparian forests, old growth forests, critical habitat of species etc. Experimental Units in Table 1 are physical entities which can be assigned, at random, for sampling purposes. This was done to reduce the probability of errors due to sub sampling and pseudo replication (Eberhardt and Thomas 1990; Hulbert 1984). In some cases the treatments units and experimental units are the same (e.g. unstable terrain), however the experimental units allow for landscape and watersheds effects associated with cumulative effects for example the changes in stream banks due to watershed condition.

Following Table 1, each question is further explored, with identification of potential hypothesis to be tested, relevance to management, a description of the experiment and study design, response variables, a highlight of decisions being influenced and ending with potential next steps.

[14] http://ilmbwww.gov.bc.ca/slrp/lrmp/nanaimo/cencoast/plan/objectives/index.html

[15] http://ilmbwww.gov.bc.ca/citbc/pubpcit.html EBM framework, Scientific Basis of EBM, EBM Planning Handbook, Hydroriparian Guide

[16] http://www.for.gov.bc.ca/hfp/amhome/Publications/index.htm AM Publications & Resources and Projects in BC and adjacent jurisdictions.

It is assumed that research teams will be created to oversee full development of any of these questions. Phase 1 and 2 - which determine whether sufficient information is available to change management today (or whether 'no' additional information will ever be sufficient to change management) need to focus on key question. After this, a more review there may be a revision of the question as focus for the retrospective study. Additional details are expected through Phase 1 and 2 that may improve the research project over what was begun in this report.

Limitations of the list of key questions and priorities

This report outlines research to answer the three highest priority questions for aquatic and two of the highest priority questions for terrestrial ecological integrity. There is a much longer list of potential research questions and we chose to limit this report to the highest priority questions identified in the documents reviewed and by topic experts; this short list of questions by themselves will require sustained effort to address at this time.

In addition, there is a long and growing list of focal species and ecosystems which would benefit from research. Use of the emerging MOE Conservation Framework (CF) is considered as a practical first step to prioritize research, inventory and monitoring for species if direction is unavailable from recovery teams. The CF approach to stewardship responsibilities is discussed under Focal Species and Ecosystems.

There is considerable activity on climate change adaptation and carbon cycling at provincial, federal and international levels. The extent that EBM research needs to lead or participate in these broader initiatives is unclear. We limit ourselves to suggesting that these be included, and the status of information linked to these from within the plan area be reviewed. It is anticipated that models supplied with data from within the area will provide a more realistic estimate of climate trends and carbon storage and cycling.

Table 1 .EBM Research Framework for Key Research Questions. See Section 4 for details.

Research Priorities	Research Question	Treatment units	Experimental units	Response Variables	Comments
4.1 Coarse Filter Hydroriparian Integrity					
Section 4.1.1 Riparian buffers associated with Active Fluvial Units (AFUs).	What are the impacts on the morphology of Active Fluvial Units (AFUs) of removing forest from floodplains and fans and adjacent riparian forest buffers?	Buffered and unbuffered AFUs Different harvest of AFU	Similar Watersheds stratified by : • Forested area • ECAs levels, • Road densities • Seral stages • Buffered and unbuffered reaches	1. Channel bed morphology (stability) Large Woody Debris (LWD) supply 2. Aquatic habitat connectivity 3. Fish cover/ productivity (litterfall)	Sampling Protocols can be based on FREP plus slope stability indicators. The functions of, and risk to, riparian forest biodiversity will be interpreted from the condition of response variables and the condition of the baselines in the unharvested controls
Section 4.1.2 Steep slope logging and impacts to hydroriparian down slope	What are the impacts on the morphology of streams from different levels of forest development on unstable terrain and near steep streams susceptible to debris torrents?	Harvested and unharvested potentially unstable terrain • Road densities • Seral stages • Steep slopes	Similar watersheds stratified so steep slopes and downslope streams are comparable	1.Channel bed morphology (stability) LWD 2. Aquatic habitat connectivity 3. Fish cover/ productivity (litter fall) 4. Slides and debris torrents	Sampling Protocols based on FREP plus slope stability indicators.
Section 4.1.3 Hydroriparian function and study of harvest impacts to small streams and karst ecosystems	What are the impacts on the biodiversity and productivity of hydroriparian ecosystems of harvesting the riparian areas of small upland streams (> 6% gradients such as S4, S5 and S6s)? A similar study can be used to address impacts to karsts.	Harvested and unharvested riparian buffers on small streams and karst ecosystems.	Buffer conditions of small streams and karsts	Species associated with Hydroriparian types and sensitive to harvesting. Sampling is expected to include vegetation, LWD, wildlife species, and invertebrates as well as changes in microclimates	There are a number of other hydroriparian types that could be included such as forested swamps, fens, wetlands, estuaries..
4.2:Coarse Filter Terrestrial Ecosystem Integrity					
Section 4.2. 1 Stand structure retention in a landscape context	Are there combinations of stand level and landscape level retention levels that pose high risk to species populations within watersheds/ landscapes?	Most and least harvested watersheds with highest and low landscape and stand level retention	Gradient of stand retention > and < 15% within a gradient of WS with older forest reserves	Species associated with older forests and sensitive to harvesting.	Low statistical power is a concern especially when sampling naturally rare ecosystem occurrences.
Section 4.2.2 Old and Ancient forests	Are old forests at the ‘young end’ of the defined age range (e.g. 180 – 300 years) biologically	Harvested and unharvested ancient forest comparisons	Older forest distribution within watersheds i.e. infrequent disturbances areas.	Structural complexity and indicators of older forest. Ecosystem processes important but difficult to monitor /assess i.e. nutrient,	Baseline information is lacking on structure and species complexity of older forests. May lead to old growth index as an implementation

Research Priorities	Research Question	Treatment units	Experimental units	Response Variables	Comments
	equivalent to much older stand and less frequently disturbed ecosystems?			water and carbon cycling.	decision support tool.
4.3: Species and genetic diversity					
Section 4.3. Focal and listed species/ecosystems	For priority species /ecosystems what is critical habitat and what level of stewardship will result in low risk management?	Harvesting impacts on habitat .	Home range and dispersal areas appropriate for species/ecosystems Detecting changes in species/ecosystems distribution and abundance linked to forestry and development.	Critical habitat and current suitability and distribution. Habitat relationships. Population census and trends. Specific species level indicators.	Expect to improve or build habitat species relationships. Complexity depends on existing inventory, habitat relations and range knowledge. Priorities needed to focus research on least understood species /ecosystems of highest ecological concern.
4.4 Climate Change Trends, Vulnerability and Adaptability					
Research Priorities	**Research Question**	**Treatment units**	**Experimental units**	**Response Variables**	**Comments**
Section 4.4 Relates to all plan elements and specific priority research areas above	What are the observed climate trends for the coast? What ecosystems/species are most vulnerable to climate change? What adaptation can be undertaken?	Confirm existing sources of monitoring Assess incremental monitoring needs.	Monitoring sites for natural disturbance baselines. Baselines and trends that can verify actual changes to ecosystems.	Ecosystems indicators linked to natural disturbances - relative changes in background rates of natural disturbances. Number of events size and frequency of windthrow forest, land slides, , peak flow low flow, fire, forest insect and diseases. stream temperatures,	Climate change has been included but is conceptually not well developed at this time. There is a lack of baseline information on natural disturbance now yet changes in background rates of disturbances will influence all ecosystems
4.5 Carbon storage and cycling					
Research Priorities	**Research Question**	**Treatment units**	**Experimental units**	**Response Variables** (Comparison of means)	**Comments**
Section 4.5 Measuring Carbon in natural and harvested forests	How much carbon is stored and cycled in different forest ecosystems in different seral stages?	Seral Stages post harvest and natural forests	Link carbon to site series and changes in seral stages.	Linked to natural disturbances and changes in background productivity and mortality within sites series and seral stages. ?	Carbon has been included but is conceptually not well developed at this time. Knowledge of carbon and accounting for carbon will be needed.

4.1 Hydroriparian integrity

Price,Tyler, Daust and Soto 2009 identify the following three areas of research as high priority: 1) assessing impacts of riparian buffers on morphology of Active Fluvial Units (AFU) [17], 2) assessing effects on stream morphology and water quality of forestry development on potentially unstable terrain and around streams subject to debris flows and 3) assessing effects of riparian forest retention on the biodiversity and productivity of selected hydro-riparian ecosystems (i.e., karst and small steep streams). The need for research on hydro-riparian integrity is more fully discussed in section two of Price et al. (2009), a knowledge synthesis based mainly on the HPG (2004); the HPG and related background reports synthesized much of literature and expert opinion on hydroriparian ecology and management to 2004. Appendix C includes some more recent references on buffers as a useful starting to Phase 2.

The concern with protection of the hydroriparian system through a buffer approach is the lack of basic understanding of these highly complex systems. First, the hydroriparian system is extensive with somewhat unknown limits (i.e. how far does it extend under different conditions from the anchoring features such as the fen, marsh, karst, forested swamp, stream, lake, ocean spray forests etc). This uncertainty makes management using a fixed buffer approach (and in many areas no buffer requirements) of unknown potential effectiveness. Each of the questions outlined here could be rephrased here as investigating our knowledge of the extent and functioning of the hydroriparian system in and around certain features in the landscape (active fluvial units, steep streams, karst etc).

4.1.1. Impacts of buffers on Active Fluvial Units (AFUs) (Floodplains)

1. Question

What are the impacts on the morphology of Active Fluvial Units (AFUs) of removing forest from floodplains and fans and adjacent riparian forest buffers? When stated as the Null hypothesis this would be: Mature and older forest buffers do not influence the functioning and integrity AFUs at different levels of forest development. Proper function is based on interpretation of number sampled variables such as Large Woody Debris, sediment transport, stream complexity which are possible with adequate training (Tripp et al. 2008). These are discussed under response variables.

2. Management relevance

AFUs are known to be biologically productive diverse ecosystems, and are among the least stable and most sensitive to disturbance (HPG 2004). Management strategies[18] for AFUs vary by region and thus vary in their likelihood of maintaining water quality/stream morphology (Price et al. 2009). In the South Central Coast, AFUs are not buffered though 90% of forest on the AFU needs to be retained. In the Central and North Coast, no harvest is permitted on AFUs and these units also require buffers of 1.5 tree heights on average, with 90% forest retention within buffers. Note that under certain conditions, FRPA riparian reserves, adjacent to streams running through AFUs, may retain more riparian forest than the SCC order. Although the SCC order is considered to be more likely to adversely impact AFU morphology than the FRPA default standards substantial uncertainty about the frequency and magnitude of a potential impact remains.

Negative consequences have already been documented in relation to harvesting on AFUs (BC MOF 1995, 2001 and Tripp 1995) and this research has led to somewhat revised management strategies for AFUs over the last two decades. Riparian retention next to streams running through AFUs increased under Fish Forestry Guidelines, the Forest Practices Code and the Forest and Range Practices Act (FRPA), but retention strategies focus on stream channels rather than on the AFU stream channel and buffers. Both the CNC and SSC orders prevent significant harvesting on

17 "active fluvial unit" means an active floodplain, where water flows over land in a normal flood event, and includes low and medium benches and the hydrogeomorphic zone of an active fan (South / Central Coast MO);

18 Note that many of the "land use objectives" contained in ministerial orders are more akin to strategies than objectives, that is they describe the means to achieve broader objectives.

AFUs themselves, and the risks associated with (or with not) having a buffer to protect AFU morphology is unclear. The high contribution of riparian forest adjacent to floodplains towards biodiversity objectives is however well documented through work completed and summarized in the Hydroriparian planning guide such as (Church and Eaton 2001, Young 2001, Price and Church.2002, Price and McLennan 2002, Price and McLennan 2002). Additional references are also provided in Appendix C of this report as an aid to Phase 2 reviewing what is known and its interpretation and comparison to practices proposed and whether these are low risk management.

3. Description of experiment and study design

Variation in buffer treatments over the last two decades provides opportunities for retrospective studies. Experimental comparison may be easier to find as the legal orders differ in their treatment of AFUs between regions, though such samples may only be available for relatively recent harvests. It is likely older buffered and unbuffered sites may be more widely available. Studies should address fans and floodplains separately, because they respond differently to disturbance. Fans occur around smaller, steeper streams than do floodplains. The provincial terrain classification provides a consistent approach for classification of AFUs[19]. Other authors (Horel 2006; Wilford, Sakals, and Innes, 2005) also provide direction on identification of fluvial fans. Classification of terrain has been undertaken by forest licensees. Currently, however, there is no consistent coast wide terrain inventory (see Appendix A for GIS data layer availability). Terrain data may be available from GeoBC[20] but the extent and consistency needs to be assessed.

There are two main variables of interest: % harvest on AFUs and % harvest in buffers (Table 2). Available sample sites likely range from sites with moderate levels of buffer retention adjacent to AFUs through full retention on AFUs with no adjacent riparian buffers to full retention AFU with buffers. There may be some floodplains which have 90% retention and others than in the past have less retention than 90% that could be included as potential samples sites and included in the design. Combinations of harvested AFUs with intact riparian buffers are unlikely. The impacts of low levels of retention on AFUs have already been documented but could be considered in this study to increase the range of conditions examined and provide a more complete range of responses. Table 2 proposes characteristics of the sample sites needed for AFUs (variable of interest) and additional confounding factors that need to be considered when selecting sample sites (covariates). It is unlikely that all the retention levels will be available so it is recommended that sampling be prioritized to unharvested baselines and oldest and least buffered sites.

Table 2. Reach and watershed variables to assess in selection of samples sites.

Type of variable	Variable	Levels/treatments*
Variables of interest	% retention of forest on an AFU	100 > 90 50 – 90 < 50
	% retention of buffer	> 90 50 – 90 < 50
Reach covariates	buffer width	variable
	Hydroriparian ecosystem	floodplain fan
	stream gradient	< 3% > 3%
	stream width	< 20m

[19] **Terrain Classification System for British Columbia** is a scheme designed for the classification of surficial materials, landforms and geological processes, it is not scale dependent. http://wlapwww.gov.bc.ca/wld/documents/techpub/moe10/index.html
[20] http://ilmbwww.gov.bc.ca/dm/fsp/index.html **FSP/FRPA Data Access for Industry Project**

Type of variable	Variable	Levels/treatments*
		> 20m
	AFU width	< 50m > 50m
	riparian side-slope	steep gentle
Watershed covariates	Glaciers % of watershed	absence or %
	Lakes	absent or number and %
	valley shape	U-shaped V-shaped
	Productive forests area % of watershed	low medium high
	Rock % of watershed	low medium high
Watershed development covariates	road density	low med high
	area harvested amount % of productive forest	low med high
	Harvest rate ECA	low med high
	upstream buffers	pre-FPC/FRPA FPC/FRPA

*Depending on the variation in levels of each variable, either stratify by or control for levels of each variable (i.e., a complete design is unlikely).

The development history of the watershed needs careful consideration. Observed changes to AFUs may reflect indirect as well as direct management effects (e.g., cumulative impacts of upstream harvesting). Watershed processes operate over large areas and over long time periods so if there are detectable negative impacts on AFU morphology, these may be evident from watersheds with the longest harvest history and greatest area harvested. Keeping separate impacts of development upstream from those on and adjacent to AFUs will require careful design and analysis. Additional information on watershed hydrology and cumulative effects of forestry can be found at FORREX[21].

Finally, it will be necessary to consider the morphology of the watershed and the hydroriparian ecosystem. Natural patterns of water and sediment movement depend on watershed morphology (e.g., parent material, presence of lakes or glaciers, steepness, terrain stability) and the age of the forest cover. At a smaller scale, the functions of an AFU depend on hydroriparian ecosystem type (floodplain or fan) and features of each type (e.g., width of stream and AFU, gradient along stream/AFU and perpendicular to stream/AFU). These variables can be categorized as appropriate (likely using statistical techniques) to provide classes for stratification.

Appendix A provides an iterative GIS process that could be used identify AFU using floodplain data. Terrain classification maps may help identify AFUs where available. Forest cover, stream gradients and topography may however serve as rough surrogates, but their use requires further investigation. This stage requires involvement of a wider multi-disciplinary technical discussion including hydrologists, aquatic specialists and statisticians.

[21] http://www.forrex.org/program/web_links.asp?AreaPkey=7 Watershed Management Links by Theme

As a first step, the GIS assessment needs to identify WS units that could potentially be sampled. Table 3 shows the proposed initial sampling strata.

Table 3. Experimental design elements for buffered and unbuffered AFUs.

Experimental Watersheds	Level of forest development			Active Fluvial Units	
	Benchmark	Low	High	Buffered	Unbuffered
See Appendix A					

Sampling the unimpacted benchmarks and the most impacted AFUs should be the initial focus of field sampling. If there are no observable differences between most buffered and least buffered stream reaches in most and least developed watersheds then it is likely that retrospective studies will not provide strong information on these questions. If differences are observed, then fine-tuning the retrospective analysis to look for finer-scale differences along the development gradient should be undertaken.

4. Response variables

Field sampling should collect data on stream reach integrity, based on protocols developed by Tripp et al. (2008) and expanded as necessary to describe AFU integrity. Sampling records information about stream reach features/indicators (e.g., sediment wedges, multiple and/or braided channels and lateral bars) to answer questions about reach integrity. Eight of the 15 questions seem most relevant to this study (Table 4); however the final study design should re-consider the value of all questions developed by Tripp 2008. It is also possible to use fish as an indicator (based on current fish distribution maps; Johnson and Slaney 1996). The sampling protocols and field cards on how to answer these questions have been developed for Fish/Riparian values and are available at http://www.for.gov.bc.ca/hfp/frep/indicators/table.htm#fish .

Table 4. Assessment questions for healthy streams (Tripp et al. 2008).

1. Is the channel bed undisturbed?
2. Are the channel banks intact?
3. Are channel LWD processes undisturbed?
4. Is the channel morphology intact (connectivity)
5. Are all aspects of aquatic habitat sufficiently connected to allow for normal unimpeded movements of fish and organic debris and sediments?
6. Does the stream support a good diversity of fish cover attributes?
7. Does the amount of moss present in shallow areas of the channel indicate a stable a productive system?
8. Does the stream support a diversity of invertebrates?
9. Does the hydroriparian zone support the pre-logging terrestrial species community?

5. Time frame and forest management decisions affected.

Sampling existing buffered and unbuffered AFUs means that it may be possible to draw conclusions in the short term (with a few years of study) on the risk of current practices on buffering active fluvial units. Since experimental units are initially sought through GIS assessment requiring a number of data layers the status of existing inventory is a determining factor in finding comparable watersheds. Ideally, finding sample sites is improved in areas where there is consistent data such as terrain classification available.

More detailed GIS assessment and follow up with air photos and remote sensed image is needed to find comparable sample sites. GIS assessment could be completed with a few months. If inventory is incomplete, or not already assembled then the “office portion” of the study become less clear and less timely. It will not be possible to easily identify potential sample sites without a consistent AFU classification in place.

Communications with the EBM steering group [22]and practitioners is also needed so there can be a discussion of expectations on comfort level for the amount of evidence that would trigger a change in LUO objectives related to buffer management. Change is meant to occur when sufficient science-based information is presented. Depending on the tolerance to errors a more complete summary of existing research on buffers may be sufficient to trigger a review of this objective. A low tolerance for errors will mean a higher sample size is needed or a higher powered experiment may be more appropriate but also more costly.

6) Next steps

1. As outlined in the four phases framework, phases 1 and 2 ask whether sufficient information is available to confirm or alter management practices today. Considerable effort has been placed on understanding buffers on fluvial units. In addition to the extensive summary of information in the CIT hydroriparian work, some additional references in Appendix C provide insight on the research evidence – this information should be fully examined before embarking on additional research. Similarly, it should be determined what level of evidence is considered sufficient to inform EBM before more detailed research is under taken. Complete phases 1 and 2 specific to this question before proceeding with a plan wide search of treatments and experimental units needed in the retrospective study design.
2. Once it has been decided that further study is necessary; select a wider multi-disciplinary technical group including hydrologists, aquatic specialists and statisticians and confirm approach and data layers. A list of potentially confounding factors associated with retrospective studies also needs to be completed. Complete a more detailed description of research and start up phase, completion of pre field assessment, data analysis and estimated duration. Include a statistician to confirm final design, see Bergerud 2003 for review and checklists of research designs. Refine GIS assessment beyond what is presented in this report.
3. Acquire photos (such as SPOT images through government) and review the selected watersheds to confirm condition and reject watersheds which the GIS did not properly select. Remote sensing images are needed to help identify larger slope failures.
4. Confirm the field sampling procedure and randomly assign sample sites. Identify infra structure and field facilities and proximity to sample sites. Ensure training on data collection is completed.
5. Meet with an EBM steering group to confirm approach, budget, and logistics and expected time frame cost sharing and infra structure support.

4.1.2 Development on unstable terrain and near streams susceptible to debris transport

1. Question

What are the impacts on the morphology of streams from different levels of forest development on unstable terrain and near steep streams susceptible to debris torrents? Stated as the Null hypothesis this would be: Primary forestry activity (harvesting, road building, maintenance, deactivation and access networks) on potentially unstable terrain and near streams susceptible to debris torrents are not high risk to the integrity of the hydroriparian ecosystems in that area over time.

2. Management relevance

In the North and Central Coast, EBM objectives aim to maintain channel characteristics and water quality in streams. Streams under natural conditions are dynamic and changing. Adverse impacts to channel characteristics and water quality are those that occur from development activities (roads and harvesting) on unstable terrain, and that result in incremental destabilisation of stream banks, loss of downed wood within streams and changes in channel morphology (Price et al. 2009). In most streams in the source zone, the probability of maintaining sufficient downed wood to maintain stream morphology and water quality is insensitive to removal of up to 30% of the forest

[22] This term is used in the absence of a governance structure for EBM it is assumed that there will be some higher level multi-party decision making body.

across the source zone, however, streams susceptible to debris flow are sensitive to 10% removal of riparian forest (Price et al. 2009).
Channel morphology provides a means to describe the basic characteristics of a stream such as pool riffle complexity, bank stability, LWD, in stream substrate etc. Changes in these occur through natural changes in streams as they are dynamic active systems. Forestry and development activities can incrementally accelerate changes to stream channel morphology and reduce complexity and productivity. Naiman and Latterell 2005 outline 8 principles for linking fish habitat to management and conservation one of which is fishless headwater streams are inseparable from fish bearing waters downstream. Some of the measurements are to confirm the function of these fishless streams on fish bearing waters and others are to clarify terrestrial biodiversity of smaller streams.

The CNC and SCC orders do not specifically address unstable terrain or small steep streams susceptible to debris flow. FRPA, however, includes requirements to prevent soil movement that adversely affects streams[23]. It requires that

"the primary forest activity does not cause a landslide that has a material adverse effect in relation to one or more of the subjects listed in section 149 (1) of the Act." and

"the primary forest activity does not cause a gully process that has a material adverse effect in relation to one or more of the subjects listed in section 149 (1) of the Act" where a gully process is defined as *"a rapid erosion of sediment that creates a channel or increases the depth of an existing channel, or a debris flood".*

While FRPA "prohibits" landslides and gully processes, neither the ministerial orders nor FRPA contain specific strategies guiding activities on unstable terrain or in riparian forest around small steep streams with high potential for debris transport. To determine what the impacts of forest development requires location of harvest activity in unstable terrain and around these unstable streams.

3. Description of experiment and study design

This study is focused on slope movement processes, and changes in impacts on aquatic ecosystems from forestry activities. Two slope processes are of interest; slope failures associated with unstable terrain and debris torrents associated with small streams. The first phase of this study will be to characterize the range of development activity that has occurred on potentially unstable terrain, and on small steep streams susceptible to debris flows. It is recommended that there be an emphasis on current practices under FRPA. If very little activity is occurring it may be hard to find an adequate number of sample sites. The study looks for direct impacts to streams from mass wasting and indirect impacts stream characteristics and water quality associated with different levels of development. There are main variables of interest area: area harvested and road length (HPG 2004; Table 5) and retention of riparian forest. Factors such as partial harvesting, landings and special road construction techniques should be controlled for. Most importantly slopes that can deliver sediment to streams must be distinguished from those that cannot. Where debris torrents are the main process the main variable of interest is the percent retention of riparian forest (Table 6). Factors such a roads and stream crossings should be controlled for.

Downstream impacts of incremental sediment delivery depend greatly on background levels. Watersheds vary greatly in their natural levels of sediment production and should be stratified accordingly, based on such factors as presence slope gradients, unconsolidated materials, lakes and watershed morphology. The overall level of development in the watershed also affects sediment production and should also be controlled for. The greater the uniformity in catchments begin sampled with regard to gullies, small stream density, and indicators of instability, the greater the

[23] objectives set by government under section 149 (1) of FRPA include conserving water quality (Forest Planning and Practices Regulation, Section 8)

likelihood of isolating the impacts of harvest. Changes in slope processes are often linked to stochastic weather events so a large number of samples may be needed both to establish background slope disturbances and incremental changes.

Watersheds with completed watershed assessments and watersheds which have had restoration work should have more detailed information about watershed features. Tables 5, 6 and 7 provide an overview of what to look for using GIS data. Appendix A illustrates the types of GIS data and what variables to select for when sampling

Table 5. Sample design for unstable terrain impacts.

Watersheds	Productive forest on Unstable slopes (Class 4 and 5)		
	Benchmark	**Low level of development**	**High level of development.**
Slope process indicators	# and types of naturally occurring mass movements		Increase in comparison to natural background levels?
Hydroriparian condition indicators	Condition of stream channel LWD Complexity		Are there changes in channels in comparison to natural background levels?

Table 6. Variables of interest and covariates in study design of impacts unstable terrain.

Type of variable	Variable name	Levels/treatments
Variables of interest on unstable terrain	Background slope disturbances	continuous
	area harvested on class IV terrain	continuous
	road length on class IV terrain	continuous
Class IV development covariates	area of landings on class IV terrain	variable
	special road construction techniques on class IV terrain	variable
	Degree of connection of slope to stream system (i.e., does water and sediment flow from the slope to the stream system?)	connected isolated
Watershed covariates	watershed morphology (e.g., steepness classes); upslope moisture sources	steep gentle

Table 7. Variables of interest and covariates in study design of streams susceptible to debris transport.

Type of variable	Variable name	Levels/treatments
Variables of interest	percent riparian forest retention	100 >90 50-90 <50
Riparian development covariates	roads in riparian area	present absent
	stream crossings	present absent
Watershed covariates	see Table 6 above	
Watershed development covariates	see Table 6 above	

<u>4. Response variables</u>

A variety of "response" indicators can be considered. Keeley and Walters 1994 provide a review of a number of indicators such as; surface erosion, mass wasting, sediment transport, wood debris budget, water quality, water yield, fish abundance and growth for the purposes of effectiveness evaluation of the watershed restoration program, many of which have evolved are now are used in the FREP program. Wieckowski et al. 2008 propose upslope indicators for important fisheries watersheds: 1) mass wasting and land slides, 2) seral stage (recovery), 3) road density and stream crossings. There is also considerable expertise on how to classify and inventory slope processes (Wilford 2003; Rollerson et al 2002).

The ability to detect mass wasting and delivery of woody debris from upslope sources depends on the power of the slope process. Some lower power processes can only be detected under mature and older canopies when on the ground. High power events that create movements of < 20m are also difficult to detect in comparison to large mass wasting events. Information is also available assessing instability from guidebooks formerly used for assessment of unstable terrain and gullies[24].

5. Time frame and forest management decisions affected.

The study of harvests on unstable terrain and harvest on streams susceptible to debris torrents may indicate whether there is an increase in impacts over background levels when compared to the incidence of soil failure and debris torrents in non harvested areas. If there is evidence of impacts from forestry activities then there needs to be a review of options for improvements or limitations in steep slope harvest practices.

6) Next steps

1) Complete Phases 1 and 2 specific before proceeding with a plan wide search of treatments and experimental units needed in the retrospective study design. If it is decided to undertake a plan-wide search for treatment and experimental units, proceed with GIS assessment to find sample sites unstable slopes and debris torrent areas. See Appendix A for examples of GIS data and the types of searches needed. Check the monitoring results in FREP[25] on unstable terrain and whether there are FREP monitoring reports and sites in the plan area.
2) Select multi-disciplinary technical group including GIS analyst, hydrologists, aquatic specialists and statisticians and confirm approach and data layers. Complete GIS assessment to find watersheds with similar amounts of unstable terrain and varying degrees of forest development and similar potentially impacted stream reaches. This will require iterative GIS supported selection and use of remote sensing (such as SPOT images through government). A review watersheds restoration projects and watershed assessments within the plan area may provide insight into potential candidates.
3) If necessary, conduct a pilot study to confirm the field sampling procedure and to collect a number of samples to obtain an initial measure of the variation as this affects the sample size. From there, randomly assign sample sites and identify infra structure and field facilities and proximity to sample sites. Ensure training on data collection completed.
4) Analyze field samples and determine if sample size was sufficient. Proceed to increase field samples as needed to achieve level of evidence required.

4.1.3 Impacts of harvesting upland streams and karst

1. Question(s)

What are the impacts on the biodiversity and productivity of hydroriparian ecosystems of harvesting the riparian areas of small upland streams (> 6% gradients such as S4, S5 and S6s)? A similar study can be used to address impacts to karsts.

[24] 1) Gully Asesssment Procedure - Fourth Edition Version 2001., 2) Hazard Assessment Keys for Evaluating Site Sensitivity to Soil Degrading Processes March 1999 - Version 2.1 (PDF 270KB) and 3) Mapping and Assessing Terrain Stability Aug 99

[25] http://www.for.gov.bc.ca/hfp/frep/values/soils.htm

Two types of hydroriparian ecosystems were provided as these were considered the areas where there were the largest knowledge gaps (Price et al 2009). The sample research design could be applied to a number of hydroriparian types such as estuaries, forested swamps etc.

<u>2. Management relevance</u>

Different hydroriparian ecosystems receive different amounts of protection under strategies specified in ministerial orders and FRPA. Small upland streams receive no specific protection although broader conservation measures apply whereas some karsts are protected through GAR orders. A GAR exists for Karsts that includes resources and professional advice outside of the LUO's.[26] The study has implications for management of small streams.

EBM objectives aim to maintain ecological integrity in general and aim to maintain hydroriparian biodiversity and productivity in particular (Price et al. 2009). Hydroriparian ecosystems exist at the interface of terrestrial and aquatic ecosystems. The presence of water moderates the microclimate and often increases the productivity and structural diversity of the adjacent forest. Forests adjacent to streams provide a source of litterfall and downed wood to the aquatic ecosystem. Old riparian forest with large trees is necessary to provide downed wood in transportation and deposition zones. In the source zone, however, smaller pieces of wood may effectively regulate stream morphology. In addition to the references used in the Hydroriparian planning guide and as an aid to Phase 2 Appendix C includes references on riparian ecosystem conservation, management and buffers.

Hydroriparian ecosystems are a key element of a biodiversity conservation strategy. Price et al. (2009) suggest that sensitive hydroriparian ecosystems such as karst can tolerate a 10% removal of riparian vegetation without adverse impacts while less sensitive ones, such as small upland streams can tolerate 30% removal (from a biodiversity / productivity perspective). The HPG recommends that rather than leaving riparian buffers around the many small streams, upland forest should be managed as a unit and retention targets should apply to the entire upland.

Under FRPA, small upland streams (< 1.5 m wide) that do not have fish or do not fall in a community watershed are classified as S6. These streams have a 20m wide riparian management zone; however, no tree retention is required.

The CNC order and SCC order[27] limit harvesting of forests in the portion of the watershed defined by upland streams[28] ("upland forest") as follows:

> *"maintain 70% or more of the forest, in the portion of the watershed occupied by upland streams, as functional riparian forest[29]."* and *"allocate retention to include upland stream reaches with unique microclimate or other rare ecological or geomorphic characteristics".*

The CNC order applies to all watersheds; the SCC order applies to important fisheries watersheds, thus harvesting is not restricted in some watersheds. More importantly, the definition of functional riparian forest means that the majority of upland forest can be harvested within a 100 year rotation, because harvested areas recover to "functional riparian forest" status within approximately 30 years. "Functional riparian forest" refers to being <u>hydrologically</u> functional with respect to runoff and does not mean the riparian forest will be functional in other ways and the impacts to these also need to be assessed in design of the research. Reframed, the research question becomes an assessment of the extent to which fully functional integrity is maintained while maintaining hydrologic functions.

[26] http://www.for.gov.bc.ca/dni/gar/GAR.htm#Karst_Resource_Feature

[27] http://ilmbwww.gov.bc.ca/slrp/lrmp/nanaimo/cencoast/plan/objectives/index.html

[28] **"upland streams"** means streams with a slope greater than 5% that are classified as S4 to S6 streams in section 47 of the *Forest Planning and Practices Regulation* .

[29] **"functional riparian forest"** means forest that has reached hydrologically effective green-up and that also contains some large trees adjacent to streams to provide for large organic debris;

Upland forest is also protected by old forest representation targets, a strategy addressing terrestrial ecosystems. The CNC and SCC orders currently specify representation targets of 50% of natural old forest abundance coast wide for the more common ecosystem types and 70% for rarer ecosystem types[30]. Karst ecosystems are rare and not identified by site series surrogates used as the basis for ecosystem representation, thus it is unclear what level of representation protection they will receive - terrestrial ecosystem representation does not consider hydrological features, provide landscape context, or combine sites into ecosystem complexes—all important aspects of hydroriparian ecosystems.

In summary, management strategies specified in ministerial orders and FRPA may not retain sufficient old riparian forest to have a high probability of meeting biodiversity/productivity objectives for upland streams or for karst ecosystems that could be considered as low risk (see Price et al. 2009). Probability estimates are based on general relationships between species and habitat and not specifically on small stream research. Impacts of harvesting on small upland streams have not been as well studied as impacts on fish-bearing streams although recent work at UBC[31] such as Richardson and Danehy 2007 are adding to the understanding of these systems. Small stream hydroriparian ecosystems contain unique species and dispersal is usually limited to stream corridors, so the potential for significant adverse impact exists.

There is also concern over the absence of classification and inventory systems similar to BEC site series for these systems. In addition, most of the riparian buffers and their need for such buffers have been related to their role for integrity of fish and fish habitat. The role of buffers near different riparian types is less well understood with regard to other non sport and commercial fish species. The key questions only focus on small streams and karst ecosystems.

3. Description of experiment and study design

Two retrospective studies are proposed. The first examines the impacts of harvesting riparian areas on the biodiversity and productivity of small upland streams that do not have a riparian reserve buffer. Around these small streams, riparian areas will likely be either harvested or unharvested. The main variable of interest is the forest age which is used as a surrogate for structure and interpretation of the condition of riparian forest. Following harvest, riparian forest re-grows and functions recover at different rates, thus harvested areas need to be divided into appropriate age strata. Partial retention of riparian forest should be controlled for. These will be compared to the experimental units with unharvested riparian forests.

The second study examines the impacts of harvesting karst ecosystems and adjacent riparian forest. The main variables of interest are age of forest on karst ecosystem (including an adjacent buffer) and road length on karst ecosystem. Partial retention should be controlled for. In both studies, it may be possible to identify paired sites (sites with and without harvesting that lie adjacent); such sites can increase the ability to detect differences.

See Appendix A for initial GIS approach to small streams. Stream integrity has some of the best developed sampling protocols such as the modified FREP procedures recommended for the preceding two questions however this does not extend to the smallest streams. Sampling protocols are anticipated for (amphibians and non sport/food fish).

Differences among streams and among watersheds need to be accounted for. Upland steams can be continuously flowing, ephemeral or seasonal and communities of aquatic organisms differ among the different stream types. Parent materials of slopes adjacent to streams affect the width and character of the hydroriparian zone. Less mobile hydroriparian species have difficult moving

[30] Though a revised version of the orders is currently available for review and comment and these targets may be increased overall.

[31] http://faculty.forestry.ubc.ca/richardson/research.html Forest6 Forest Stream Linkages Project.

across watersheds. Watershed characteristics that affect the relative magnitude of peak flows and sediment loads should also be considered.

Table 8. Variable of interest and covariates in impact study of upland streams.

Type of variable	Variable	Levels/treatments*
Variables of interest	age of riparian forest	0-5 5-10 10-20 20-40 40-80 80-250 250+
Stream covariates	% retention of buffer upstream reaches	% intact riparian
	flow continuity	continuous seasonal ephemeral
	stream width	< 1m > 1m
	stream gradient	> 6% 7 – 20% 20-30% > 30%
	riparian side-slope	steep gentle
Watershed covariates	productive forest of total forest	%
	hydrologic effective green up forest	%
	roads	density
	stream crossings	Number
	glaciers	present absent
	lakes	present absent
	valley shape	U-shaped V-shaped

*Depending on the variation in levels of each variable, either stratify by or control for levels of each variable (i.e., a complete design is unlikely).

4. Response variables

A wide range of aquatic and terrestrial taxa should be sampled as well as key aquatic and terrestrial habitat features. Key aquatic habitat features related to stream structures are described by Tripp et al 2008. Water chemistry can also be measured. Key terrestrial features include horizontal and vertical measures of heterogeneity and the abundance and decay class of snags and coarse woody debris. Biodiversity sampling should consider, for example, aquatic invertebrates, terrestrial invertebrates, plants, mosses, bryophytes, lichens, soil invertebrates and vertebrates known to prefer riparian areas (especially amphibians). Both species presence/absence and community structure should be examined. Bunnell et al. (2001) provide a grouping of vertebrates and those considered most strongly related to hydro-riparian ecosystems and older seral stages. Fenger et al. (2007) provide information on species with high dependence of wildlife trees. The Resources Inventory Committee RIC provides wildlife species sampling protocols.

A broader range of terrestrial species may be sampled to complement other studies if such an approach increases the efficiency of field work.

A focus in the experiment is to establish baselines for features under natural condition and obtain data on changes in water chemistry, flora and fauna species. This baseline data is expected to lead to identification of practical indicator of aquatic ecosystem integrity. Are there detectable differences in terms of species (flora and fauna) and have there been shifts in sensitive species and other indicators in these areas?

5. Time frame and forest management decisions affected.
It is unclear whether GIS inventory data suitable to accurately to locate small streams and karst (Appendix A provides some examples of GIS layers that could be used.

6. Next steps
1) Undertake Phase 1 and 2: Review existing research on listed features, i.e. estuaries, forested swamps etc. and vulnerabilities and sensitivities from roads and harvesting. Compare current management direction to guidance on vulnerabilities in the literature and is there evidence to support current practices. See Appendix C for initial list of research on forest buffers. A first step would be to conduct a meta-analysis (if not already done) and a gap analysis to identify specifically what issues require focus in relation to riparian types and the role of buffers on biodiversity maintenance. Some hydroriparian features have a low probability of impact from forest develop than others for example road may permanently change ground water and alter systems whereas some level of harvest may change the system but vulnerable and sensitive species recover. The biological importance, productivity and contribution to conservation for each type are relatively poorly understood. Move on to step 2 if insufficient information is available today to confirm or change management.
2) Assess LRDW and inventories available from CFCI members for GIS inventories for small streams and karst ecosystems and whether it is feasible to assess current condition using GIS inventory. Where there are fundamental gaps in inventory classification and mapping assess whether the use of surrogates can locate the extent of these hydro riparian features and the condition of the buffer forests.
3) Complete the assessment of current conditions and narrow the study to features with most relative risk and highest vulnerability due to absence of objectives for buffers.

4.2. Terrestrial Ecological Integrity

Price, Tyler, Daust and Soto 2009 identify a number of potential research areas and the highest two areas related to terrestrial ecosystems were; 1) Variable retention within the context of older forests in the surrounding landscape and 2) ecological differences between old forests based on infrequency of disturbance. Uncertainties are described in more detail in Price et al. 2009. Appendix C provides selected references on ecological integrity.

4.2.1. Implications of varying stand level retention within a varying landscape context.

1 Question
Are there combinations of stand level and landscape level retention levels that pose high risk to species populations within watersheds/ landscapes? In particular, risk is expected to be higher when both stand and landscape level retention levels are low. This question focuses on testing the efficacy of a range of stand level retention levels when found in a potentially higher risk landscape context.

2 Management relevance
Stand level retention can be as low as 15% as defined by the land use objectives. It has been suggested that if implemented at this lowest permitted level stand level retention may be inadequate to maintain the broad array of species expected for these forests (Kremsater et al. 2008). It is expected that such an effect may be exacerbated within landscapes that also have lower levels of retention.

Price et al (2009) describe the ecological role of stand-scale retention as:

"At the stand scale, retention serves three primary functions:

1) *maintaining species and processes that would otherwise be absent from early seral stands,*
2) *enriching re-established forest stands with structural legacies, so that they develop complex structures and begin to function as older stands sooner than they otherwise would; and;*
3) *enhancing landscape connectivity by providing a habitat mosaic in which organisms can move over small scales. Stand level retention starts to provide benefits in the form of structural legacies at above 15 – 20%, and to provide benefits for maintaining species in stands at above 30%. Even at high levels of retention, harvested blocks are not equivalent to undisturbed forest. The probability of success at achieving the stand-level components of ecological integrity increases… as a larger proportion of the block is retained as standing trees…"*

The value of stand-level retention is expected to vary with landscape context—less stand level retention may be needed if the amount of landscape-scale old forest representation is high and vice versa—raising the notion that higher levels of retention may be necessary in higher risk landscapes, and conversely, lower levels may be possible in low risk landscapes. Kremsater et al. (2008), points out that landscape-level and stand-level retention serves different ecological functions and recommend situations when "excellent" stand retention can contribute to landscape-level retention.

Trading off stand-scale and landscape-scale retention provides managers with flexibility to achieve other objectives, however the ecological trade-offs are not clear: literature examining the trade-off between landscape-level and stand-level retention is apparently sparse (Kremsater et al. 2008).

One assumption is that maintaining stand structure will provide an area-weighted benefit in terms of stand recovery (Holt and Sutherland 2004); effectively, the greater the retention the faster the recovery of the second-growth stand towards old forest. Maintaining a minimum of 15% retention depending on distribution and quality of retention often results in the majority of an opening not being under mature and older "forest influence" Forest influence is defined as the biophysical effects of trees on the environment of the surrounding land. The degree, type and distance of influence can vary widely; however, within and adjacent to harvested areas, most forest edge and residual tree influences begin to diminish significantly at distances greater than one tree length from a standing tree, group of trees or forest edge (Kremsater et al. 2008).

The priority sampling for this study design is at the potentially higher risk end of the spectrum – which is considered to be low stand level retention combined with low landscape level retention context. However, however, the FPB (2008) reports high retention (70 to 85%) is now occurring in the north coast and central coast and this provides an opportunity to assess a broader array of combinations of stand and landscape level retention occurring if time and money are available.

3. Description of experiment and Study design

Learning about the trade-off between landscape-level and stand-level retention requires examining the ecological value of landscape-scale retention patches and stand-scale retention patches over a range of combinations of stand-scale and landscape-scale retention. Finding sufficient combinations for a retrospective study in which there is, for example, high stand level VR in many stands and low landscape older forest reserves is unlikely. An experimental study in which treatments were randomly assigned to many watersheds would be needed to create sufficient combinations (and replicates) and would be costly.

Therefore the recommended approach to make the trade-off question more tractable is to focus on only one side of the trade-off: how does landscape context influence the value of variable retention patches? VR patches and species therein become the focus of study. Similar VR patches (e.g., size, edge, and site series) will be compared across a range of landscape contexts and characterized by the distance to adjacent older forests.

Table 9 provides an outline for a GIS assisted search of comparable watershed units with differing levels of retention. The stand level VR portion requires confirmation using site level information (RESULTS). Appendix A provides overview data on seral stages and productive forests that will help find comparable landscapes with differing levels of development.

Table 9. Experimental units for sampling of sensitive species.

Stand Level Retention Gradients	Landscape retention			
	Control Watershed (Park)	Treatment Watersheds Percent remaining of original old forest Sort on raw data and decide the sample units after review of harvest history.		
	100%	High > 70	Moderate	Low < 30
> 70%	NA			
< 70 >50	NA			
< 50 > 30	NA	Priority effort		
>15 <30	NA	Priority effort	Priority effort	
< 15%	NA	Priority effort	Priority effort	

Organizing watersheds into groups with difference older forests levels will help selection of VR sampling sites.The main variable of interest is proportion of old forest nearby to the patch and species associated with these. The definition of "nearby" varies with species considered. GIS analysis can be used to calculate the area and proportion of old forest in concentric circles surrounding the VR patches. The scale (area of concentric circle) appropriate for sampled species can be determined prior or during analysis. Focus initially is on extremely different landscape contexts (e.g., < 30 vs. > 70% old). If the sampling design is not able to provide differences in responsible variables at the extremes it cannot be expected to inform on more subtle differences in variation of landscape level reserves and use of VR patches.

Variation in VR patches, including patch size, patch edge, BEC variant and site series, need to be controlled for. Different species are associated with different variants and site series. Species composition may also vary by watershed, so patches in the same watershed should be compared when possible as well as sampling of unharvested areas. Variation in nearby forest, including age of harvested area, proportion of old stand with cedar selectively removed, BEC variant and site series should also be controlled for. Table 10 show some of the factors that need to be controlled for. Note, categories may need to be collapsed after power analysis is undertaken (e.g. looking at <20%; 20 – 50% etc. The potential confounding factor of a north / south gradient in developed watersheds may be problematic for the sample.

Table 10. Variables of interest and covariates; stand level and landscape level retention study design.

Type of variable	Variable	Levels/treatments*
Variable of interest	Species with high dependence on older forests	
	percent of old forest in concentric circle around VR patch Natural benchmark similar ecosystem	<10 10-30 30-50 50-70 70+ 100
VR patch covariates	patch size (ha)	< 1 1 – 3

		3 – 5 5 – 7
	patch shape (ratio of long-axis to short axis); could also use edge metrics, but edge depends on patch size	1 2 3 4+
	Variant	CWHvh1 CHWvh2 etc.
	Site series	dry moist wet
	percent of block retained (may not be needed given concentric circle approach?)	10-15 15-20 20-25
Landscape-context covariates	age of harvested portion	0-20 20-40 40+
	percent of old forest with cedar selectively removed	0 1-50 >50
	Variant	CWHvh1 CHWvh2 etc.
	Site series	dry moist wet
	Watershed	WS A WS B etc.
	Ecosection General north / south gradient	variable

*Depending on the variation in levels of each variable, either stratify by or control for levels of each variable (i.e., a complete design is unlikely).

4. Response variables

The FREP stand level biodiversity protocol may provide a starting point for description of VR patches. However, FREP does not sample for species so a species protocol would need to be developed which would focus on the detection and presence of potentially sensitive indicator species (likely those with poor dispersal ability and strongly linked to old forest would be good initial species – though a more thorough review of sensitive species is needed (Kremsater et al. 2008 listed a number of species than needed to be further explored). Some sensitive species have been put forward, such as epiphytes, small mammals and amphibians (e.g., Price and Hochachka 2001, Pearsall, I. 2003, Gibbs 1998) but a more thorough review is necessary. Understanding of species in unharvested stands (controls) is needed and may come from sampling associated with old and ancient forests (next question) and sampling for species presence and the levels of representation of common ecosystems (preceding question).

5) Time frame and forest management decisions affected

If a retrospective study is possible (i.e. sufficient sites are found that are adequate to deal with confounding factors), it is possible that a number of years of sampling may shed light on this question. If an experimental study is required (i.e. sufficient sites are unavailable) then many years of pre- and post-harvest data are anticipated to provide insight into landscape and stand level retention. Within-season sampling will depend on the specific indicators chosen and when sampling is most effective.

Where a retrospective study is undertaken, a secondary outcome from the study would be information on 'implementation monitoring' to determine the quality of the VR in relation to the advice from Kremsater et al. 2008.

6) Next steps

1. It is our understanding that there has been very little analysis of landscape / stand level trade-offs, and so a move straight into data collection (i.e. without phase 2) will be likely. It remains necessary however to determine management context and determine what level of evidence is needed to change management before embarking on the experimental design portion. As part of this it is also necessary (in this and ever other case) to undertake a power analysis to determine what level of sampling will be required to detect the required level of effect.
2. Complete the GIS assessment of potential number of sampling units. Confirm VR from RESULTS data and confirm potential sample sites using remote sensed information.
3. Confirm the GIS assisted summary of adjacency of older forests (distance to nearest old forest concept.
4. Review FREP stand level biodiversity sampling protocol and field cards for utility. Confirm sensitive species list and sampling protocols. The same species sampling is needed for all three terrestrial biodiversity projects.
5. Conduct a pilot to test the protocols and report on preliminary findings in the sampled WS units and controls.

4.2.3. Old and Ancient forests

1) Research Question

Are old forests at the 'young end' of the defined age range (e.g. 180 – 300 years) biologically equivalent to much older stand and less frequently disturbed ecosystems? Stated as the Null hypothesis this becomes: Old forests classified as 180 – 300 years do not differ from forests with trees older than 500 and 1,000 years.

[*Note that throughout the period of 2008/2009 the implementation plan for old growth representation has been in flux (and remains so as of March 2009). Originally, site series surrogates were being used as the unit of representation, and in the current proposed LUOs a combination of site series and site series surrogates is possible. This leaves the implementation question of whether the LUOs are adequately representing the full range of fine scaled ecosystems present. There are a number of sub-questions relating to this – first, in areas where site series surrogates are still being used, it is known that these do not adequately reflect the range of site series present (A. Mackinnon pers. comm. reflecting two background studies – by Green 2008 and Price 2008). Secondly, where a combination approach is being used, how well is this being coordinated? In either scheme: Are there some site series that are left with poor representation after implementation? This is not a 'research' question but an important implementation question and should be included as part of the presumed broader implementation monitoring that will occur as part of EBM implementation. This "old and ancient forest" research question builds on the idea that ecosystem representation is adequate, but that temporal representation may not be. However, this first assumption should also be tested as the LUOs are finalized. This implementation question was not included as a priority question here because we assume that the* ***intention*** *of the LUOs will be to move to site series representation everywhere as soon as based data are available to do so]*.

2. Relevance to management

Old growth forest is managed within the LUO's as forests greater than 250 in age. It is assumed that the implementation process will result in retained 'old' forest that will represent the full range of age ranges present naturally (i.e. planning will focus on maintaining the oldest of the old stands first). However, the extent to which this will occur within the current planning framework is unknown. Current implementation assumes that the age class distribution within the retained forest will closely match the natural distribution of ages, and this may hold true under some circumstances (e.g. when a large percentage of the landscape remains unmanaged). However, where a high percentage of a SSS is located within the THLB, then the shift away from maintaining a natural true 'old age' class distribution will increase (Kremsater et al. 2008).

To determine the extent to which this may compromise maintenance of ecological integrity, this research focuses on whether structure, composition, complexity, biodiversity and process/ functions in forests that are around 250 years are the same as those in older forest stands. One technical difficulty is that of determining specific stand age in older stands. Using best available ageing techniques, combined with a GIS method to determine sites less susceptible to wind throw, burning and mass movements it should be possible to find least disturbed forest stands, and at minimum place them in broad 'age' groups for sampling. Older stands can then be compared with stands in areas more frequently disturbed areas to see if there are differences in elements.

A concerted program of integrated research would improve fundamental understanding of the rainforest, and could be linked to more focused research around natural disturbance types (i.e. where on the landscape really ancient forests can be expected – this would involve a fine-tuning of known information on natural disturbance events). This AM project could be the home for a number of research projects focusing on ancient temperate rainforest stands and continue the work undertaken to date at UBC, Simon Fraser University (SFU) and U. of Victoria to date by academics such as; Lertzman, Daniels, Winchester and colleagues. This suggested project could build upon and add a longer temporal horizon to the recent work on the recovery of plant communities in younger stands (see Banner and LePage 2008). However, it is intended that other elements in addition to plant composition would be included (e.g. to include at minimum stand structure as well).

2. Description of experiment and study design:

The intention is to compare species and stand complexity of the oldest stands in the least disturbed portions of the coastal forests, with more frequently disturbed younger stands.
The location of sample sites will be aided by GIS assessment and mining of the VRI data to the fullest extent possible. GIS assessment will be needed to locate low frequency disturbance areas (low wind exposure and stable slopes away from fluvial processes, as well as high frequency disturbance sites – this can aid in the process of finding relatively young and relatively older stands – but age will need to be confirmed as far as is possible at the stand level. Care must be taken at this stage not to confound the study by choosing samples that differ completely in landscape position however.

Use the population of experimental watersheds from within which to seek stands greater than 180, 250, 350, 450, etc. These watersheds provide a means to randomize sampling and avoid pseudo replication that is associated with multiple samples within the same watershed (see Hurlbert 1984). VRI stand age may aid in preliminary stratification of stands – but more focused stand age estimates will be required. Assessing whether PEM/TEM improves location of infrequent disturbance sites is also needed, for example does use of moist and hygric sites improve the location of infrequently disturbed forests stands?

Using a variety of sources Price and Daust (2003) were able to estimate frequency and extent of stand replacing natural disturbance and found increased frequency at BEC variant level between variants with the lowest frequencies in the CWH hyper maritime, then the very wet maritime, then the dry maritime and most frequent being the very dry sub-maritime variants. This implies the least area in ancient forests would be in the very dry sub-maritime and this may need to be the priority for research and sampling.

4) Response Variables

Table 11 provides the range of samples from which to seek differences in complexity and sample to establish whether some species occur only in the older and least disturbed stands.

Table 11. Sampling biological species along a forest ecosystem disturbance gradient.

Undeveloped natural watersheds.	**Stand age (estimated by VRI, stable terrain, wind exposure)**			
Benchmark stands may come from within undeveloped watersheds.	> 180 years	> 250 years	> 500	> 1000 years
	Largest stands	Largest stands	Largest stands	Largest stands
Site series	# of watersheds	# of watersheds	# of watersheds	# of watersheds

Outcomes from this study potentially will contribute to identification on sensitive and vulnerable species associated with VR (see above on landscape and stand level retention).

In Banner and LePage (2008) data from a range of stand ages are compiled in the form of identifying similarities and differences between vegetation composition in relation to age of stands. This provides one approach to summarizing this type of data. Alternatively, developing 'indices of old-growth' (Franklin and Spies 1991; Holt et al. 1999) is an alternative approach to analysis which allows the investigator to look for differences between stands based on suites of multiple attributes and then provides a format to compile any differences into a practical format. Indices of old-growthness across a very wide range of stand ages may therefore provide a useful compilation tool.

In addition, longer term sample sites may provide future sites suitable for monitoring to detect trends associated with climate change. Increases in older forest mortality attributed to climate change were found in a study based on a 30 years of periodic older forest measurement (van Mantgem et al. 2009). Old forest sample sites may be able to serve a similar purpose and allow remeasurement and tracking of background mortality and recruitment.

<u>5) Time frame and forest management decisions affected</u>

Results from this type of analysis can be available in relatively short timeframes (1 to 2 years if sufficient funds are provided for sampling), and can inform the extent to which management practices are being effective. The GIS assessments and "mining of the existing data" is expected to provide benefit to landscape level decisions.

<u>6) Next steps</u>

1. Complete Phase 1 and 2. We assume there is insufficient information existing on this topic to date, however some old growth attribute work has previously been collected (through projects at UBC), and should be incorporated into a review prior to moving forward. In addition, the implementation issue (identified as a side-issue above) may inform whether a change is required in order to ensure that all site series are adequately represented.
2. Review VRI forest stand age and ability to distinguish younger and older stands (see Appendix A for initial GIS assessment to provide a suite of candidate stands.
3. Develop a GIS method to differentiate low frequency disturbance areas and "ancient forests" and identify potential sampling sites. This means looking for high frequency disturbance sites such as exposed aspects, unstable terrain using, dry more fire prone aspects using PEM/TEM and TRIM. Apply the GIS assessments to locate potential sample sites within the experimental watersheds. Randomize which sites to field sample. Confirm sites are as predicted using air photos or high resolution remote sensed images such as SPOT. Consult a statistician on the practicalities of rejecting sites and access to sampling.

4. Develop a sampling protocol that includes at minimum, species that may be sensitive to age of stands (e.g. including invertebrates and lichens etc), vegetation sampling, and stand structure. Some in-canopy sampling may be available from active harvest areas as trees in approved permits that meet old and ancient definitions are felled.
5. Conduct a pilot to the test the protocol and obtain some preliminary findings on the population of old and ancient sites sampled.

4.3. Single species integrity consideration within EBM.

1) Research Question

For priority species /ecosystems what is critical habitat and what level of stewardship will result in low risk management? Price, Tyler, Daust and Soto (2009) indicate that due to absence of targets for protection of critical habitat and migration/dispersal there may be a high risk for loss of integrity for biodiversity. As a result, they provide a generic focus for single species research towards studies of critical habitat and habitat for migration and dispersal, but species-specific research questions are currently unavailable.

Horn (personal comm.) provides implementation direction on locations for focal species and how there are additional projects for co-location that coordinate species need with timber supply and access impacts are minimized while species benefits are maximized. Horn (pers comm.) indicates that in species-specific habitat information are summarized but there may be research priority for the focal species. These were not available as this report was written as these projects were concurrent. There are two relevant species recovery teams - Marbled Murrelet (MAMU) and Northern Goshawk (NOGO) – who are best able to set research priorities and determine whether addition research and field studies are needed to define and locate critical and dispersal habitat for these two species, and we assume that these groups will prioritize research needs for these two species. However, in the absence of active recovery teams and known research priorities we suggest that the EBM research team undertake a project to set research priorities for wildlife species and then conduct field studies for priority species needs for critical habitat and dispersal. Since there is a lack of internal direction about appropriate species of concern (e.g. from the CIT or elsewhere), we propose applying the Ministry of Environment Conservation Framework as a means to narrow and prioritize single species for study. Although this process has not yet been implemented, the framework provides a theoretically reasonable approach to setting conservation action priority. We assume therefore that the MOE conservation list should also provide a useful prioritisation scheme for identifying priority species' research questions. Note that this CF process was designed specifically to avoid prioritising currently-listed species only, and instead aims to identify from a broader and 'smarter' list (see below). We are assuming it will identify functionally important species (e.g. keystone or strongly-interacting species) but initial results are not yet available for review. It should also be noted that it currently does not include a climate change factor – therefore the results should be assessed to ensure that in fact species identified are relevant under both todays, and the future climate.

2) Relevance to management

Under objectives for Biodiversity in the LUO there is reference to single species/ecosystems and direction to minimized impacts for timber supply when managing for single species and "*to the extent practicable, include within old forest retention areas, stands of monumental cedar for future cultural cedar use, rare and at risk old forest ecosystems, habitat elements important for species at risk, ungulate winter range, and regionally important wildlife, including:*

(a) mountain goats;
(b) grizzly bears;
(c) northern goshawks;
(d) tailed frogs; and
(e) marbled murrelets."

Price, Tyler, Daust and Soto 2009 indicate that due to absence of targets for protection of critical habitat and migration/dispersal there may be a high risk for loss of integrity for biodiversity. However, they estimate lower risk to species when >70% critical habitat is maintained and sufficient suitable habitat for dispersal also maintained. In addition, climate change is expected to directly impact a wide array of species, though possibly with lower impact in coastal ecosystems than in other BC ecosystems.

Recent LUO amendments (under review while this report was written) establish targets in the North Coast for Grizzly protection of bear habitat from forestry impacts in which there is protection of 100% class 1 and 50% class 2 grizzly bear habitat. The Class 1 and Class 2 habitat is shown on a map which is part of the LUO order (Schedule 2). The South Coast plan area has no numeric habitat target or prohibition on forestry development in grizzly bear habitat instead management is guided by objectives in which forest developments harvest in bear habitat must not have a materially adverse impacts on bear habitat. This direction to have no material impact on grizzly bear habitat is for class 1 and 2 habitat as set out in a map the Schedule 2. This means there are no numeric targets for in the South Coast area. Kermode bear habitat is protected through special management zones in which no more than 30% of forest can be in early seral forests and after logging regenerated stands are left with 70% crown closure at end of free growing period.

Scrutiny of species-specific management for some listed species is expected to remain high and there have been two special reports on Marbled Murrelets prepared by the FPB (2003, 2004) expressing concern over lack of direction and implementation of conservation provisions within FRPA. Research on listed species, especially those under the Federal Species at Risk, will also require continued research.

MOE[32] has developed a Conservation Framework (CF) which is intended to use a systematic framework to prioritize species and ecological communities for conservation action.

The Conservation Framework (CF) has three goals which should be complementary to the EBM goal of overall low risk to biodiversity. Conservation Framework principles are: act sooner, smarter and together to achieve its goal:

1. Contribute to global efforts for species and ecosystem conservation
2. Prevent species and ecosystems from becoming at risk
3. Maintain the diversity of native species and ecosystems

We recommend that EBM use the CF to set priorities for EBM species and if appropriate for ecological communities. At this time, the CF is not being used to prioritize broader 'ecosystems' for conservation action, however if this aspect becomes developed it may also provide additional guidance for research foci in future.

2. Description of experiment:

Where they exist, support research priorities identified by Recovery Teams. In the absence of recovery team research priorities apply the Conservation Framework developed by MOE to identify which species should be prioritized for research and monitoring. For high priority species develop habitat models and assess current distribution of critical habitat models and habitat for dispersal. It is proposed that existing literature and expert advice is used to build species models as an aid to field study. Horn (pers comm.) in a focal species study includes elements of species

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[32] http://www.env.gov.bc.ca/conservationframework/whatis.html. The **Conservation Framework** is British Columbia's new approach for maintaining the rich biodiversity of the province. Developed by the Ministry of Environment in collaboration with other scientists, conservation organizations, industry and government, the Framework provides a set of science-based tools and actions for conserving species and ecosystems in B.C. The Framework ensures that ***British Columbia is a spectacular place with healthy, natural and diverse ecosystems that sustain and enrich the lives of all.***

habitat relationships as does Ministry of Environment, Lands and Parks (2004) in the species accounts. All factors affecting populations such as predation can be included in complex models to partition and weight all factors affecting maintenance of a healthy of population. Habitat models linked to GIS will likely continue to be a significant EBM research team supported function. Habitat models are expected to assist in habitat inventory, monitoring and risk assessment, inform plan implementation certification and development of FSP forest plans.

3) Experimental units
Experimental units will be species-specific. Direct measurement of populations seldom exists, except for some harvested species. Thus managing forestry impacts to focal species and species of conservation concern is through understanding of habitat species relationships and habitat supply models which estimate suitable habitat distribution (Table 12). Building species habitat models that can be linked to plan should be undertaken to complete risk assessment and periodic reporting.

Table 12. Habitat relationships for focal species and MOE conservation framework species.

CF prioritized species and ecosystems	Critical habitat definition Linked to GIS and modeling	Dispersal/ Connectivity habitat requirements.	Expected Range based on suitable habitat	Presence in expected range	Low risk and current risk	Research, inventory focus
Focal Species (Horn reports and recovery team information)						
Species 1						
Species of Conservation Concern MOE Conservation Framework						
Species 2						

4) Sampling considerations
No comment possible at this stage.

5) Time frame and forest management decisions affected
It is expected that a year will be needed apply the CF to the land use plan area and for the stewardship obligations to be identified. For priority species definitions of critical habitat and connectivity requirements should be defined and tested. It may be possible to test low risk for species with recovery teams as these are most advanced in definition of critical habitat.

Baseline information on habitat use and population ranges gathered through this process can be incorporated into understanding the potential effects of climate change on species ranges and habitat use.

6) Next steps
1. Complete the Conservation Framework to confirm priority species for conservation action. Consider also which of these may be faced with increased vulnerability from climate change.
2. For priority species and ecological communities define critical habitat and conduct a GIS assisted plan-wide assessment of distribution and current risk.
3. Field sample to validate critical habitat using RICS standards.
4. Generate habitat models capable of decision support to be applied at a tactical planning level.
5. Formally link modeling to decision support and strategic and operational decisions.

4.4. Climate change adaptation

What are the observed climate trends for the coast? What ecosystems/species are most vulnerable to climate change? What adaptation can be undertaken?

The ability of ecosystems and species to adapt to climate change will be key drivers of future integrity and resilience, for all regions of the globe. Although predictions suggest a relatively lower impact of climate change in BC's coastal ecosystems than for other BC ecosystems (Utzig and Holt 2009 – in prep[33].), impacts are still expected, and may be very significant for sensitive elements (e.g. cold water fish species, or frequency of processes such as landslides in some locations).

Climate change has added a new level of complexity and uncertainty to research of natural ecosystems. Climate change will be a factor affecting all experiments, and this should be built into any sampling plan (retrospective, or experimental) – likely increasing sampling effort required to detect effects. It will not be possible to 'control for' climate change (since there is no control where CC is not occurring), so detection of trends associated with other impacts (e.g. from harvesting) will be increasingly difficult to parse out. Baseline monitoring should be initiated for a wide range of indicators (potential indicators are currently under development as part of MoF FFEI program), and linkages with an EBM adaptive management program should be made.

Climate change also has the potential to shift the bar of what has been identified as 'precautionary' management, and can also influence overall goals of EBM. The true implications of climate change to EBM implementations are really only starting to be discussed – we include this as a research question because we believe it may have profound implications in future, but also understand that the field is moving rapidly and that what is proposed may be taken on by others, and / or may need to be reassessed as events develop.

1) Issues and Research Questions

Climate change has been underway for some time but changes to ecosystems are only just beginning to become known (Utzig and Holt 2009). Though the extent and speed of climate change is not well understood a review of past climate data indicates the trend is underway (Spittlehouse 2008[34]). Forecasting changes to ecosystems is less certain as the trend in greenhouse gas emissions into the future cannot be predicted.

Spittlehouse 2008 states that if there is limited success internationally to control future emissions, British Columbia could see a warming of 3–5°C by the 2080s. With significant reduction in emissions the warming in BC is lower between 2–3°C by the 2080s. These two scenarios have the winter minimums in northern British Columbia increasing by 4–9°C by the 2080s and summer maximums increasing by 3–4°C. The frost-free period, growing-degree days, and frequency of extremely warm days will also increase. Spittlehouse 2008 also estimates that south portions of the coast forests will experience a warmer and drier late spring and summers could bring increased fire risk and decreased water availability. Increased water stress will affect species such as western red cedar on marginal sites. The wet, cool mid and north coasts will likely see improvement in growing conditions. Increases in storm number and intensity will likely increase windthrow and breakage of trees. An increase in the severity of storms could increase the probability of landslides and debris flows.

In an analysis of background (non-catastrophic) mortality rates of old growth in unmanaged forests, van Mantgem et al. (2009), found that there has been a doubling of forest tree mortality rates in natural old stands within the last 17 and 29 years. Old forest mortality increases were pervasive across elevations, tree sizes, dominant genera and past fire histories, and were not attributable to the aging of old trees. Likely contributing factors were warming and consequent increases in water deficits.

[33] Utzig and Holt 2009 – in prep. Impacts of climate change on BC's forest and range ecosystems. Prepared for MoE FFEI Program. Will be available at www.veridianecological.bc.ca

[34] http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr045.htm

Changes in extreme storm frequency and intensity have implications for managing to low risk. A study on the BC coast forecasts a change in sea level of between 0.25 to 1.16 m at Prince Rupert by 2100 (Bornhold 2008 and Thomson et al 2008.). This has implications for estuarine habitats as well has human infrastructure. Increases in landslides also occur with the severity of storm events (see references in Utzig and Holt 2009), and general changes in other background disturbance levels (fire, insects, disease, windthrow) can all have implications for forestry and conservation.

Currently, we lack baseline information on natural disturbance frequency and distribution – and do not monitor to detect trends in frequency and severity of fires, insects, disease windthrow, landslides, and peak flows. Price,Tyler, Daust and Soto 2009 acknowledge that without baseline information, understanding and managing appropriately for trends in these landscape drivers will be very difficult. Similarly, there are expected to be significant aquatic changes and impacts: the retreat of glaciers, alteration of precipitation patterns and storm severity, stream flow and stream temperatures. As with disturbance rates, lack of baseline information it make it difficult to understand and adapt appropriately to these trends if they manifest.

Much of the forecasting of climate change is based on global climate models. Spittlehouse 2008 indicates predictions will likely improve due provincial level initiatives to "down scale" these models. This will provide estimates of changes and greater confidence to assess possible impacts to ecosystems at local levels. Using existing changes in climate envelopes it is possible to visualize changes using BEC variants such as those produced by Hamman and Wang (2006) for different times in the future. Understanding potential futures, such as changes in tree lines and shifts in BEC zones, will also provide a basis for incorporating climate change into management decisions.

Natural disturbances are the primary drivers of ecosystems and habitat distribution and direct many processes across the landscape. Changes in these elements are therefore expected to have significant cascading impacts throughout ecosystems. How species ranges and distributions will respond to these higher level impacts is unknown, and raises a wide variety of questions.

In summary – climate change raises a large number of requirements for 'baseline trend' monitoring in order to understand the degree to which primary drivers for ecosystems may change through time. A project is underway, as part of the MoF FFEI program – to design an efficient baseline monitoring program for key elements likely to be affected by climate change (John Innes and colleagues, UBC). The future EBM Research teams should look for way to integrate with this (or similar) projects as they develop. Given that this program is intended to be provincial in scope, it may be necessary for focused attention on the coast: Is there evidence to support broad scale trends in ecosystem distributions, and which processes are most affected??

2. Description of experiment:

We are not recommending any particular 'experiments' at this time – rather, baseline information needs to be gathered, as does more specific hypothesis generation of key elements most likely to be affected. This work can then direct future research.

The first step is to review existing forest monitoring now available from within the area. Summarize data from existing sources (permanent sample plots for growth and yield, BEC classification plots, larger data bases such as RESULTS and information on silviculture, invasive species (plant and animal)). In addition, other monitoring projects are being initiated in relation to climate change (under FFEI), and it should be determined whether these projects can converge.

The MoF FFEI Program[35] is also in the early stages of undertaking a vulnerability assessment (focused on potential policy review), with a focus on looking for key ecological (and in the future key social) vulnerabilities. Once it becomes sufficiently robust, a vulnerability assessment decision support tool can provide hypotheses around which elements are most likely to be affected, and how

[35] http://www.for.gov.bc.ca/hts/Future_Forests/

climate change may alter our current 'low risk' hypotheses. Identifying those elements most vulnerable to climate change can help information adaptation options to reduce future risks.

3) Experimental units

This work is intended to establish baselines within the area where gaps exist (assuming a coordination with other climate change monitoring programs as above). Monitoring ecosystem types (sites series) and species distributions (wildlife, trees, fish and invasive species) will be influential in decision support. Permanent Sample plots (PSP) for estimates of growth and yield can indicate increases and decreases in productivity used to inform forest level forecasting and decisions. Detecting increases and decreases in species ranges and productivity and natural disturbance affecting plants, animals and ecosystems may not be possible from existing monitoring programs. Table 13 – 15 shows some of the potential base line information that would be valuable for decision support and vulnerabilities under the plan.

Table 13. Potential baseline monitoring information aquatic systems and climate change/adaptation.

Aquatic integrity				
	Aquatic dependent species	Listed/vulnerable species distribution	Hydroriparian Characteristics	Watershed characteristics (Disturbances)
Selected natural areas Watersheds Baselines	Species profiles in natural areas	Critical habitat and sampling of presence and absence	Stream and lake Temperature; channel morphology; Peak/low flow	Landslides current

Table 14. Potential baseline monitoring information terrestrial ecosystems and climate change/adaptation.

Terrestrial integrity				
Selected natural areas Watersheds Baselines	Forest species	Listed/vulnerable species distribution	Terrestrial Ecosystem Characteristics	Landscape characteristics Disturbances
	Ecosystem profiles natural areas.	Higher density sampling to establish a baseline for forests and forest species with watersheds	BEC and PSP type plots. Ecosystems (TEM) and VRI validation	Fire, insects, disease Windthrow Disturbance baselines

Table 15. Potential baseline monitoring information for focal species and species of conservation concern and climate change/adaptation.

Focal Species and Vulnerable species baselines (Natural Areas) (over entire plan area)		
Selected natural areas Watersheds Baselines	Forest species	Listed/vulnerable species distribution
Current ranges species and critical habitat entire plan.	Increases or decreases in habitat and ranges?	Increases or decreases in habitat and ranges?

4) Experimental design, sampling and analysis considerations

A review of existing baseline and our ability to detect shifts in background from all existing data sources BEC plots, PSP, VRI data bases, landslides, windthrow, fire, stream temperature profiles is considered essential to monitor for changes in background rates. The distribution on climate and hydrology information from within the area may also be poor. This may mean new monitoring stations to detect changes at all elevations. Monitoring of plant responses may also be appropriate – e.g. bud break, arboreal lichen loading and monitoring of changes in arrival of migratory species. Identification of elements where key thresholds may occur within the range of change expected (e.g. temperature for fish) should prioritize the research focus.

5) Time frame and forest management decisions affected
Uncertain.

6) Next steps.

1. Review types of monitoring data and location of current monitoring within the plan area. Assess whether adequate information is being collected on change in climate and changes in disturbances and fundamental ecosystem characteristics and estimation of baselines suited to adaptation? Based on assessment and vulnerability improve baseline monitoring. Link to provincial level monitoring strategies being developed under Future Forests Ecosystems Initiative[36].
2. Identify monitoring gaps in relation to improved decision support (TSR) and vulnerability assessment.
3. Include sample points from all experiments as potential sites for future monitoring.

4.5. Carbon storage and cycling.

How much carbon is stored and cycled in different forest ecosystems in different seral stages? As with the climate change question above, there many questions, and many separate paths beginning to investigate the issue of carbon as a resource, and how it may factor into long-term implementation of EBM in coastal ecosystems. On the assumption that there will be a potential future for some level of carbon trading, we suggest that fine-tuning information on carbon may be a critical factor in aiding this development.

1) Issues and Research Question
Accounting for forest carbon storage and sequestration requires knowledge of carbon cycling in forests. The cap-and-trade system currently under development through the Western Climate Initiative[37] is expected to put a ceiling on carbon emissions. Polluters that won't reduce emissions will be able to purchase carbon offsets to make up the differences mandated under the cap, which could give B.C. a significant revenue stream from sequestering and storing carbon on behalf of others less able to do so. The Canadian Forest Service's Forest Carbon Accounting Program[38] is a national initiative involving scientists from across the country and is a pilot project in the BC interior. However, there remains a need to fine-tune information on above and below-ground carbon storage and cycling in coastal forests.

Ingerson (2007) provides a basic review of the complexities of carbon and climate change assessment – the potential utility of sequestration versus storage differs in different ecosystems, and depends upon a wide variety of factors. Coastal ecosystems have one of the highest storage values per hectare of forests in Canada making sequestration in younger forests a less viable alternative to maintenance of carbon in existing older forests – however, since these are complex issues specific information on carbon storage and cycling at finer scales is needed. Decay rates and

[36] http://www.for.gov.bc.ca/hts/Future_Forests/
[37] http://www.westernclimateinitiative.org/ This is collaboration began in 2007 and now includes seven U.S. governors and four Canadian Premiers.
[38] http://carbon.cfs.nrcan.gc.ca/index_e.html The goals of this program are to: 1) Improve stakeholder understanding of the role of Canada's forests in the global carbon cycle; 2) Establish the National Forest Carbon Monitoring Accounting and Reporting System (NFCMARS) to meet reporting requirements such as the UNFCCC, criteria and indicators reporting under the Montreal Protocol, reporting to the FAO, and others; and 3) Develop forest carbon accounting tools and methodologies to enable forest resource managers to consider carbon in their forest-management activities.

the influence of disturbances are also poorly understood but important to forecasting the most efficient approach to reducing greenhouse gas emissions.

An example research question would be: How much carbon is stored and cycled in different forest ecosystems in different seral stages? Stated as a Null hypothesis this would be; Forest stand in different ecosystems in natural and managed condition and in different seral stages do not differ in carbon storage and cycling.

2. Description of research:

At the broadest level, coastal temperate rainforests are known to have some of the highest average carbon storage levels for Canadian forests (see information in Wilson and Hebda 2008). And in addition, localized information shows some sites having storage levels considerably higher than these averages (see Trofymow and Blackwell 1998). As a first step in this process, a full review of information for coastal systems should be undertaken. Various pieces of work are underway at this time that will help to highlight carbon information gaps (e.g. modeling at UBC via Gary Bull and colleagues etc).

The research will be expected to inform on the carbon storage potential of conservation vs. harvesting strategies. Future revenue implication may be based on decisions to hold forest for carbon credit or harvest for forest products and insight into trade offs will be needed. Currently carbon is being considered as a potential output of the TSR process, and fine-scale information will be needed to inform this modeling.

3) Experimental units.

A review of methods of estimating and accounting for carbon is needed first. It is possible to measure sites and compare differences along a gradient of development, from natural ecosystems to ecosystems managed for timber.

4) Sampling considerations units

A review of biomass and methods for estimating and accounting of carbon is first needed. Linking estimates of carbon to permanent sample plots or and BEC plots with addition of early seral sites may provide some suitable data for plan wide modeling.

5) Time frame and forest management decisions affected

It is not clear when information on carbon can be used to influence management of coastal systems. It is anticipated that assembling and assessing the adequacy of information on what is available, gaps and more detailed sampling on how to calibrate models can be done in a relatively short period (within a few years).

Longer term monitoring, including detecting changes in background disturbance levels may also be important. The urgency and incentive may be determined by the economic opportunity for carbon trading. A decision support system on trade offs between harvesting forest or holding for carbon can be developed in the short term and may help focus sampling.

6) Next steps

1. Review of research and monitoring on carbon and assess models under development and whether existing data is sufficient to calibrate carbon accounting models.
2. Retain a focus on disturbances that affect carbon within coastal forests.

Section 5. Logistic and social implementation issues

Incentives for application of AM research

There have been significant efforts to apply AM in forest management in BC through initiatives such as the Fish Forestry Interactions Program[39], Watersheds Restoration Program and other projects summarized on the MoFR Adaptive Management web site[40]. There have also been large initiatives in the US through Northwest Forest Plan[41]. Recently, Tyler et al. (2009) described an Adaptive Management Framework to support coastal EBM implementation, and the lessons learnt from these experiences are also well documented (Tyler et al. 2008, Taylor, Kremsater and Ellis 1998).

Researchers, academic and strategic thinkers are all enthusiastic about AM but there has been resistance to real implementation. Reasons for resistance were clarified through a survey in northern BC (Osbourne 2002) which identified major problems: 1) higher costs and workloads, 2) disincentives in forestry legislation and policies and 3) insufficient science to support AM-EBM locally as there was no overwhelming agreement on priorities. Similar pragmatic barriers are expected in coastal BC, though some have been reduced as a result of EBMWG initiatives. For example, priorities for AM research are now apparent through the coastal knowledge summary (Price et al. 2009). Legislated barriers have been removed and it is now possible to undertake what has been described in this report as Phase 4 research projects or AAM within Forest Stewardship Plans. The extent to which full-scale AAM will be implemented through the LUOs however remains to be seen.

Funding for continued support of AM is likely a serious challenge. The costs associated with Phases 1 and 2 in this research framework are probably not prohibitive as they are of a planning and communications nature. However, retrospective studies (Phase 3) will require both fairly significant costs immediately and also through time to detect trends (if that is part of the experiment). However, Phase 3 retrospective costs are likely overall to be 'reasonable' at this stage. In comparison, Phase 4 would involve significant costs – as a result of creating experiments (involving planning and harvesting), and the real cost which is attached to the required long-term nature and high effort of monitoring and sampling required to produce statistically meaningful results.

Pojar et al. 1999 provided information that forestry operations using conventional harvesting methods were close to the economic margin and sensitive to minor changes operating costs. AAM trials, if undertaken, may need cost recovery beyond what is potentially available through access to more timber to offset AM costs. There are no apparent cost recovery incentives for those engaging in AAM research except for increased access to timber beyond default provisions. This may limit current AAM only to experiments that access wood below default provisions as these will contribute towards cost recovery. Experiments above default (i.e. those higher than current practice minimums) may be avoided unless there is cost recovery and a willingness by government to provide alternate incentives (e.g. adjust stumpage for those participating in AAM research trial under EBM –though it is possible that current minimal stumpage levels already applying to the coast may reduce the potential here). There may also be resistance to support below cost harvesting facilitated by AAM. What is the purpose in obtaining experimental information if this information will never become operationally feasible?
In a review of 16 current projects that may link to adaptive management, Zielke et al (2008) found that EBM increased the cost of operations, but in the more comprehensive operational pilots this

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[39] http://www.for.gov.bc.ca/hre/ecoearth/Water.htm Watershed Research in BC Fish Forestry Interaction Program, Carnation Creek Fish Forestry Interactions program, Compendium of Forest Hydrology and Geomorphology in British **Columbia**

[40] http://www.for.gov.bc.ca/hfp/amhome/index.htm Adaptive Management Initiatives in the BC Forest Service

[41] http://www.fs.fed.us/r6/pdx/northwest-forest-plan.shtml **Pacific NW Forest Plan**

was primarily in planning costs and additional office analysis (GIS, harvest and financial planning) to assist additional field engineering. A potential barrier may be the willingness of companies to pool resources and agree to plan-wide priorities over AM projects directed at the individual company level. The AM projects reviewed by Zielke et al 2008 shows that AM projects provided company-level discretion to improve inventories, planning, GIS decision support with potential to improve FSP planning efficiencies. This discretion is diminished when individual company needs are ranked against entire plan area priorities. In a review and workshop with BCTS Daust and Price (2009) also suggested that AM planning left to the discretion of individual companies may not necessarily be tied to the highest priority knowledge gaps for EBM. This remains a concern but is potentially decreased through cooperation between companies which under the CFCI initiatives appear to collaborate and have made commitments to cooperate through Forest Stewardship certification initiatives implying greater between company cooperation is underway through data management and sharing.

Government and stakeholder cooperation and support

In the U.S., large amounts of money were spent in planning and a number of AM Areas were mandated under the NW Forest Management Plan[42] – however few of these persist today. Johnson 1999 provides some insight based on the Oregon experience within the USFS. Johnson (1999) concludes that AM occurs as long as powerful stakeholders agree to support AM it – but if support is reduced then AM will not be implemented:

> *"Even though adaptive management might be the best choice for complex, a large scale issue, success is not assured (Halbert 1993, McLain and Lee 1996, Walters 1997). Many applications of adaptive management have stopped at the assessment phase and have failed to implement meaningful changes in management (Walters 1997). There are various reasons for this lack of implementation, but most involve either intransigence by powerful stakeholders (including agencies) or the unwillingness of stakeholders to accept the risk of short term losses that might occur under experimental management (Halbert 1993, Walters 1997, Gunderson 1999)"* - Johnson 1999).

There are number of land use plans and implementation committees in BC with the mandate to implement and monitor land use decisions and strategic level directions. Many of BC's land use plans have experienced problems with regard to implementation and lack of budget to follow monitor, assess and amend directions to ensure plan implementation. The Forest Practices Board (2008) raises concerns over current shifts away from maintenance of strategic land use plans by government. The approach to EBM is different and this is a new model for integrated land use and strategic direction that has not been previously used – still success will likely depend on continued support and budget for projects. Problems that plague other provincial implementation and monitoring committees are expected to be similar. Tyler et al. (2009) recommend an independent organization funded by a trust in order to reduce these funding-related challenges. The mechanisms for building such a Trust and the ability to use FIA[43] funds for such purposes are unclear but this is an area to be further explored.

Onus of proof and how much proof?

The key questions identified in this report can be examined by looking at the strength of the evidence relating to ecological integrity, and in light of the level of risks people are willing to accept. For many of these questions, we already have data or insight based on existing evidence, so before more research studies or assessments are undertaken clarity is needed on what is considered to be sufficient to warrant a revision in plan implementation or changes in practices or when inventory and assessments are warranted? There are different drivers affecting whether 'better direction' is implemented:– for some types of information, there are practical reasons why 'known'

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42 http://www.reo.gov/general/aboutNWFP.htm **Northwest Forest Plan (NWFP) Overview**

43 http://www.for.gov.bc.ca/hcp/fia/ Forest investment Account Home

information isn't incorporated into management (e.g. lack of mapping for a particular value) or simple 'inertia' due to lack of will to change direction, or prioritization of other values (e.g. timber versus ecology resulting in impact caps to wildlife management provisions). Or it can be some combination of a number of factors (e.g. a decade or more inertia to move to site series representation). An AM framework requires that stakeholders are in fact interested in responding to new information, and that a process is in place for doing so.

Interested parties therefore need some agreement on what evidence they would consider sufficient to make changes. This is partly a question of understanding risk and gaining some agreement on what constitutes acceptable risk. This is anticipated by the expectations there will low risk overall while accepting some higher risk. What does low risk mean and over what scale and time frame? An independent science group can help build decision support to assess and inform on risk, scale and timeframe but cannot define acceptable risk. If there is a low level of agreement on the evidence needed on risk and integrity it becomes more difficult to provide information for EBM implementation.

Data collection, maintenance and sharing.

In assembling the GIS data layers to locate potential experimental watersheds, many gaps in some data layers were noted, and there is variation in quality and completeness of data. VRI data in Tweedsmuir Park for example is not maintained to the same quality as that in the THLB. Road density is not current in some areas. There are also data access issues: access to Tree Farm License data was not equally available to other tenures, creating holes in the potential assessment areas. There are the beginnings of a corporate data base which has been assembled over the life of the plan, and there is obviously a high need to have this available across the plan area and kept current - for research as well as plan implementation and operational forest planning. Effectively managing and sharing data will significantly influence EBM implementation and efficiencies.

Reporting cumulative effects and risk within Timber Supply Review

Concern has been expressed in this report regarding support for monitoring and implementation committees under land use plans and the ability to sustain efforts to monitor and implement plans. There are budget challenges and shifts in government agency mandates. The approach under EBM offers an alternate approach that may avoid problems observed in other areas of the province. We propose an approach that links to the Timber Supply Review process, and would afford accountability and periodic reporting on cumulative effects.

The approach proposed is a decision support system linked to the Forest Act where there is periodic assessment of risks in the EBM plan area. Setting an Allowable Annual Cut is a statutory requirement for government within instruction set out in regulation and requires data, assessment and a rationale for harvest levels.

Strategic assessments are required of the Chief Forester on behalf of the government under the Forest Act sections 8a) and 8b) in keeping with sustaining other forest resource values. This periodic assessment of forest is managed within the Timber Supply Review process by the Forest Inventory Analysis Branch within the Ministry of Forests and Range[44]. There are three TSAs within the plan area. North Coast, Mid Coast and Kingcome in various stages of strategic assessment[45]. Use of TSR to assess the efficacy of provisions within the plan and to report periodically on relative risk and vulnerabilities may avoid the loss of effort and accounting for resources experienced in other strategic land use plans.

Research from strategic retrospective studies can be used to strategically improve data packages and development of modeling approaches. Assessment of ecosystems is consistent with the intent

[44] http://www.for.gov.bc.ca/hts/tsr.htm Timber Supply Review

[45] Kingcome TSA is nearing an AAC determination estimated for July 2009, Mid Coast is posted as delayed and North Coast is scheduled for a new AAC determination by November 2012.

of the Forest Act and helpful to the AAC determination as the Forest Act seeks "clarification on short and long term implications to the province" which is not limited in legislation to a forecast of timber alone. This is consistent with advice to the CIT from Walters 2004 who advised that to be successful EBM would need *development of not just maps, but also dynamic landscape planning models that are widely accessible to stakeholders.*

Research infrastructure facilities and field stations.

There are significant challenges to research and monitoring in coastal forests. This report recommends significant expertise be developed and maintained to support research, plan implementation and complete and report on results for periodic environmental assessment.

It is unclear whether a central location for the research would be feasible. Although often providing an impetus for doing much of this type of work (e.g. Bamfield Marine Station), it also requires a significantly different amount of resources to become established. With or without a central location however, a core group is needed to provide consistency in the longer term (see recommendations in Tyler et al. 2009).

Walters (2004) notes in his advice to CIT that there is the need to face the tremendous monitoring problems of adaptive management more squarely and this is best done through maximum use of residents who are interested, can be trained, are close enough to access field sites and have budget for tasks. This requires coordination and commitment. Walters also notes that when in place an EBM AM program will attract researcher and grants from outside the area provided there is infrastructure and field facilities suited to access to field sites. There are community level benefits related to supporting field stations and providing access for sampling. However, the multiple experimental watershed approach outlined here encourages sampling from a wide variety of watersheds rather than focusing a more intensive research effort in a single watershed. This means many field stations (camps) or research vessels capable of providing field stations presumably with home ports.

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Appendix A. Findings of GIS Assessment Experimental watersheds.

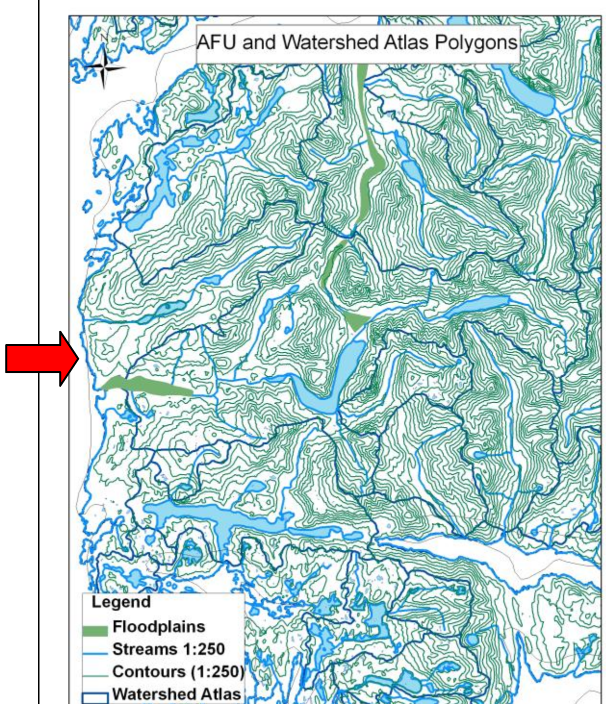
Appendix A. Findings of GIS Assessment Experimental watersheds.

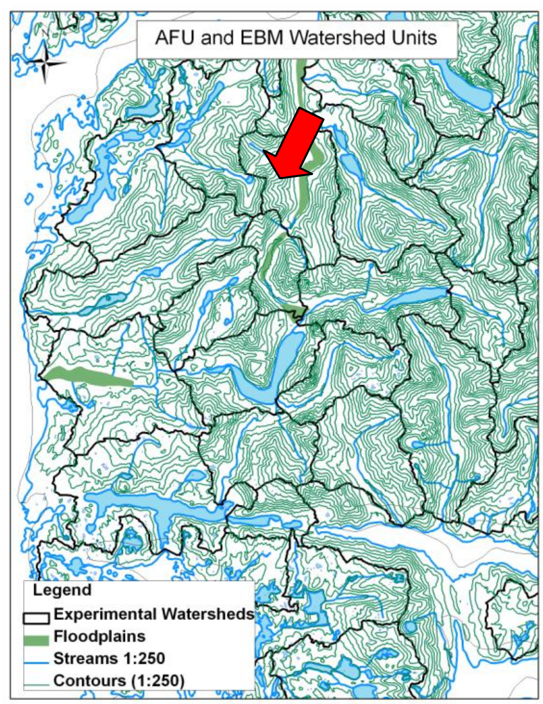
This report outlines seven potential ecosystem based research studies, a climate change study area and carbon sequestration study area. All research studies will require additional GIS assessment to refine the experimental units begun here. The figures below are at a tactical or operational scale however the data has been compiled for the entire study area. The use of GIS is considered integral to EBM decision support so development of GIS capability for risk assessment and vulnerability based o modeling is anticipated. GIS support is also will be required for sampling design.

Study 1. What are the impacts on the morphology of AFUs of removing adjacent riparian forest?

This study is described in section 4.1.1 of the report. A key component of selection of experimental units is to have sampling in watersheds with similar hydrologic response, size, amount forested, etc. Then within the groups of similar watersheds seek buffered and unbuffered AFUs for field sampling. Two watershed data bases are available for the study area. Figure 2 shows the floodplain layer available. Both watershed data layers accessed are helpful but need to be used judiciously to identify comparable watershed and treatments units. Figure 2 illustrates some of the difficulties of using either the existing 3rd order watersheds or EBM watershed units.

Figure 2. A comparison of AFU and potential experimental watershed units.





The arrow shows a floodplain near tidewater and the watershed affecting that unit as identified by the Watersheds Atlas. The watershed east of the lake in the centre of the map influences the floodplain near tide water and would need to be included.	The arrow shows a significant amount of floodplain entirely within a watershed. Seven EBM units are identified within the same area defined by the watersheds atlas. EBM WS are segments of a watershed some of which include drainage not affecting the AFU near tide water.

The conclusion is that both the WS Atlas and the EBM watershed units can be used successfully to locate treatment units and controls but not without a knowledgeable person. There is a need to subdivide or amalgamate units to define the initial set of experimental watershed for the AFU study. The floodplain layer used did not differentiate between AFU fans and floodplains which requires more detailed terrain mapping. Detailed terrain mapping is available for only a portion of the study area.

At the time this report was written the watershed Atlas was undergoing revision through identification of first order, second order stream orders increasing the provincial number of watersheds identified by the atlas from approximately 20,000 to a million + (Malcolm Gray pers comm). This will be helpful for AFU study but it is unlikely that the initial selection of comparable units can done in an automated GIS manner even with the revised WS atlas boundaries

The search for samples sites within comparable watersheds could begin by looking at AFU using GIS data and classify potential samples sites into fan and floodplain types then identification of similar sized drainages affecting AFUs. This selection of comparable WS then requires a more rigorous GIS assessment such as percentage of total forest, productive forest, bedrock, lakes, and potentially unstable terrain within the drainage above the AFU. This information is then used to select a group of WS with a range of characteristics deemed to be hydrologically comparable.

Since the interest is in impacts from forestry the range of developments above the AFU also needs to be assessment in terms of seral stage, road density, buffers as well as the condition of buffers on the AFUs that were used to anchor the search.

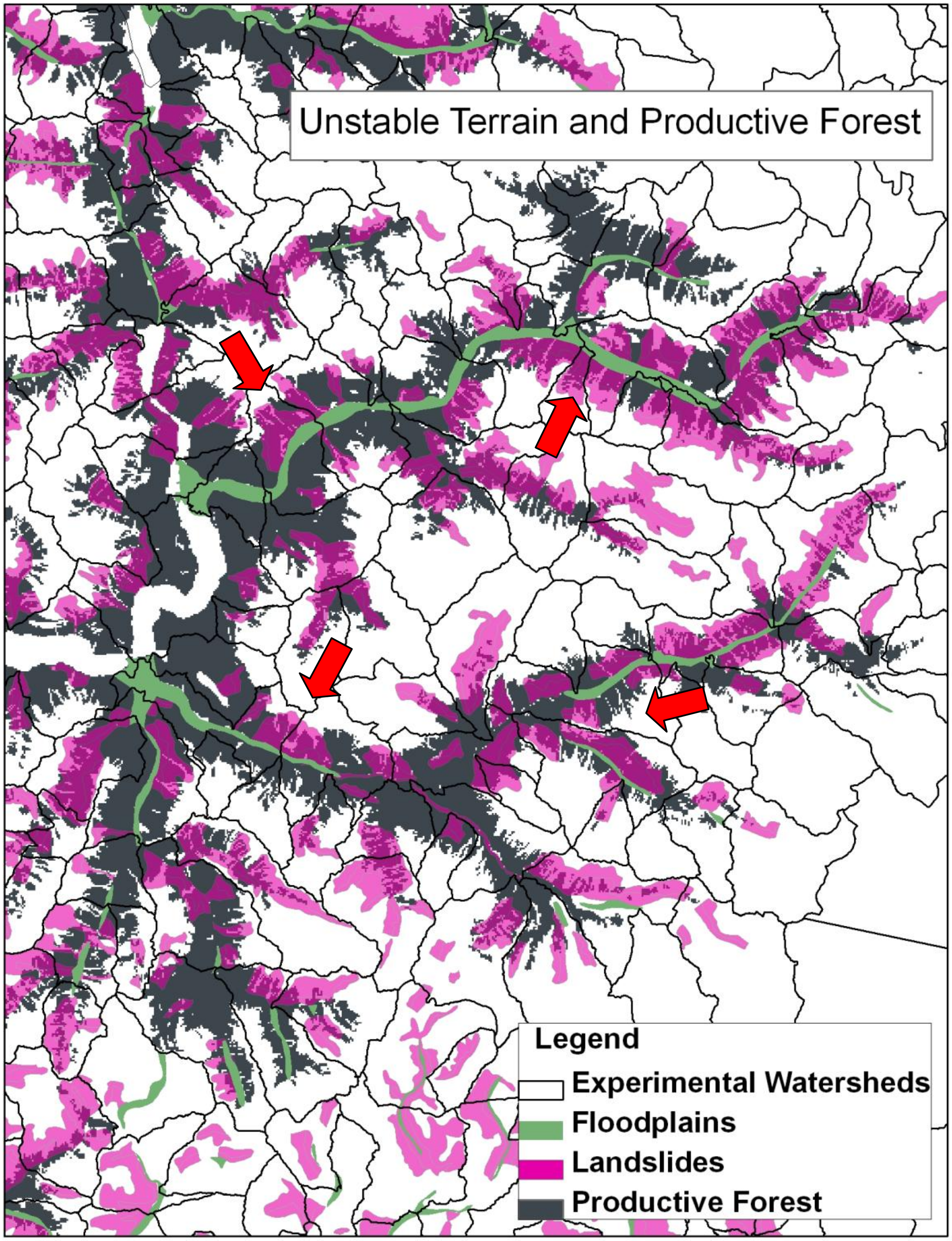
Study 2. What are the impacts of different levels of forest development on unstable terrain and near streams susceptible to debris torrents on soil movement and stream morphology?

This study is described in section 4.1.2 of the report. Since the study focuses on changes to hydro riparian selection of unstable slopes within WS with similar proximity to hydro riparian is needed. Figure 3 is an overview of productive forests with unstable terrain directly above floodplain units. Since streams with debris torrents and galleys are part of the hydro riparian system potential sample sites will need to be assessed likely using remote sensing (air photos or high quality remote sensing image like SPOT to seek these finer scale features. Unstable terrain was available for the south and central portions only. Additional information may be available through licensee completed information.
An alternate approach in the absence of unstable terrain inventory is to initially seek unstable areas based on digital information (TRIM) and productive forest on slopes > 60%.

Figure 4 shows hydro riparian features for which there is a need to sort controls and samples sites based on harvest extent. This could be done during the process of checking the similarity of productive areas. An over lay of roads on potentially unstable terrain may also speed identification WS in which to focus some of the sampling. The need to have baseline information on massive movements and debris flows and condition of hydroriparian in these drainages requires identification of unharvested slopes and comparison to those with forest development which can which can be indicated by seral stage and roads.

There is a need to have an experienced terrain scientist assess site selection aided by GIS and airphotos. Watershed restoration areas may also provide some additional background on the types failures experienced. This information in this sample map in Figure 3 is from a data set called landslides which was supplied by (Deep Filatow in Ministry of Environment) who has offered to help with more specific questions of the data.

Figure 3. Unstable terrain and productive forest.

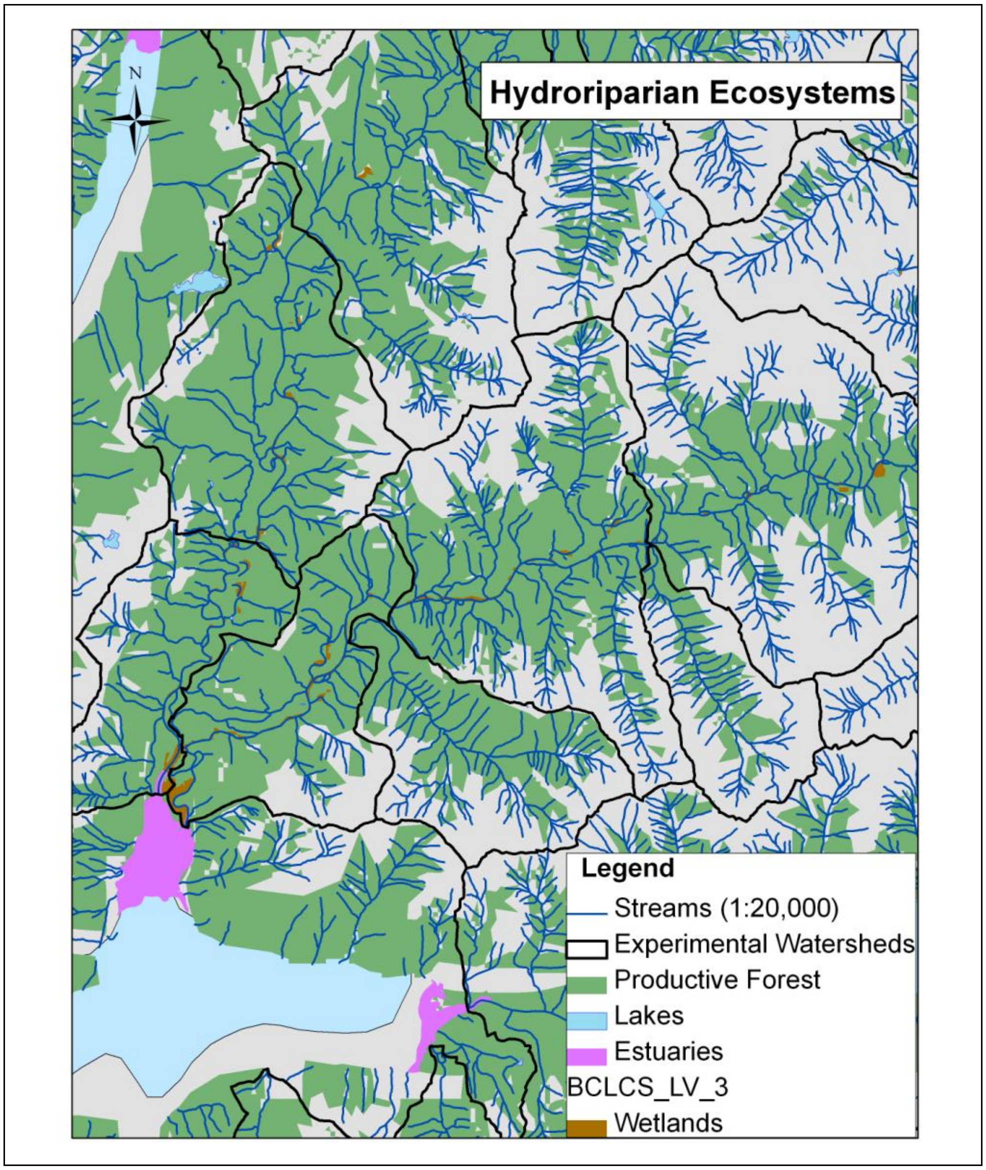


The EBMWG watershed units are shown for reference only. The darker pink areas indicated by the arrow show where there is most overlap between productive forests and unstable terrain and where these are adjacent floodplain units.

Study 3. What are the impacts of harvesting the riparian areas of small upland streams (> 6% gradients) on the biodiversity and productivity of these hydroriparian ecosystems?

This study is described in section 4.1.3 of the report. The small streams within the productive forest and impact to these hydro riparian types is the focus of this study. GIS data is helpful for finding sampling sites. The TRIM 1:20,000 stream layer shows some of the streams but the smaller streams will not be visible. GIS data is available for wetlands, lakes, estuaries and floodplains and when all the GIS data is viewed together within productive forests these will guide sample site selection. Figure XX shows a sample of this from within the EBM area. The extent to which stream classes S4, S5 and S6 are available is uncertain but these are helpful where available. The EBM WS boundaries are shown for context. Additional GIS assessment can be done once the sample sites are selected to determine stream gradients i.e. > 6% and WS sizes and productive forest portion of streams > 6%. The stratification initially needs to find similar WS and then include past harvesting roads and extent of development of small stream areas. The EBM watersheds are provided for context. Though the water bodies appear the same in Figure 4 the estuary is correctly identified as the water body adjacent is an inlet.

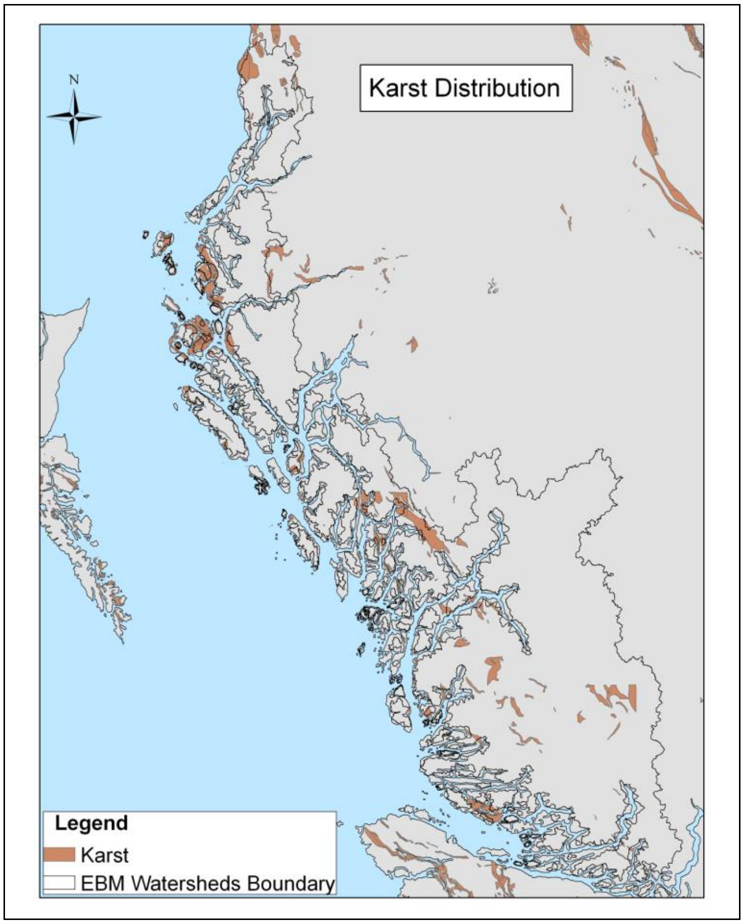
Figure 4. Hydroriparian features and a context for small stream studies.



Study 3 What are the impacts of harvesting karst hydroriparian ecosystems on the biodiversity and productivity of these hydroriparian ecosystems?

The study of karst hydroriparian is described in section 4.1.3. Figure 5 shows the bedrock types where karsts may develop. More detailed inventory and assessment of karsts will be needed in these areas. The extent to which inventory and assessments are available at an operational scale may help identification of potential sample sites. The RIC 2001 provides an inventory and assessment approach to karsts that if available, would provide more appropriately scale information. RIC 2001 provides standards for assessment of karsts, MOF 2001 produced a Handbook for management and the FPB 2007 provide a special report on karst management. Some Karsts are now protected under GAR. These sources will also help how to identify sampling sites for study of impacts to karst from forestry.

Figure 5. Distribution of karst bedrock types within the EBM area.



Ministry of Forests 2003. **Karst Management Handbook for British Columbia,** http://www.for.gov.bc.ca/hfp/publications/00189/Karst-Mgmt-Handbook-web.pdf

RIC Resources Inventory Committee, 2001.**Karst Inventory Standards and Vulnerability Assessment Procedures for British Columbia,** Prepared by The Karst Task Force for the Version 1.0 http://ilmbwww.gov.bc.ca/risc/pubs/earthsci/karst/karst-02.htm

FPB 2007. **Protecting Karst in Coastal BC Special Report.** http://www.fpb.gov.bc.ca/assets/0/114/178/184/360/39e5b943-b759-4910-a32d-3a96d57cd813.pdf

Study 4. Are LUO for stand retention of 15% low risk to terrestrial ecosystem integrity in landscapes with different long term old forest reserves?

These studies are described in section 4.2.1and 4.2.2 and are placed together here as the GIS data needs for each study are similar. Finding sample sites can be guided by the EBM watersheds together with the productive forests. The aim is to find WS that are similar with reguard to size, productive forest, and elevation ranges etc. Figure 6 shows a sample of productive forests with EBM WS units. This information is available for the entire plan area and can be summarized by the EBM WS polygons to ease the search for similar WS. This is an example of the productive forest data and EBM WS boundaries that will be needed to locate WS that are similar.

Figure 6. Productive forest example with EBM WS units

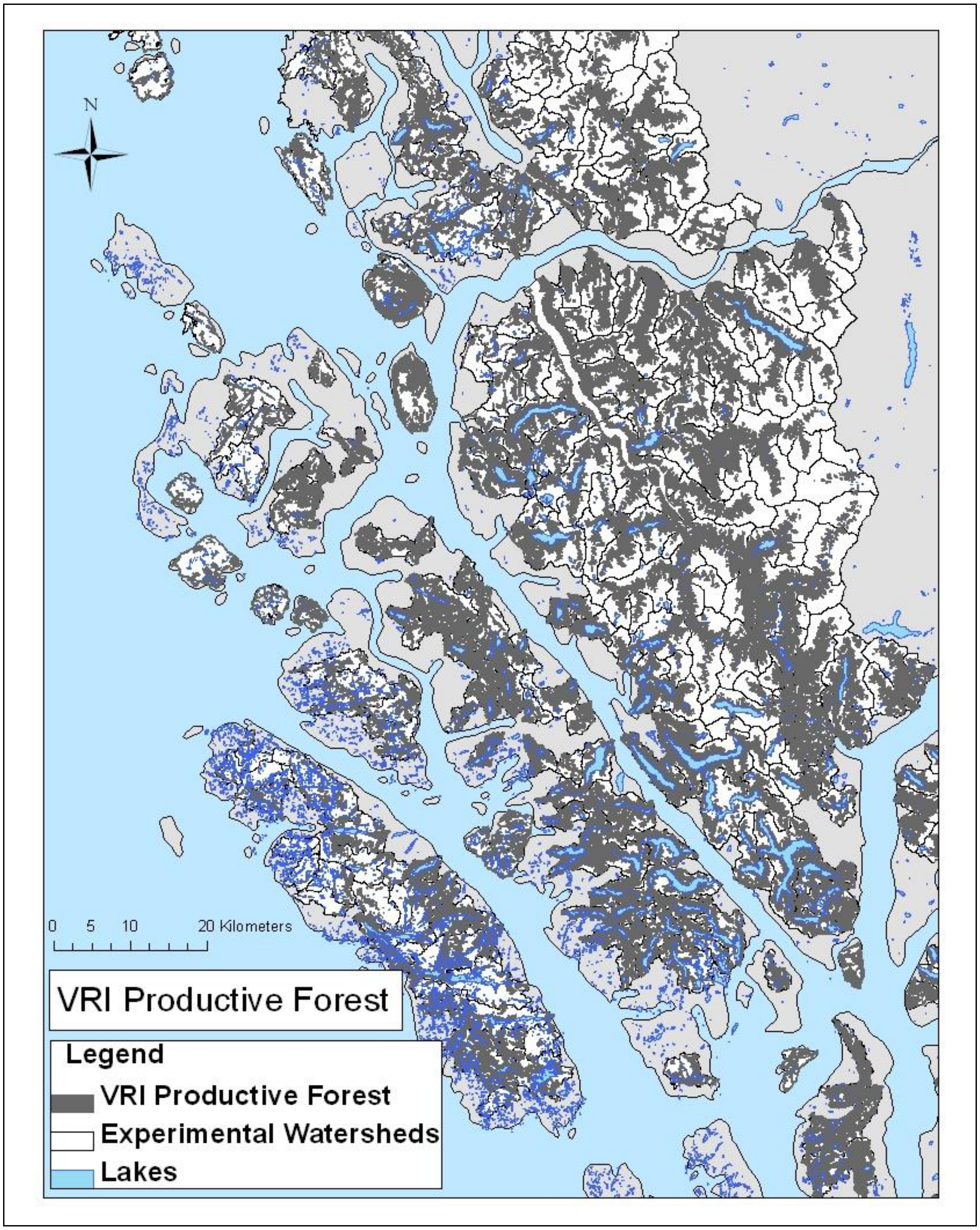
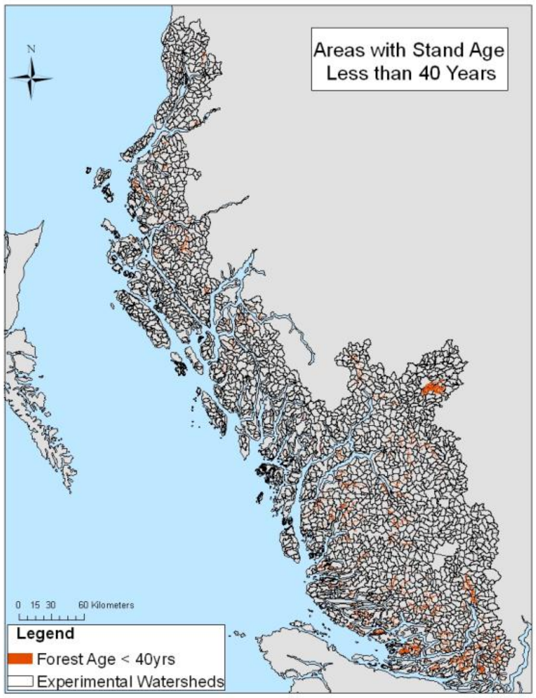
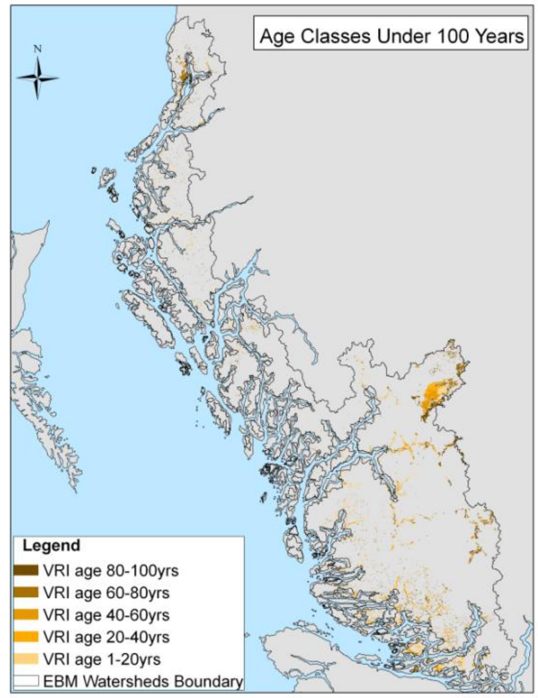


Figure 7. Distribution of Forest Age < 100 and < 40 presumed to have been logged.



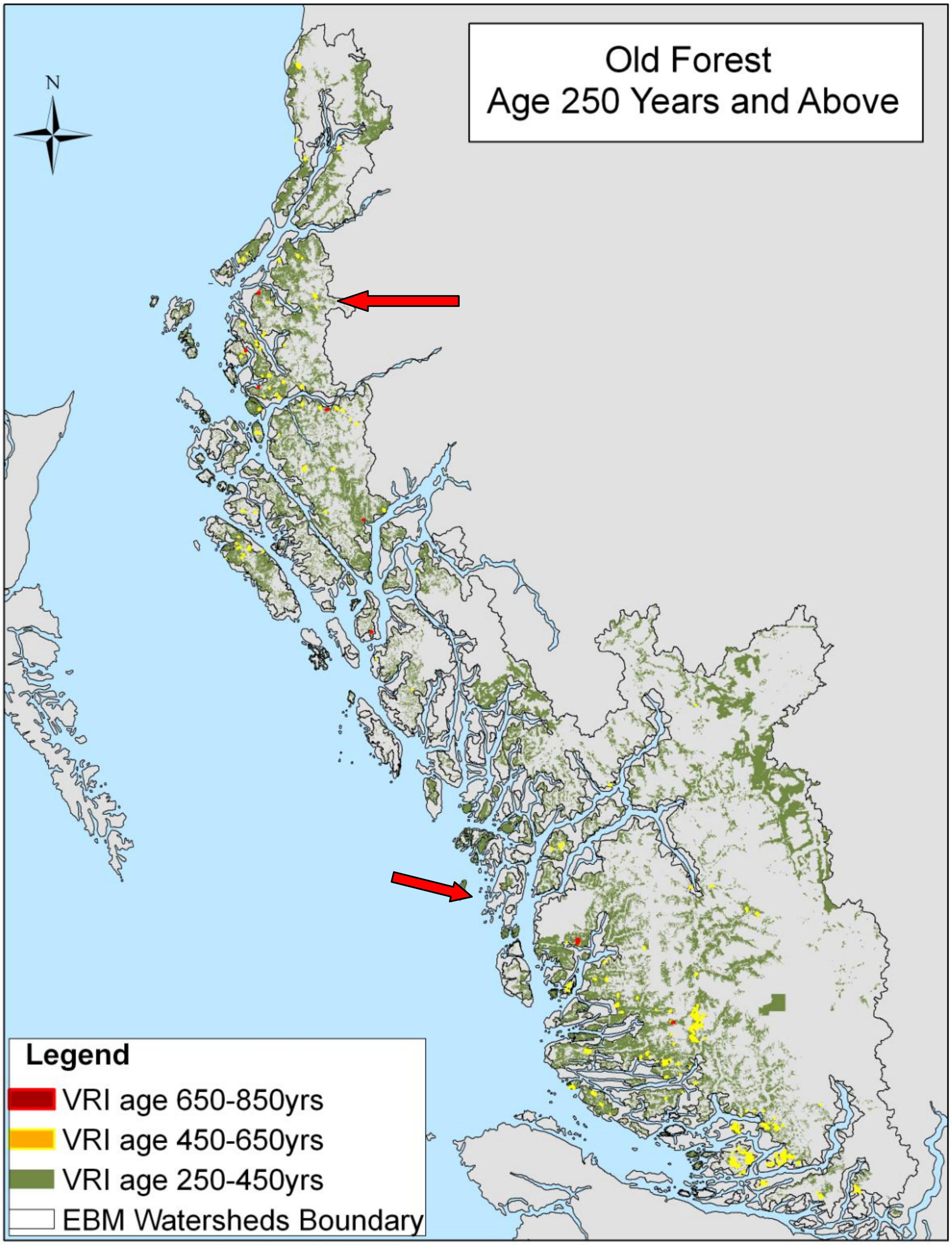
This map simply illustrates the most recent harvested areas and the EBM WS units



This map simply shows forests less than 100 years by 20 year increments.

Study Question 5. Are old forests close in age to 250 years biologically equivalent to much older stands?
This study is described in section 4.2.3. Figure XX used VRI data show the distribution of stand ages by 200 year increments above 250 years. The extent of the oldest stands is lowest so some of the polygons in the 650 to 850 year class were buffered so they can be detected. Each forest cover polygon has a specific stand age in the VRI data set. Stand age is one factor that can be used to seek less disturbed sites. Other factors to consider are exposure to wind storms as well as aspect and fire probability. Some forests stands have not had a significant disturbance for thousands of years. Older trees are difficult to age for classifiers even when on site. There is an expectation that some older stands within the 250 to 450 years group also are not classified accurately to age and were simply considered to be within age class 9 which is a broad group defined as 250+ years.

Figure 8. Stand ages 250 years and above



The oldest group is least extensive and difficult to show. There are three units for example north of the Skeena River (upper arrow) and two units south of the lower arrow.

A review of the EBM WS data.

The data set was assessed for size ranges shown in Figure 9 and 11 and presence and absence of fish Figure 10.

Figure 9. Size range with EBM WS data set.

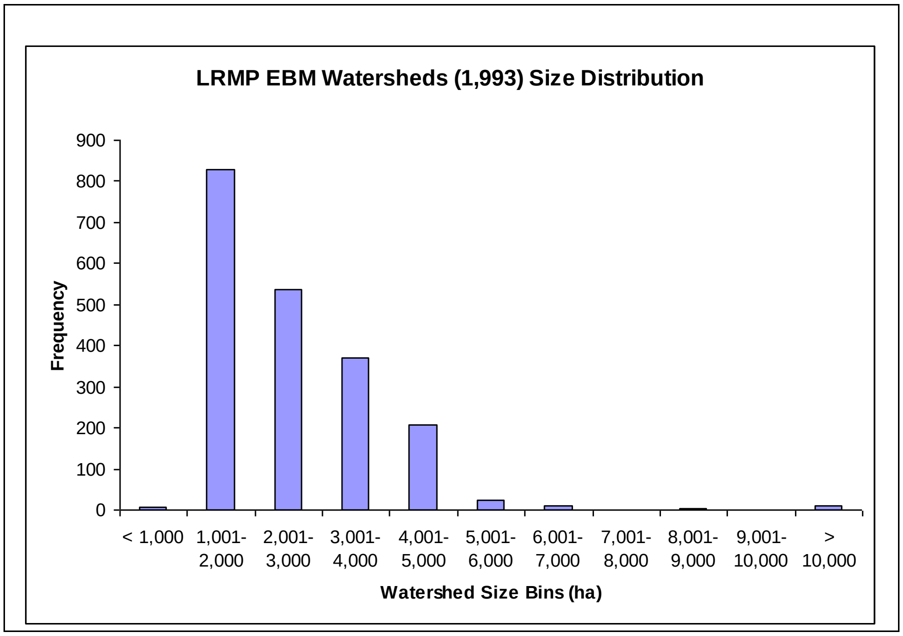


Figure 10. Watershed sizes with Fish observation.

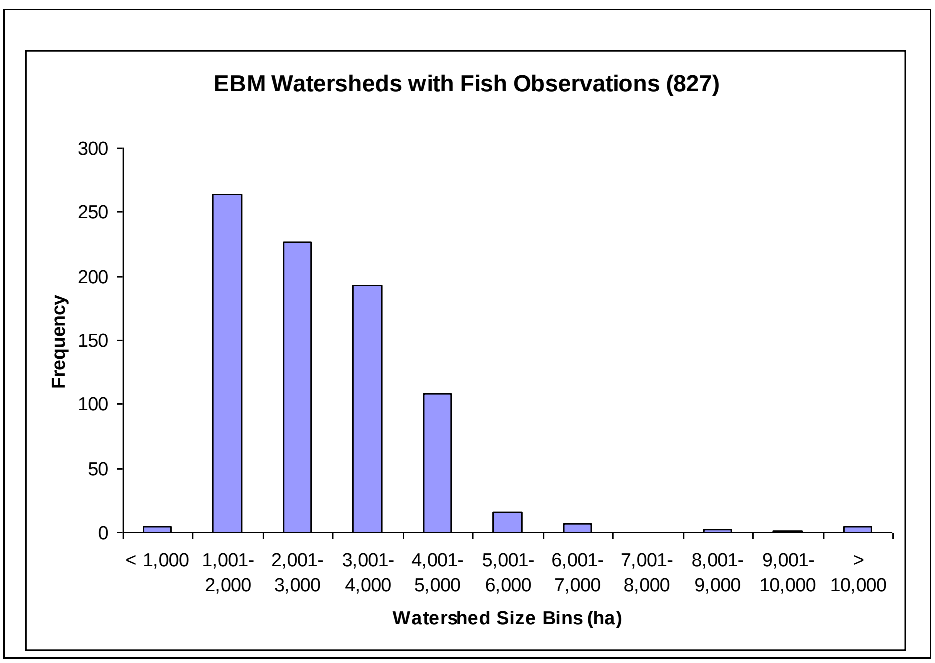


Figure 11. Distribution of EBM WS units by 4 size classes

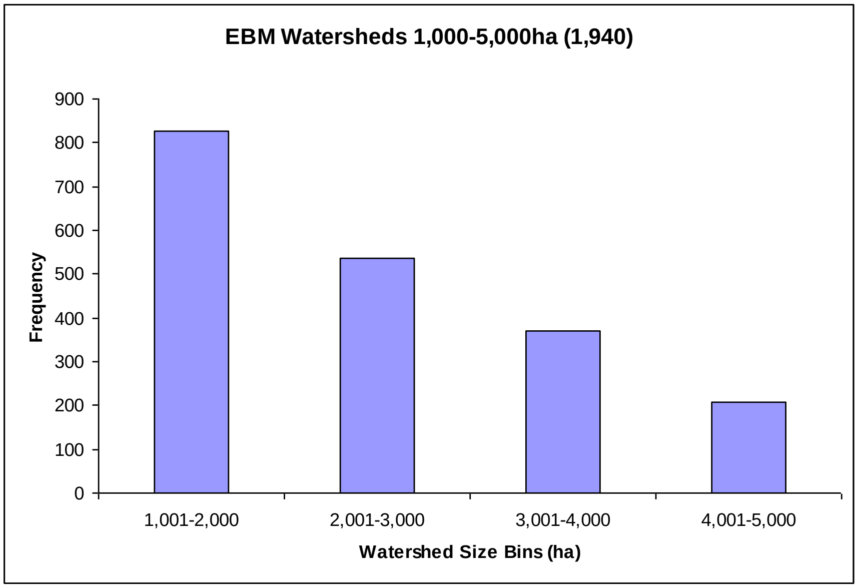


Table 16. EBM WS size Frequency most common sized units

Size class	Frequency
1,001-2,000	827
2,001-3,000	536
3,001-4,000	371
4,001-5,000	206

The EBM WS units are administrative units so some are entire watersheds and other portions of watersheds. The EBM WS are useful in that they allow a summary of data for many stands and help to find comparable areas when over laid with other data sets. Table 18 shows data used and anticipated. Additional information is available on data coverage in a separate contract that was conducted simultaneously for the EBM WG. Information in this table has not been coordinated with the report by Horn 2009 entitled "Creating a Data Management System to Support Ecosystem-Based Management".

Table 17. GIS and other Data to support EBM studies**.**

Data	Coverage	Source	Contact	Use	Used
VRI	complete except for tree farm licenses, which can be requested from forest companies	LRDW	Tim Salkeld	forest stand information, also some basic information about non-forested areas and harvest history. There are difficulties obtaining TFL data. SELES data was used to assist in TFL areas	yes
BEC variants		LRDW		Representation	no
RESULT S	complete	Special request	Caroline MacLeod	could be used to update VRI with more recent cutblock information	no
PEM	complete: covers north coast forest	EcoCat (http://a100.gov.b c.ca/pub/acat/publ	Corey Erwin	vegetation and ecosystem information	no

	district and central coast / QCI projects	ic/welcome.do also ftp.env.gov.bc.ca/dist/wis/pem/warehouse/)			
Digital Road Atlas	complete	Special request	DRAINFO @gov.bc.ca.	road density	no
Watershed Atlas	complete	LRDW	Malcolm Gray	Watershed area, watershed code, connectivity between watersheds etc.	no
EAU BC	complete	LRDW	NCC	Hierarchical watershed classification (rivers, lakes, drainage units, fish presence etc.)	no
EBM WS	North and Central Coast	EBM WG	John Sunde	Watershed assessment units (updated from WSA)	yes
Parks and Protected Areas	complete	LRDW?		Identifies parks and protected areas	yes
Terrain Process Zones	complete	ILMB	Deepa Filatow	Identifies floodplains, avalanches, and landslides	no
Terrain Maps (1:50k)	incomplete	ILMB	Deepa Filatow	Detailed terrain mapping Unstable terrain study	no
Terrain Maps (1:20k)	incomplete	ILMB	Deepa Filatow	Detailed terrain mapping Active Fluvial Units study	no
Stream Classes	uncertain	LRDW		Small streams studies	no
Watershed Assessments	uncertain	ECOCAT		Selection of sample sites unstable terrain	no
TRIM	complete	LRDW		Stream gradients, slope classes, upland streams	no
Bedrock occurrence	uncertain	?		Impermeable surfaces affect runoff	no
Lake	complete	LRDW		Hydro riparian study	yes
Streams	complete	LRDW		Hydro riparian study	yes
Glaciers	uncertain	?		Hydro riparian study	no

Table 18. GIS data layers created, source, analyses and output information.

Data Layer Created	Source Layers	Analyses	Output Information
LRMP_ws_units_FINAL	ws_units_FINAL (from EBM WG) and LRMP boundaries	Watershed units from EBM WG clipped to LRMP boundaries. Discretion used at boundary to include watersheds that crossed the boundary.	EBM WG watershed units within LRMP boundary for North and Central Coast.
LRMP_ws_units_Dslv	ws_units_FINAL	Watershed units dissolved to show	Overall study area

	(from EBM WG) and LRMP boundaries	outline of study area.	boundary
Wshd_VRI_comb_merge1 93F_VRI_wshd2	LRMP watershed units VRI (VRI tiles: 103P, 103O, 103I, 103J, 103G, 103H, 093E, 103A, 093D, 093C, 093F, 102P, 092M, 092N, 092L, 092K)	VRI tiles were intersected with LRMP watershed units, and then merged to create a VRI layer clipped to watershed boundaries. The Wshd_VRI_comb_merge1 layer contains all relevant VRI tiles except 93F, as this tile was added at a later date after a VRI update and was not easily merged with the other VRI files.	VRI information within LRMP watershed units plus additional fields to calculate various volume and age classes*
Wshd_VRI_comb_merge1_noTFL_veg_treed	As above TFL data	TFL areas were erased and only polygons classed in BCLS as vegetated and treed were included. Use in combination with 93F_VRI_wshd2 to cover entire study area	Forested area and watershed boundaries
Prodforest_Merge_Intersect_wshds	SELES	Seles data converted from raster to vector and intersected with LRMP watershed units	Productive forest within watersheds.
LRMP_fish_units_1-5k	LRMP watershed units FISS Observation Points 2008	Fish observations (including species) clipped to LRMP watershed units between 1,000-5,000 ha	Watersheds with recorded fish observations

*Additional fields calculated
V_area_cal: updated calculation of volume of each polygon after clipping to watershed.
Sum_vol175: Summary of volume for all species within the polygon at 17.5cm
Vol_Area 1-7: Area (ha) of volume for seven volume classes in 100m3 increments from <100m3, 100-200m3, etc. to >600m3)
Area_Age 1-6: Area (ha) of volume for six age classes. Traditional age classes 1-5, and the 6th being anything >100yrs.
The information in the above fields can then be summarized by watershed using the unique_id field.

Appendix B. Expanded rational for support of Ecosystem Based AM research

1. Search for Knowledge and Confirmation of Facts for Sustainable Forestry.
Sustainable resource management is a global challenge recently characterized in the Millennium Ecosystem Assessment Report[46] as a question of whether we are depleting natural capital or drawing on interest. Achieving sustainability means living from nature's interest and begins with developing an understanding natural systems well enough to know the difference between resource extract that spends the natural capital (depletion and degradation) and resource extract that spends what is interest on the natural capital (long term sustainability of ecosystems goods and services).

A research program in temperature rainforest would need to deliberately explore the question of natural capital and living off nature's interest. This is central to sustainable communities as well a ecosystem integrity and avoiding "boom and bust" cycles can be enhanced through research linked for forest management decisions. Maintaining natural capital links well to the EBM vision for low risk ecosystem based management.

2. Pursuit of greater certainty
An EBM research program fully supported by interested parties is considered a major asset for all who participate because it will speed understanding or sustainable resource use and provide greater certainty for coastal communities**.** Research of a sufficiently independent nature is a concrete approached inform debate and decision making. The decisions on what constitutes acceptable risk will remain a social negotiated decision however understanding stresses, thresholds and ecosystem limits and consequences will require an analytical research perspective.

3. Need for independent evaluation.
Throughout the history of industrial scale renewal resource based economies there has been a goal of sustainability or reference to harvesting consistent with sustainability. Forest Practices Code pilots, forest certification systems, Forest Practices Code and the more recent Forest Practices Range Act. All there are approaches to sustainable forestry including the current EBM vision for the coast is an experiment in sustainability. Regardless of which approach is being evaluated factual information is needed to assess risk and likelihood of success. Research (defined earlier as an approach to seeking factual information) is needed to inform on whether access to wood is sustainable and whether the ecosystems many functions are sustained.

4. EBM research and AM experiments meant to trigger plan and practices amendments.
The onus of proof for changes has been shifted so that research findings are expected to be a major avenue to clarify how to make incremental improvements. Research linked to AM is the mechanism to revise policy, practices and plan objectives. Observational studies can merely suggest correlative conditions and logical hypotheses to test in subsequent experiments. It is necessary to go beyond passive adaptive management and or monitoring and deliberately seek thresholds to guide changes in plans and practices.

5. Model validation and reporting on ecosystem integrity will improve EBM

Perhaps the most significant modeling for sustainability is the modeling done as a requirement under the Forest Act which requires the Chief Forest to make periodic Allowable Annual Cut (AAC) determinations. Currently the assumptions in models presume that plans achieve goals. This assumption can be tested with support from an EBM research program.

As a delegated decision maker the Chief Forester is required to determine a harvest rate and to decide what level of harvest is appropriate and inconsideration of the short and long term

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[46] http://www.millenniumassessment.org/en/index.aspx

implications to British Columbia of alternative rates of timber harvesting from the area[47]. This is normally completed every five years. There are a number of assumptions inherent in the forecasting of timber supply. The periodic assessment and determining AAC need not be limited to models reporting on the forecast a single variable (timber) alone. The inclusion of short and long term implications is inclusive of environmental indicators and reporting of ecosystem integrity together with the AAC determination. Models of timber and forecasts of indicators of ecological integrity depend on modeling assumptions underscoring the need for validation of modeling assumptions.

The EBM area is divided into three Timber Supply areas: 1) the North Coast TSA, 2) the mid Coast TSA and 3) Kingcome TSAs. To support the Chief Foresters AAC determination there is a Timber Supply Review process. [48], [49], [50]. Timber Supply Reviews include 1) data package assembly and opportunity for review, 2) analysis report and forecasting and opportunity for review and 3) the AAC determination and rational. Though the Chief Forester has the mandate in legislation to set harvest rates and is able to consider analysis can be done collaboratively outside of government as is the case in the Kingcome TSA where licensees have agreed to complete data assembly and analysis specific to Kingcome TSA[51] on which the Chief Forester will base the harvest levels. The analysis report in underway and will be used to set the AAC. Inclusion of risk and reporting within the context of EBM indicators will be informative for all the interested parties. This will mean inclusion of numerical models that report on ecosystem factors as well as timber volume over time.

7. Improved logistics and cost efficiencies from cooperative EBM research.
Coastal BC is a difficult region in which to conduct research, distances are great and forests are not connected by roads so water and air access is part of the research infra structure. There are many participants in natural resource use and management. Table 20 shows the major anticipated participants in an EBM research framework. In light of the difficulties in research cooperation between all potential participants can decrease costs as well as build long term relationships. Pooling resources increases capacity over what any individual group could achieve on their own. The term research program is used deliberately as a research program as an entity is considered more likely to persist and be able to address the key research questions.

Table 20. Governments and groups with interest in EBM research program.

First Nations Governments • Multiple government to government agreements.	Federal Government • Environment • Department of Fisheries and Oceans	Provincial Government • ILMB • MOFR • MOE
Coastal communities (Infra Structure)	EBM research program	
ENGOs • Numerous •	Academia • Numerous institutions sponsoring research now.	Industry Coast Forest Conservation Initiative

First Nations
Participation and support by FN governments, on a pragmatic level, means increased capacity for FN from coastal communities who have direct involvement with research and scientific approach in their traditional territories. A research program is expected to provide involvement through development of research infra structure (field camps and their maintenance), transportation for data

[47] http://www.qp.gov.bc.ca/statreg/stat/F/96157_02.htm#section8 Forest Act AAC determinations
[48] http://www.for.gov.bc.ca/hts/tsa/tsa21/news.htm Next AAC determination expected in 2012
[49] http://www.for.gov.bc.ca/hts/tsa/tsa19/ Mid Coast TSR site
[50] http://www.for.gov.bc.ca/hts/tsa/tsa33/docs.htm
[51] http://www.timberline.ca/kingcome/

collection/monitoring, data collection, maintenance and use of research equipment and training to protocols and data management. Over time it is expected that there will be benefits overall from integration of traditional knowledge on ecosystems and management

Forest Industry

Participation by forest companies can provide efficiencies over individual company to leadings its own research program. An active and supported research program is also expected to provide benefits for developing materials for forest certification and help improve forest inventories. Forest companies do have access to Forest Investment Account (FIA) funds which they have discretion. The EBM program may afford sufficient benefits that FIA can be directed towards this initiative. Any active adaptive management project can only be achieved with fully support by licensees. Coast Forest Conservation Initiatives (CFCI)[52] website shows the high level of existing cooperation between industry as well as pursuit of Forest Stewardship Council Certification.

Provincial governments

There is considerable research capacity within the provincial government particularly within Ministry of Forest and Range who have maintained a research program for many decades. There are regional MOFR staff working on the north coast (based in Smithers) and the mid coast and south coast staff (based in Nanaimo) as well as headquarter staff scientists (based in Victoria). Ministry of Environment in the past had a research section and currently has a science program supporting endangered species monitoring and research.

Federal government.

Department of Fisheries and Oceans has the marine research station in Nanaimo as well as regional Offices in Prince Rupert. Data from monitoring of salmon on coastal systems is considered central to understanding fish forestry interactions. Canadian Wildlife Service has research capacity with a focus on migratory birds.

Environmental Non Government Environmental Organizations

ENGOs that were instrumental in initiating EBM in temperate rainforests have a significant number independent on-going research projects. Capacity to undertake larger long term experiments on ecological integrity would be increased through collaboration. The Raincoast Forest Conservation Foundation website shows [53] shows a considerable number of research projects and the strong ties to academic institutions already established.

Academia

There have been many research scientists from U of Victoria, UBC and SFU managing research projects and applying research grants to ecosystem and species research through undergraduate, masters and doctoral degrees. The coast is a difficult place to conduct research and a longer term coordinated EBM program will facilitate research work. Transportation and appropriate quality field research facilities will improve the longer term research and funding on coastal research.

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[52] http://www.coastforestconservationinitiative.com/

[53] www.raincoast.org .

Appendix C. Selected references of literature on riparian buffers

References in this appendix are provided separately as they were not cited in the report but are provided as a potential starting point should more detailed literature review be undertaken as part of Phase 2 questions on aquatic integrity and next steps in sections 4.1, 4.2 and 4.3.

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Cockle, K. L., and J. S. Richardson. 2003. **Do riparian buffer strips mitigate the impacts of clear cutting on small mammals?** Biological Conservation 113:133-140.

Cole, E. C., W. C. McComb, M. Newton, J. P. Leeming, and C. L. Chambers. 1998. **Response of small mammals to clear cutting, burning, and glyphosate application in the Oregon Coast Range.** J. Wildl. Manage. 62(4):1207-1216.

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Appendix D. Selected References on Ecological Integrity

References in this appendix are provided separately as they were not cited in the report but are provided as a potential starting point should more detailed literature review be undertaken as part of Phase 2 questions on aquatic integrity and next steps in sections 4.4, 4.5 and 4.6.

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