Adaptive Management Plan:

Estimating Windthrow Damage

in

Riparian Areas in the North Coast

prepared for the

EBM Working Group

by

Dave Daust

250-846-5359
pricedau@telus.net

March 3, 2009

Disclaimer

This report was commissioned by the Ecosystem-Based Management Working Group (EBM WG) to provide information to support full implementation of EBM. The conclusions and recommendations in this report are exclusively the authors', and may not reflect the values and opinions of EBM WG members.

Preface

This plan outlines the rationale and general approach for undertaking an adaptive management study to characterize windthrow damage in riparian areas in the North Coast. It describes the study methods in sufficient detail to support preparation of a Request for Proposals. The final details of the study should be prepared by the team that takes on the project.

This plan resulted from a pilot study, with BC Timber Sales and the EBM Working Group, that explored how best to develop adaptive management plans for the purposes of obtaining flexibility under land use objectives. This plan is a companion document with

Daust D., and K. Price. 2009. Issues and recommendations arising from the BCTS Adaptive Management Planning Pilot Study (AM 04b). Report for the Ecosystem Based Management Working Group.

The above report provides a template for an adaptive management plan, outlines First Nations participation in the planning process and discusses some of the challenges related to implementing adaptive management under ministerial orders.

Potential issues to address with adaptive management were discussed in a workshop with researchers and BC Timber Sales foresters (see appendix in companion document). In subsequent discussions, BC Timber Sales felt that the issues identified in the workshop were not sufficiently linked to flexibility and suggested the adaptive management plan should address an issue related to riparian management. Thus, this plan addresses windthrow in riparian areas.

Acknowledgements

Ian Smith, Dave Nicholson, Mike Viveiros and Les Pawlak (BC Timber Sales, Terrace, BC) and Allen Banner (MFR Research, Smithers, BC), Laurie Kremsater (consultant, Abbotsford, BC) and Karen Price (consultant, Telkwa, BC) participated in a workshop that outlined the content needed in an adaptive management plan and discussed potential study topics. Tavis McDonald (BC Timber Sales—Branch, Terrace, BC) provided additional guidance on study topics after the workshop. Allen Banner also provided some example research work plans that guided the structure of this adaptive management plan. Karen Price helped me describe methods. Karen Price and Laurie Kremsater reviewed the draft plan. I appreciate everyone’s contribution.

1 Project leader

Ian Smith
BC Timber Sales, Skeena Business Area
200 - 5220 Keith Avenue
Terrace, BC, V8G 1L1

phone (250) 638-5145. fax (250) 638-5176
E-Mail ian1.smith@gov.bc.ca

2 Management context

Riparian reserves and riparian management zones (RMZ) are an important component of an overall strategy to maintain ecological integrity under ecosystem based management (EBM). Riparian forest also provides some of the largest and most valuable timber in a watershed. Learning more about the consequences of riparian management has the potential to increase economic benefits and/or improve riparian management. Current knowledge suggests that riparian forest contributes to achieving several EBM objectives. The following information is taken from the Central and North Coast Knowledge Summary (Price et al. 2009) which is based on a review and synthesis of background documents (Appendix 1) and was prepared to support EBM implementation:

Objective: Maintain Channel Characteristics (Including Stream Morphology, Bank Stability and Downed Wood) and Water Quality Within Range of Natural Variability.

- Riparian forest maintains bank stability, regulating sediment input, and provides a source of downed wood, affecting stream morphology. The sensitivity of stream banks to loss of riparian vegetation depends largely on the erodibility of the bank material. Stream banks in transport and depositions zones (alluvial banks) can tolerate very little if any loss of riparian vegetation[1,2]. Source zone stream banks in non-erodible material can tolerate approximately 50% removal of riparian vegetation.

- In the transportation and deposition zones, most downed wood in streams comes from adjacent riparian forest (although wood can still be delivered downslope to streams with a narrow valley flat). Old forest with large trees is a necessary part of the riparian area in transportation and deposition zones. In the source zone, however, smaller pieces of wood may effectively regulate stream morphology. Transportation and deposition zones can tolerate 20% loss of riparian cover; source zones can tolerate 30% loss (from the perspective of downed wood supply).

Objective: Maintain Hydroriparian Biodiversity and Productivity: Coarse Filter

- 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. Riparian habitats are thus a key element of a biodiversity conservation strategy. Forests adjacent to streams provide a source of litterfall and

[1] Estimates of tolerable losses of riparian vegetation, presented in this document, aim to maintain a low-risk, similar-to-natural condition.
[2] For definitions of source, transport and deposition zones, see CIT 2004.

downed wood to the aquatic ecosystem. Sensitive ecosystems (e.g., karst, estuaries, small streams susceptible to debris flow, fans, floodplains, forested swamps) can tolerate a 10% removal of riparian vegetation; less sensitive ones can tolerate 30% removal (from a biodiversity/productivity perspective).

Objective: Protect and Sustain High-value Fish Habitat: Fine Filter

- Protection of fish habitat requires that all hydroriparian functions be maintained. Habitat depends on riparian structure as well as water flow, quality and temperature. Large pieces of downed wood increase channel complexity, form pools and provide shelter. Riparian vegetation moderates water temperature, filters sediment, stabilises channel banks and provides nutrients to the aquatic system. High-value fish habitat is sensitive and, in general, no removal of riparian vegetation is considered tolerable.

Objective: Hydroriparian Biodiversity—Connectivity

- Connectivity is important for maintenance of biodiversity. Riparian areas are natural candidates for corridors due to their lineal nature and use as travel corridors in natural systems. This objective depends mainly on the number of streams with uninterrupted corridors and is less sensitive to the amount of riparian vegetation removed in a particular area.

Strategies in the ministerial order[3] (in the form of “land use objectives” or “LUO”s) specify the width and level of retention in riparian management zones and reserves (Table 1). Strategies do not cover all hydroriparian ecosystems (e.g., karst). For the hydroriparian ecosystems covered in the ministerial order, the strategies appear consistent with the EBM objectives, with one large and broadly applicable uncertainty: the definition of functional riparian forest potentially allows for a wide range of vegetation removal (over and above the percentages specified in Table 1; e.g., removing 30% of large trees may still retain “functional riparian forest”). The range of harvest levels and patterns within riparian areas considered to be consistent with maintaining functional riparian forest is currently unclear.

In addition to the standard levels of retention, lower retention levels are allowed in certain circumstances (referred to as flexibility; Table 1), but require site assessments, adaptive management plans and consultation with affected First Nations.

Table 1. Summary of riparian management strategies listed in land use objectives.

LUO topic	Standard	Flexibility
High-value fish habitat	100% reserved (average 1.5 tree buffer*)	not applicable
S1 to S3 streams, lakes, marsh, fen	> 90% of functional riparian forest in RMZ (average 1.5 tree buffer for streams and large water bodies; average 1 tree for smaller water bodies)	> 70%
Forested swamps	> 70% of functional riparian forest in RMZ (average 1.5 tree buffer)	> 60%
Active fluvial units	> 90% of functional riparian forest in RMZ (average 1.5 tree buffer)	> 80%

*in all LUOs, buffers can be altered in width by ± 0.5 tree heights to capture actual riparian ecosystems
**“functional riparian forest” means forest that has reached hydrologically effective greenup and that also contains some large trees adjacent to streams to provide for large organic debris.

[3] Central and North Coast Order, December 19, 2007, Ministry of Agriculture and Lands, BC.

Several factors cause uncertainty about the appropriate amount of riparian vegetation to retain in riparian reserves and management zones[4]:

- **Rates of windthrow are not quantified. Windthrow affects bank stability, rates of woody debris input and litterfall, microclimate and other functions provided by standing riparian forest. Thus, riparian management must account for windthrow and limit excessive windthrow by altering the amount, pattern and location of riparian retention.**

- **Riparian reserves and management zones may not accurately capture actual riparian vegetation. Buffer location reflects the judgement of the people that flag the riparian buffer. This uncertainty is particularly important for the hydroriparian biodiversity and productivity objective.**

- **Stream banks vary in their erosion potential, particularly in source zone streams. Classifying this variation would allow strategies to be refined.**

- There is lack of knowledge about the influence of riparian forest cover on bank stability in the transport zone.

- There is lack of knowledge about the influence of large wood on channel characteristics in source zone streams.

- **The range of management practices and level of retention in riparian management zones is unknown (relates to the definition of functional riparian forest).**

- **The accuracy of high value fish habitat maps is unknown.**

- The likelihood of sedimentation from upstream sources in not known. Poor upstream management may cause sedimentation of high value fish habitat.

Increasing knowledge about the influence of riparian vegetation on bank stability, about the influence of downed wood on channel characteristics and about sedimentation from upstream requires relatively sophisticated studies and may be best undertaken as part of a large project that examines several aspects of riparian function concurrently.

Addressing some of the other uncertainties (i.e., windthrow, buffer accuracy, stream classification, variation in practices, habitat map accuracy) will require relatively less sophisticated studies (than the uncertainties not shown in bold) . Windthrow is a significant uncertainty for all objectives listed above. First, the extent to which windthrow occurs in riparian areas in the North Coast is not known[5]. Second, the impacts of windthrow have not been studied. The remainder of this adaptive management plan focuses on estimating the amount of windthrow in riparian areas in the North Coast.

[4] The relatively tractable uncertainties requiring less expensive studies are highlighted in bold text.
[5] Riparian assessments conducted under the Forest and Range Evaluation Program provide some limited information on windthrow in the North Coast (assessments include approximately 30 mostly S5-S6 streams with few leave trees, mostly pre-FRPA; pers. comm. Mike Grainger, FREP, North Coast Forest District, Prince Rupert).

3 Research problem

Standing riparian forest serves several important ecological functions, as discussed above. Windthrow can adversely affect the functionality of riparian forest by removing cover, exposing soil and adding surges of woody debris to stream channels. Consequently, one key purpose of riparian management zones is to prevent windthrow in adjacent riparian reserves (Province of BC 1995). The importance of these windthrow-induced effects varies with the type of riparian area considered (e.g., deposition zone versus source zone).

Wind damage in riparian reserves and management zones occurs frequently in coastal BC (Mitchell 1995). Murtha (2000) found that 32% of the area of riparian reserves strips (24.4 km in total) had blown down (visible as holes on remotely-sensed images). Rollerson and McGourlick (2001) found 21% windthrow in riparian areas. In general, exposing pre-existing forest by removing adjacent forest (e.g., next to cutblock edges, retention patches and riparian strips) leads to windthrow in coastal British Columbia (Scott 2005, Lanquaye 2003 and Mitchell 2003). Windthrow affects some riparian management areas and not others.

Windthrow is a natural phenomenon. Environmental factors affecting windthrow include topographic exposure, stand characteristics and soil characteristics (MOF 2002; Dorner and Wong 2003). Ridgetops oriented perpendicular to prevailing winds and valley bottoms oriented parallel to prevailing winds experience the highest wind speeds. Harvesting creates openings in the forest and increases the exposure of residual trees to wind.

Stand density affects tree form and windthrow susceptibility (MOF 2002). In open stands, trees are exposed to wind and adapt by developing tapered stems and flat tops. In a closed canopy forest, trees develop tall, slender stems in order to compete for light and consequently have weaker stems that also act as longer levers when exposed to wind. Some tree species (e.g., hemlock) are more susceptible than others (Table 3 in Lanquaye 2003).

Poorly drained soils, soils with physical barriers that lead to restricted root depth, and low strength organic soils reduce the strength of tree anchorage (MOF 2002).

Riparian areas are particularly susceptible to windthrow. First, they are often wet and thus restrict rooting depth. Second, options to orient riparian reserve/management zone boundaries are limited by the path of the watercourse: windthrow in riparian strips correlates with the speed of wind blowing roughly perpendicular to the strip (Ruel et al. 2001, Moore 1977).

The consequences of different amounts of windthrow in riparian areas have not been well studied. One approach for estimating acceptable levels of windthrow uses unmanaged riparian forest as a benchmark: if windthrow in managed riparian forest falls within the range of natural conditions, then functionality should be also be near to natural.

4 Project objectives

This adaptive management plan aims to determine the extent to which riparian reserves and management areas suffer windthrow. To assess the consequences of windthrow in managed stands better, the background "natural" rate of windthrow will also be quantified. Specifically this project aims to answer the following three questions:

1. What proportion of the area of riparian reserves and management zones blow over?
2. How does windthrow vary among different types of riparian ecosystems?
3. What is the background ("natural") rate of riparian windthrow?

This is a descriptive, retrospective study, characterizing the condition of riparian forest under natural versus managed conditions. By determining the amount of riparian forest that remains standing, it reduces uncertainty about the relationship between unharvested riparian forest in the cutblock and riparian function. It will develop rather than test hypotheses.

Several options exist for extending this study:

- Develop a predictive windthrow hazard map to focus windthrow management efforts (see Appendix 2)
- Examine hydrological and/or ecological impacts of windthrow (e.g., in conjunction with Experimental Watersheds Program)
- Examine the accuracy of riparian reserves and management zones at capturing actual riparian forest (a different topic, but may be coordinated with this study for efficiency).

5 Potential benefits to management

The benefits of this study relate mainly to professional practice. Within limits, forestry practitioners have discretion over the exact location of riparian reserves and management zones and over the content of management zones. Because windthrow can negatively impact riparian areas, professional practice aims to design riparian reserves and management areas to limit windthrow. If this study suggests that windthrow is a problem, then steps can be taken to examine and potentially improve professional practice. For example, windthrow hazard maps may be developed to identify areas of special concern and alternative windthrow management practices can be tested.

Over the longer term, improved understanding about the necessary width and content of riparian management areas will influence the amount of timber available for harvest from riparian ecosystems. Part of this improved understanding is better estimates of how much windthrow can be expected under different conditions.

5.1 Information provided by this study

This study will clarify the magnitude of windthrow and provide an estimate of the proportion of riparian forest that may benefit from windthrow management.

5.2 Reliability of this study

This study should accurately measure both larger and smaller patches of windthrow, because it uses multiple, complementary sampling approaches.

5.3 Potential changes to management

If substantial windthrow exists, then a variety of windthrow mitigation practices should be tested for operational feasibility and cost within BCTS. General options for limiting windthrow include altering the exposure of residual trees to wind and modifying the susceptibility of residual trees (Bjorninen 2001). One of the most useful options for modifying wind exposure—orienting harvest boundaries—is not practically available in riparian areas, where stream course dictates reserve and management zone boundary locations. Other options include not harvesting the adjacent stand (e.g., in cases with high riparian values) or alternatively harvesting the entire riparian area (e.g., in cases where impacts of windthrow may be worse than those of harvesting; Bjorninen 2001). Management options that focus on residual trees include creating fine-scale irregularity in boundaries ("feathering") to alter stand-scale wind flow, and topping and pruning residual trees (Mitchell 1998).

5.4 Limits to management response

Windthrow management is limited mainly by the costs of management options and by moderate uncertainty about the long-term effectiveness of certain treatments (Mitchell 1988).

6 Target Audience

Minimizing windthrow and related impacts falls to the judgement of forest professionals. This study supports development of best practices in BCTS. It does not directly affect provincial policy. Results of this study will also be of general interest to coastal forestry practitioners (in companies and Forest Districts), in particular those working in the North Coast, because windthrow in riparian areas has not been extensively studied in coastal BC. First Nations with territories in the North Coast will also be interested in study results. First Nations have a particular interest in riparian management because it affects the culturally important fish resource.

7 Geographic scope

The exact study locations have not yet been finalized. Likely, this study will look for larger windthrow patches (remotely) across most of the BCTS operating area and smaller patches (using field sampling) in selected watersheds (e.g., Verney Canal area). Study results will apply best to nearby watersheds that experience the same prevailing wind patterns and have similar topography (and orientation to prevailing winds), soils and vegetation as the study watersheds.

8 Study Design and Methods

Methods presented here are meant to provide a general outline of the project—to be used for the purposes of preparing and evaluating a Request for Proposal. Final study design should be the responsibility of the researchers undertaking the project. Prior to preparing a Request for Proposal and particularly if this project is not implemented for several years, the latest information about windthrow in riparian areas should be examined and the scope of this project confirmed (e.g., check on status of ongoing research and monitoring projects by contacting the Windthrow Research Group at the University of British Columbia and the Forest and Range Evaluation Program).

Estimating the amount of windthrow requires a multi-scale sampling approach, particularly because the typically less-obvious "natural" levels of windthrow are to be estimated. Air photos (approx. 1:20,000) provide a relatively cheap means of sampling a large area, but cannot detect low levels of damage (Mitchell and Lanquaye-Opoku 2004). In general, larger patches of windthrow are detectible as gaps in the forest on air photos, however, windthrow-induced gaps can be hard to distinguish from natural gaps that arise for other reasons and windthrow-induced gaps along boundaries can be hard to distinguish from gaps created by harvesting, if original boundary locations are unknown. Downed wood is difficult to see on air photos. Small patches of windthrow (e.g., < 5 trees) can be detected by ground sampling. Low-level air photos also provide a promising means of detecting low levels of windthrow, but should be tested further (Price and Lloyd 2007) in this project. This project proposes three sampling methods, to be applied to managed and natural riparian forest:

1. Use air photos (or orthophotos) to identify large patches of windthrow.
2. Use low-level air photos (from helicopter) to identify smaller patches of windthrow.
3. Use ground sampling to quantify windthrow in sites sampled by low-level air photos.

The study divides into two phases, which can be pursued in different years. The first phase applies method one to a substantial portion of the operating area. The second phase identifies smaller windthrow patches, using method three, and also tests the ability of low-level air photos (method two) to identify smaller patches, in selected portions of the operating area.

8.1 Phase I. Identify larger patches of windthrow

8.1.1 Collate available data

This first step collates readily available data for selected watersheds (Table 1). Not all desired information may be available. The final selection of study watersheds will be based partly on the availability of information. Information gathered here will also be used in Phase II, where accessibility will be an important consideration.

Table 1. Information needed and potential sources[6]

Data	Purpose	Source
watershed boundaries for 3rd and 4th order watersheds	used to create distinct sample strata	Watershed Atlas, ILMB
water features	identify streams and other water bodies	TRIM, ILMB
elevation contours	determine stream gradient for stream classification	TRIM, ILMB
fish stream and/or riparian class (S1-S6) inventories	determine stream class	BCTS?
fans and floodplains	determine stream/riparian class	terrain maps (PEM is not usually sufficiently accurate), BCTS?
forest cover (age, vegetation cover and species composition)	identify large windthrow events (size, location, decade)	VRI, ILMB
cutblock/site maps (1: 5000)	identify riparian buffers not shown on forest cover	BCTS
Orthophotos	identify large windthrow events and verify forest cover maps	ILMB

[6] If maps of fish streams and riparian classes are not available, streams may be divided into classes based on gradient alone (i.e., stream morphology correlates with gradient).

8.1.2 *Identify sample sub-basins*

Identify 3rd and 4th order sub-basins that contain both natural and managed riparian areas. Randomly select a sample of these sub-basins for study. If sufficient sub-basins are available, consider stratifying sub-basins into classes based on orientation to prevailing wind (e.g., Figure 1 in Rollerson and McGourlick 2001)

8.1.3 *Classify stream reaches*

In order to compare windthrow under managed and unmanaged conditions in different types of streams, streams need to be classified. Streams should be classified by type (beyond S1 to S6), because ecological functions and processes, and possibly windthrow, vary among reaches. Streams can be classified in a variety of ways, but classification is limited by available data. Useful classification features include gradient, width, order, zone (e.g., transport versus source; CIT 2004), presence of fish, presence of gully or wetland and Biogeoclimatic Variant. Some or all of these features can be combined to define a reasonable number of stream types for subsequent analysis using techniques such as principle components analysis. Such remote classification of riparian forest is useful for monitoring, but needs field verification before being used in operational planning.

8.1.4 *Estimate windthrow using existing air photos*

Within sample sub-basins, identify and delineate windthrow patches on air photos along all riparian reserves and management zones. Then randomly select locations on photos and flag the nearest naturally-forested stream reach. Identify and delineate windthrow patches within 60m of selected streams. Estimate percent canopy loss in each windthrow patch.

8.2 *Phase II. Identify smaller patches of windthrow*

Phase II uses information generated in Phase I, describing different stream classes and sample sub-basins (8.1.1-8.1.3).

8.2.1 *Low-level photography*

Select stream reaches to sample using maps and air photos. Candidate watersheds, based on accessibility, occur near Verney Canal. Samples should come from sub-basins and ideally should be distributed equally among different stream reach classes (see Phase I). Select sites that meet one or more of the following three criteria:

- riparian buffers in or adjacent to cutblocks
- randomly selected unharvested reaches
- paired stream reaches (within cutblocks and above cutblocks in unharvested forest)

The first set of sites are used to estimate windthrow in managed riparian forest. The second set are used to estimate the natural windthrow rate. The third set provide treatment/control pairs that allow better estimates of the difference between managed and natural riparian forest (provided that adjacent cutblocks do not greatly affect natural riparian forest).

Photograph riparian strips from a helicopter. Locate sample points using a global positioning system (GPS) and maps. Take digital photos at approximately 300m above ground level with either a belly-mounted camera or with a photographer leaning out of the open helicopter door (observing appropriate safety precautions). It is important that the camera be horizontal to the ground. Record time or photograph number on the photo and use a voice recorder to link GPS coordinates to photo time or number. Periodically photograph landmarks to verify location.

Interpret photography. Identify and delineate windthrow patches. Estimate percent canopy loss in each patch. Summarize data for each stream reach.

8.2.2 Field plots

Select a sub-sample of photographed (low level) sites for field sampling. Investigate stand structure within managed and natural riparian forest, by counting the number of live trees by diameter class (e.g., 10-cm increments), snags by diameter and decay class, and downed wood[7] (originating within the plot) by diameter and decay class within 10 x 50m plots (see methods in Province of BC 1998). Note disturbance agent (e.g., windthrow, flooding, insects). Locate the plots parallel to the stream channel and with the midpoint 10m from the stream, hence examining tree structure from 5 – 15m from the water. Where riparian buffers are too narrow, place plots within the existing buffer, and decreased the width of the plot to 5m as necessary. Also record information on site series and stand age (based on a single core of a co-dominant tree), and coarsely assess the functionality of buffers with various levels of windthrow, considering bank stability, shade and in-stream structure.

Compare the amount of recent downed wood (decay class 1 and 2) in unharvested and buffer plots. To compare stand structure in unharvested and harvested riparian forest, look at the number of trees and the ratio of live to dead trees.

To search for further windthrow in managed riparian buffers, walk parallel to the stream for the length of the cutblock and record recent windthrow and estimate live tree density within a 10m strip.

[7] http://ilmbwww.gov.bc.ca/risc/pubs/teecolo/fmdte/cwd.htm

9 Budget

9.1 Phase I

Task	Project leader		Assistant		TOTAL
rate	*500*	*per day*	*400*	*per day*	
	days	**cost**	**days**	**cost**	
1. Aquire data					
GIS and paper maps			1.5		
Air photos (or orhophotos)			2		
Total Step 1	**0**	**$0**	**3.5**	**$1,400**	**$1,400**
2. Classify riparian areas					
select sample watersheds	1		0.5		
compile stream data from maps			4		
classify streams (e.g., statistically)	4				
map stream classes			3		
Total Step 2	**5**	**$2,500**	**7.5**	**$3,000**	**$5,500**
3. Estimate windthrow from air photos					
identify windthrow patches and estimate canopy loss	6	$3,000	6	$2,400	
Total Step 3	**6**	**$3,000**	**6**	**$2,400**	**$5,400**
4. Prepare report & extension material	**4**	**$2,000**	**1**	**$400**	**$2,400**
TOTAL PHASE I		**$7,500**		**$7,200**	**$14,700**

9.2 Phase II

Task	Project leader		Assistant		Helicopter		Boat/Truck		TOTAL
rate	*500*	*per day*	*400*	*per day*	*1100*	*per hr*	*150*	*per day*	
	days	**cost**	**days**	**cost**	**hours**	**cost**	**days**	**cost**	
1. Estimate windthrow from low-level photos									
identify sample sites	0.5								
take digital photos from helicopter	1		1		4				
identify windthrow patches and estimate canopy loss from low level photos	3		3						
Total Step 1	**4.5**	**$2,250**	**4**	**$1,600**	**4**	**$4,400**			**$8,250**
2. Estimate windthrow from field sampling									
identify sample sites	0.5								
sample plots	8		8				4		
data analysis	2		1						
Total Step 2	**10.5**	**$5,250**	**9**	**$3,600**			**4**	**$600**	**$9,450**
3. Prepare report & extension material	**5**	**$2,500**	**1**	**$400**					**$2,900**
TOTAL PHASE II		**$10,000**		**$5,600**		**$4,400**		**$600**	**$20,600**

BCTS will provide access to GIS data and existing air photos (this task may take several days and is not included in the budget). Multi-year funding should not be necessary for a given phase.

10 Schedule

Data collection should be scheduled to coincide with forest operations to reduce transportation costs. In particular, helicopter-based photography should coincide with other projects requiring a helicopter.

11 Project Team

The project team may be contractors or staff. Team members should ideally have skills in the following areas: hydroriparian ecology, windthrow ecology, GIS analysis, statistical analysis, photo interpretation, helicopter photography, and field data collection (particularly ecological surveys). The team should also be familiar with the challenges of working in coastal forests.

12 Partners

No partners have been identified yet. Steve Mitchell and colleagues at UBC are currently examining windthrow in riparian areas and may be interested in collaborating over the long term.

13 Evaluation of Management Implications

Estimates of windthrow in riparian areas will be used to reduce uncertainty about the link between riparian management and riparian function. If windthrow is minimal, management direction is confirmed, however, the Central and North Coast Knowledge Summary (Price et al. 2009) should be updated to show reduced uncertainty related to windthrow. Significant levels of windthrow suggest that riparian management may not achieve intended objectives. Ecological consequences will depend on the extent (number and size of patches), distribution (relative to different riparian classes) and severity (percent canopy loss) of windthrow. Hydrologists and terrestrial ecologists may be able to estimate impacts and/or may suggest additional studies. Windthrow experts and practitioners can identify options for reducing windthrow.

14 Management Feedback

This study will identify the magnitude of windthrow in different stream types. It will identify areas (within the study and similar areas outside the study) that would benefit from windthrow management. Improving best practices related to windthrow management should begin with seeking advice from windthrow experts. More formal windthrow hazard mapping may be warranted and likely a series of pilot studies to test different windthrow management options will be needed. BCTS should consider allocating a small budget to pilot projects (or operational trials) to ensure some incentive exists to try new management approaches. Policy recommendations are unlikely.

15 Academic products

Results of this study should be presented at a management-oriented conference and published in a management-oriented journal (e.g., BC Journal of Ecosystem Management).

16 Extension products

Study results should be of interest to licensees and practitioners along the coast. The full report should be made available on a website (ideally supported by the coastal adaptive management initiative). Over the longer term, workshops may be used to discuss and develop appropriate windthrow management strategies.

Literature Cited.

Bjorninen, A. 2001. Windthrow in riparian leave strips in the Coastal Western Hemlock Biogeoclimatic Zone in British Columbia. BSc. Forestry Graduating Essay, Faculty of Forestry, UBC, BC.

CIT (Coast Information Team). 2004. Hydroriparian planning guide. Victoria, BC. http://ilmbwww.gov.bc.ca/citbc/ebmhydr.html

Dorner, B., and C. Wong. 2003. Natural disturbance dynamics in the CIT area. Report to the CIT.

Lanquaye, 2003. Empirical modelling of windthrow risk using geographic information systems. MSc Thesis, Faculty of Forestry, UBC, BC.

Mitchell, S.J., 1995. A synopsis of windthrow in British Columbia: Occurrence, implications, assessment and management. *In* Wind and Trees. M.P. Coutts and J. Grace (Eds.). Cambridge University Press, Cambridge, UK.

Mitchell, S.J. 1998. Windthrow risk assessment and management in riparian areas in coastal British Columbia. Pages 259-262 *in* M.K. Brewin and D.M.A. Monita, tech. coords. Forest-fish conference: land management practices affecting aquatic ecosystems. Proc. Forest-fish Conf., May 1-4, 1996, Calgary, Alberta. Nat. Resour. Can., Can. For. Serv., North For. Cent., Edmonton, Alberta, Inf. Rep NOR-X-356.

Mitchell, S. 2003. Windthrow hazard mapping using GIS, Weyerhaeuser Stillwater Timberlands. Report to Weyerhaeuser Limited, Nanaimo BC.

Mitchell, S. and N. Lanquaye-Opoku. 2004. Windthrow hazard mapping using GIS, Canadian Forest Products TFL 30, McGregor Model Forest. Report to Canfor, Prince George, BC.

MOF (Ministry of Forests). 2002. Windthrow course. Ministry of Forests, BC. http://www.for.gov.bc.ca/hfp/training/00015/index.htm

Murtha, P.A. 2000. Monitoring riparian leave strips with multi-temporal Radarsat C-band satellite data. *In* L. M. Darling, editor. Proceedings of a Conference on the Biology and Management of Species and Habitats at Risk, Kamloops, B.C., 15 - 19 Feb.,1999. Volume Two. B.C. Ministry of Environment, Lands and Parks, Victoria, B.C. and University College of the Cariboo, Kamloops, B.C. 520pp.

Price K. and R. Lloyd. 2007. Riparian ecosystems and fish habitat: Babine Watershed Monitoring Trust Project 2005-1, Smithers, BC. http://www.babinetrust.ca/documents.html

Price K., S. Tyler, D. Daust and C. Soto. 2009. Adaptive Management Framework for the Central and North Coast of British Columbia—Knowledge Summary: Information used for assessing probability of success and uncertainty for EBM strategies. Report to the EBM Working Group.

Province of B.C. 1995. Riparian management area guidebook. http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/riparian/rip-toc.htm

Province of B.C. 1998. Field manual for describing terrestrial ecosystems. Land Management Handbook #25, Victoria, BC. http://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh25/Lmh25.pdf

Rollerson, T. and K McGourlick. 2001. Riparian windthrow—Northern Vancouver Island. In S.J. Mitchell and J. Rodney. Windthrow Assessment and Management in British Columbia. Proceedings of the Windthrow Researchers Workshop Jan 31 – Feb 1, 2001. Dept. of Forest Sciences, UBC, BC and Forestry Continuing Studies Network, Vancouver, BC.

Ruel, J.C., D. Pin and K. Cooper. 2001. Windthrow in riparian buffer strips: effect of wind exposure, thinning and strip width. Forest Ecology and Management, Vol. 143-1, pp. 105-113.

Scott, R. 2005. Modelling windthrow in coastal variable retention using tree, neighbourhood and stand attributes. MSc Thesis, Faculty of Forestry, UBC, BC.

Appendix 1. Selected Riparian References used in Central and North Coast Knowledge Summary

Church, M and B. Eaton. 2001. Hydrological effects of forest harvest in the Pacific Northwest. Technical Paper #3 for Hydroriparian Planning Guide.

CIT (Coast Information Team). 2004. Hydroriparian planning guide. Victoria, BC. http://ilmbwww.gov.bc.ca/citbc/ebmhydr.html

Price, K. and Church, M. 2002. Risk to ecosystem functions. Summary of expert workshops. Hydroriparian Planning Guide Background Information. Participants: Gordon Butt (Madrone Consultants); Dan Hogan (Ministry of Forests); Peter Lewis (Ministry of Sustainable Resource Development); Michael Miles (M.A. Miles and Assoc.); Kyle Young (Simon Fraser University); Kristie Trainor (UBC); Nick Winfield (Department of Fisheries and Oceans), Michael Church (UBC), Jim Pojar (Ministry of Forests), Allen Banner (Ministry of Forests), Laurie Kremsater (UBC), Doug Steventon (Ministry of Forests), Rachel Holt (Veridian Ecological Consulting), Karen Price (consultant)

Price, K and McLennan, D. 2002. Impacts of Forest Harvesting on Terrestrial Riparian Ecosystems of the Pacific Northwest. Technical Paper # 7 for Hydroriparian Planning Guide.

Young, K. 2001. A review and meta-analysis of the effects of riparian zone logging on stream ecosystems in the Pacific Northwest. Technical Paper #4 for Hydroriparian Planning Guide.

Appendix 2. Extending study to predict windthrow hazard

The main study, described above, characterizes the extent to which windthrow is a problem. This potential extension asks whether windthrow hazard can be predicted.

Windthrow management options are limited for riparian areas and can be expensive. An ability to predict windthrow hazard can focus management effort and minimize costs. Recently, Steve Mitchell (UBC Forestry) and colleagues have developed quite accurate models (e.g., 72%, Mitchell 2003) to predict windthrow along cutblock boundaries and in partial retention blocks in coastal and interior forests of British Columbia (e.g., Mitchell 2003, Mitchell and Lanquaye-Opoku 2004, Lanquaye 2003, Scott 2005). This extension study aims to answer the following two questions:

- What remotely-sensed environmental factors, correlate with windthrow in selected North Coast watersheds?
- Can windthrow hazard be predicted reasonably accurately and what does the windthrow hazard map look like?

This potential extension study is not described in detail in this report. It should be designed in collaboration in Steve Mitchell, who is a BC expert on windthrow hazard mapping. Mitchell and colleagues have used air photo interpretation of windthrow and GIS analysis of inventory data to develop predictive models (for cutblock boundaries and retention patches). An example of potential methods follows:

Table 1. Summary of procedures used to build the windthrow risk model[8].

1 Information Assembly

- Obtained GIS layers for ecosystem, stand, logging history, roads and hydrology data.
- Obtained 1:5,000 salvage paper maps.
- Obtained 1:15,000 aerial photographs.
- Obtained TRIM point elevation data.
- Obtained BC Hydro wind resource data (1km scale).

2 Data Translation to ArcView format

- Coverages received in ArcInfo interchange (*.e00) format were converted to ArcView shape files using ArcView import wizard.

3 Windthrow detection and mapping

- Identified potential edge windthrow on 1:20,000 color aerial photos taken in August 2001.
- Digitized windthrow on-screen using ortho-image made up from August 2001 photographs as a base.
- Estimated percent canopy loss within each windthrow polygon.
- Corrected forest cover and logging history polygons to match opening boundaries on orthophotos.
- Mapped or corrected retention patch locations to orthophotos.
- Sub-divided retention patch polygons according to percent crown loss.

[8] from Mitchell, S. 2003. Windthrow Hazard Mapping using GIS, Weyerhaeuser Stillwater Timberlands. Report to Weyerhaeuser Limited, Nanaimo BC.

4 Creation of sample units

- Created buffer of 25m along the cutblock boundaries from logging history coverage.
- Divided each buffer into 25m long*25m deep segments.
- Wrote Avenue Scripts and calculated edge exposure scores using UTM coordinates of segments.

5 Determination of topographic variables

- Produced Digital Elevation Model (DEM) using interpolation between TRIM elevation points.
- Determined topographic variables aspect, elevation, slope.
- Calculated TOPEX-to-distance scores and ground curvature.

6 Construction of segment database

- Overlaid coverages with edge segments and extracted segment database.
- Kept segments with forested boundaries (SI >= 7, Age >=20) for analysis (14,000 segments).
- Deleted points crossing harvested areas.

7 • Initial data analysis

- Imported database into SAS.
- Calculated % of segment damaged and created set of response variables based on % of segment area damaged, and % of canopy loss.
- Built and graphed contingency tables for damage outcome (low severity damage threshold, WTT310, see below) versus independent variables
- Correlation between independent variables
- Spatial correlation

8 Model fitting and testing

- Creation of model fitting and model testing data sets independent of each other in terms of spatial correlation. Created 125m*125m panels and retained only 1 segment per panel (3000 segments).
- Randomly assigned these segments to 3 datasets.
- Fit logistic regression models using dataset one.
- Tested predictions using other 2 datasets.
- Used variables from best performing models to refit overall model using complete dataset.
- Repeated fitting process for 25m buffer with 3 different response variables:

  > 30% of segment area damaged and >10% crown loss (WTT310, low severity threshold),

  > 50% of segment area damaged and >50% crown loss (WTT550, moderate severity threshold)

  > 90% of segment area damaged and >50% crown loss (WTT950, high severity threshold)