Coast Information Team

c/o Cortex Consultants Inc., 3A–1218 Langley St. Victoria, BC, V8W 1W2
Tel: 250-360-1492 / Fax: 250-360-1493 / Email: info@citbc.org

February 18, 2004

The Coast Information Team is pleased to deliver the final version of the *Hydroriparian Planning Guide (February 2004)*.

The Coast Information Team (CIT) was established to provide independent information for the central and north coasts of British Columbia and Haida Gwaii/Queen Charlotte Islands using the best available scientific, technical, traditional and local knowledge. The CIT was established by the Provincial Government of British Columbia, First Nations, environmental groups, the forest industry, and communities. It is led by a management committee consisting of representatives of these bodies; and is funded by the Provincial Government, the environmental groups and forest products companies, and the Federal Government of Canada. The technical team comprises nine project teams consisting of scientists, practitioners, and traditional and local experts. CIT information and analyses, which include this *Hydroriparian Planning Guide*, are intended to assist First Nations and the three ongoing sub-regional planning processes to make decisions that will achieve ecosystem-based management (as per the April 4th 2001 Coastal First Nations—Government Protocol and the CCLRMP Interim Agreement).

In keeping with the CIT's commitment to transparency and highly credible independent analysis, the *Hydroriparian Planning Guide* underwent an internal peer review and the CIT's independent peer review process chaired by University of Victoria Professor Rod Dobell. Peer reviews of the draft document and the authors' response are found at http://www.citbc.org/abostru-comm.html. The final document reflects changes made by the authors to address peer review comments.

We encourage all stakeholders involved in land and resource management decision-making in the CIT area to use the information and recommendations/conclusions of the *Hydroriparian Planning Guide* in conjunction with other CIT products as they seek to implement EBM and develop EBM Land Use Plans. We are confident that the suite of CIT products provides valuable information and guidance on the key tenets of EBM: maintaining ecosystem integrity and improving human wellbeing.

Sincerely,

Robert Prescott-Allen, Executive Director
on behalf of the CIT Management Committee:
Ken Baker, Art Sterritt, Dallas Smith, Jody Holmes, Corby Lamb
Graem Wells, Gary Reay, Hans Granander, Tom Green, Bill Beldessi

Coast Information Team

Hydroriparian Planning Guide

The Hydroriparian Planning Guide Work Team

January 30, 2004

Acknowledgements

Members of the *Hydroriparian Planning Guide* Work Team and contributors to this Guide were Laurence Brown, Michael Church, Herb Hammond, Karen Price, Warren Warttig, Nick Winfield, and Ken Zielke. The group facilitator was Alex Grzybowski. Kristie Trainor provided technical support for the team's activities.

Preface

30 January, 2004

The *Hydroriparian Planning Guide* Work Team hereby presents its *Hydroriparian Planning Guide* for the Central and North Coasts and Haida Gwaii/Queen Charlotte Islands of British Columbia. This document has been developed, at the direction of the Coast Information Team, over two years by successive working groups. Those members of the final Work Team who were contributors to this Guide are listed inside the cover.

Anyone appraising or using this Guide must bear in mind a number of important contextual issues. Most important, it must be recognized that, despite substantial experience in managing forest lands in coastal British Columbia, the scientific basis for establishing rational management procedures remains uncertain in most respects. Many of the bases for specific hydroriparian management proposals made in this report remain to be tested against further experience. This circumstance has dictated several major features of the Guide.

- Management options are presented in terms of basic precautionary guidelines that the work team judges will assure sustainable management of the forest, or alternatively in terms of actions that will secure greater resource values but that recognize an element of risk of environmental damage.
- To ensure that scientific knowledge will increase and will be incorporated into forest management, risk-taking strategies require managers to adopt adaptive management protocols.
- The guidelines are functional and adaptive, rather than being fixed rules. This allows additional experience and learning to be incorporated immediately into continuing forest management. In particular, the risk curves in this Guide should be regarded as hypotheses for testing, with the possibility to modify them regionally or locally when documented evidence is compiled indicating that this is an appropriate action.

One advantage of attempting to write guidelines for sustainable forest management in the absence of a firmly established scientific basis is that the guidelines themselves direct attention to those aspects of forest and ecological science that are most urgently in need of additional investigation. The Work Team recognizes that the state of supporting science must improve before ecologically based forest management can be assured. The Work Team also expects that scientific work will be productively directed toward issues raised by the guidelines presented in this report.

Rational management of the forests requires that basic information about the land and forest be available. In framing the guidelines, the Work Team assumed that established forest inventories, including TRIM, terrain mapping, and some form of ecological mapping, will be available. This Guide also incorporates the assumption that best management practices will be followed so that, for example, roadways will be constructed and maintained to high engineering standards.

The *Hydroriparian Planning Guide* is designed to support the broader *EBM Planning Handbook,* also under development for Central and North Coast and Haida Gwaii/Queen Charlotte Islands forest management. Accordingly, this Guide does not incorporate the social and economic considerations that will be an important part of management decisions, particularly for levels of risk needed to realize desired resource values. Hence, the *Hydroriparian Planning Guide* is not a stand-alone forest management handbook.

This Guide emphasizes planning at the watershed level, because, in many ways, the watershed is the fundamental unit of landscape function. This planning is contextualized by considering subregional- and landscape-level planning criteria that are consistent with what is desired at the watershed level. The Guide also continues planning to the site level, to show how watershed-level plans affect, and can be modified by, site-level information. However, the Guide is not an operational field manual.

Scientific information that forms the basis for the management proposals in this Guide is summarized in a series of seven technical reports that were commissioned by the Work Team, and in certain other documents commissioned for the North Coast LRMP (see Appendix 1 for a list of these reports). The technical reports are internal working documents of the Work Team. Accordingly, they have not been externally peer-reviewed. They do, however, summarize the peer-reviewed literature that forms the basis of our current knowledge. Knowledge moves on, though. More recently, a conference held at the University of British Columbia in February 2003, has examined knowledge of headwater stream systems, and a new set of review papers is forthcoming to update the scientific basis for resource management around forest streams.

The Work Team hopes that the *Hydroriparian Planning Guide* will prove to be a practically useful report that serves to move forward knowledge and methods for sustainable, ecosystem-based forest management.

Table of Contents

1.1 List of Figures

1.2 List of Tables

1 Introduction/Executive Summary

1.1 Purpose

The *Hydroriparian Planning Guide* (the Guide) forms one component of the **Ecosystem-based Management** Framework designed to "*ensure the coexistence of healthy, fully functioning ecosystems and human communities*" in coastal British Columbia.[1] It provides a description and rationale of the hydroriparian concepts and methods presented in the *Ecosystem-based Management Planning Handbook* (referred to hereafter as *EBM Planning Handbook*).[2]

The purpose of this Guide is to facilitate the design of forest management plans that are likely to maintain **hydroriparian functions** at a **watershed** scale in Central and North Coastal British Columbia and Haida Gwaii/Queen Charlotte Islands. It specifies and describes a series of steps, consistent with those in the *EBM Planning Handbook*, needed to fulfill this aim.

1.2 Audience

This *Hydroriparian Planning Guide* has two principal audiences:

1. participants at Land and Resources Management Planning (LRMP) tables, or equivalent bodies, and First Nations Land Use Planning tables for whom the Guide will provide information and assistance toward managing risks associated with forest land use at a strategic level in a way that will effectively link to more detailed levels of planning;
2. forest planners who require advice and assistance to design practices to achieve specified acceptable levels of risk.

The document presents the full rationale and bases for the planning process, and assumes that readers have some level of expertise. Nevertheless, many kinds of expertise are required in forest land management, so it is supposed that few readers will be familiar with all the topics discussed. Accordingly, Appendix 7 lists a glossary of technical terms. The first occurrence in the text of each term defined in the glossary is signified by bold type. This document is not an operational field guide.

1.3 Hydroriparian Ecosystems

Hydroriparian ecosystems consist of aquatic ecosystems plus those of the adjacent terrestrial environment that are influenced by and influence the aquatic system. Such ecosystems occur wherever land contacts water bodies in the earth's surface environment. They extend along stream courses from steep alpine headwaters to the ocean, transporting water, sediment, nutrients, organisms, and wood through watersheds. They include river floodplains and extend around lakes and wetlands, and along estuarine and ocean shores to the edge of reciprocal terrestrial and aquatic influences. They extend vertically below ground into a water-saturated zone inhabited by invertebrates and microbial organisms. Hydroriparian ecosystems contain

[1] *Ecosystem-based Management Framework Draft 4*. January 27, 2003.

[2] *Ecosystem-based Planning Handbook*. Draft. January 2004.

much of British Columbia's **biodiversity** and represent the most productive part of the **landscape,** including the most productive forest **sites**, particularly in riverine floodplains. Like all ecosystems, hydroriparian ecosystems continually change, modified by disturbance effects of flooding, erosion, and sedimentation and the ecological processes of recovery and succession. Appendix 2 lists the characteristics of important hydroriparian ecosystems of the CIT region.

Hydroriparian zones are the physical land and water surface areas occupied by biophysical hydroriparian ecosystems. They carry water from the surface of the land, the quality of which is critical to safeguard. British Columbia's streams and lakes contain diverse and valuable fisheries. In the wet Central and North Coast of British Columbia (including Haida Gwaii/Queen Charlotte Islands), the distinction between upland and wetland is often unclear, and riparian ecosystems can extend considerably beyond channels and wetlands. To ensure healthy fish habitat requires that land development practices be managed to maintain all hydroriparian ecosystem functions.

To meet the objective of maintaining the functions of hydroriparian ecosystems, hydroriparian zones must be defined with those functions in mind. For practical purposes, hydroriparian zones are delineated as extending to the edge of the influence of water on land defined by plant community (including high-bench or dry floodplain communities) and/or landform (e.g., gullies) plus one-and-a-half site-specific tree heights (horizontal distance) beyond. Furthermore, it is assumed that hydroriparian zones and hydroriparian ecosystems are coextensive, but it is necessary to recognize that some hydroriparian ecosystem characteristics (such as the range of non-obligate riparian animals) cannot practically be delimited.

1.4 Approach

Land managers face a fundamental problem in that we have imperfect knowledge about land resources and their associated ecosystems. Decisions about management must be made without complete information about land history and current condition. Likely outcomes of particular resource development strategies are often even less clear. The scientific bases for the approach to forest land management presented in this Guide are contained in seven technical background papers[3] that detail aspects of hydroriparian ecosystems, list potential management impacts, and compare management policies among jurisdictions. The papers were prepared in 2001 and 2002 and represent the state of science at that time. The information they contain, insofar as it is drawn from studies of the British Columbia landscape, largely predates application of the current Forest Practices Code. However, much of the information in any case derives from elsewhere in the Pacific Northwest, where land management regulations are quite different. Because of these circumstances, and because the science is continually developing, substantial scientific uncertainty attends the proposals for land management put forward in this Guide. For this reason, precautionary and risk-based approaches to land management are adopted, the latter accompanied by a requirement to institute **adaptive management** to ensure that relevant knowledge will continue to be systematically developed from analysis of forest management actions, and promptly applied.

[3] Titles listed in Appendix 1.

The implications of managing the hydroriparian zone extend to the entire **drainage basin**. Because water and sediments move downhill, impacts at a particular place in the hydroriparian ecosystem are determined by events in the entire upstream system. Furthermore, water, sediments, wood, nutrients, energy, and organisms themselves move laterally into and out of the hydroriparian system, as well as along it. Hence, land management in the entire drainage basin has implications for successful management of the hydroriparian zone.[4] These implications are discussed by defining "**hydroriparian process zones**" that partition the drainage basin into discrete source, transport, and deposition zones with respect to the movement of water, sediment, and organic material (full definitions are given in Section 6.1.2). In each zone, the movement of sediment and organic material toward and through streams and standing water occurs in distinct ways. A watershed spatial scale with a corresponding temporal scale of centuries is consistent with ecosystem-based management of hydroriparian ecosystems.

Resource development changes patterns of material and energy flow and storage in the environment. These changes can, in turn, pose risks to continued ecosystem viability. **Risk** is defined, following the definition adopted by the B.C. Ministry of Water, Land and Air Protection,[5] as exposure to danger or loss. This definition is different than an industrial definition of risk, which entails the probability of loss multiplied by the consequence of the loss, often expressed as the value of the loss. Valuation of ecosystems is difficult and is, in the end, a social judgement rather than an expert procedure. In this Guide, then, risk signifies the probability that loss of ecosystem functions and reduction of ecosystem viability will result from some management action. In an ecosystem-based management philosophy, such losses must be minimized. Hence, the **risk assessment** procedure that is introduced in this Guide for forest land management in the CIT area is based on the potential for loss of ecosystem structure and function.

Although the risk-assessment approach described in this Guide represents current scientific knowledge (based on literature reviews in the technical reports) modified for the region by expert opinion (based on workshops with topic experts familiar with coastal ecosystems), the risk relationships provided must, due to limited scientific knowledge, be considered as hypotheses requiring testing. When this Guide was developed, the specification of quantitative risk curves for application to forest management planning decisions was still novel. Very few data were presented appropriately for developing the curves; hence there is substantial reliance on expert opinion. In most cases, data were insufficient to draw different curves for different landscapes, watersheds, or ecosystems, but available experience and common sense may dictate immediate modifications in landscapes of a particular character. Extensive empirical testing and refinement of the risk curves are necessary. Carefully designed adaptive management experiments and monitoring will be critical to improve the general curves and to design suites of curves that can be applied to different types of landscapes, watersheds, and ecosystems. Providing that the rationale is documented and the newly drawn curves are used as a basis for adaptive management, such refinements are within the intent of the Guide.

Sometimes, information is insufficient to assess risk with sufficient accuracy. In this case, ecosystem-based management requires that a precautionary approach be adopted. Such an

[4] *Technical Report 3*.

[5] See B.C. Ministry of Environment, Lands and Parks (2000).

approach adopts management procedures that are unlikely to pose significant risk to ecosystem function, even though thresholds for substantial change are not known. In this circumstance, failure to adopt precautionary procedures may result in substantial loss of resources in the long term. **Precautionary** management **guidelines** are conservative management recommendations based on forest management and research experience to date, as summarized in several of the supporting technical reports. The precautionary guidelines in the Guide are consistent with the risk curves presented. Curves redrawn for local use should not be used to alter the precautionary guidelines, intended for application across the CIT region, until scientific knowledge provides sufficient certainty.

Both risk-based and precautionary approaches to management are based on planning indicators. An **indicator** is a measure of environmental condition. A planning indicator is a measure that can be obtained *before resource extraction* activities begin. Indicators are selected to be accessible (information is available), information-rich (relatively few indicators carry the necessary information), relevant (they pertain to planned activities), and economical.

A further consequence of imperfect knowledge is that systematic efforts must be made to improve knowledge of the forest environment in the region, and of the effects of forest land management. Accordingly, it is recommended that, whenever feasible, forest management actions be carried out within "adaptive management," which is a process of "learning by doing." Properly applied, adaptive management entails the establishment of formal experimental techniques, including identifying a range of treatment options and selecting replicated treatments and controls, to ensure that critical comparative information is obtained to discriminate between desirable and undesirable management actions. Because risks associated with forest harvesting are themselves imperfectly known, adoption of the risk-assessment approach requires technical support and a commitment to adaptive management and appropriate monitoring. Adaptive management is also encouraged when development follows precautionary guidelines.

This Guide is designed to evolve as knowledge improves. In particular, the risk curves forming the basis for the risk assessment represent hypotheses to be tested and refined through use of this Guide.

1.5 Assumptions

Some important assumptions underlie the approach to hydroriparian management proposed in this Guide.

- the procedures proposed are appropriate to apply everywhere in the Central and North coasts and on Haida Gwaii;
- organisms are adapted to the contemporary regime of natural disturbances in the region;
- **natural disturbance regimes** provide a basis for judging the comparative impact of proposed management actions;
- drainage basins are fundamental units of ecological organization of the landscape;

- the hierarchical organization of drainage basins in the landscape requires a hierarchical organization of planning and management through successive scales from subregion to work site; and
- expert judgements offer a valid basis for estimating risk in the absence of documented results gathered for the purpose.

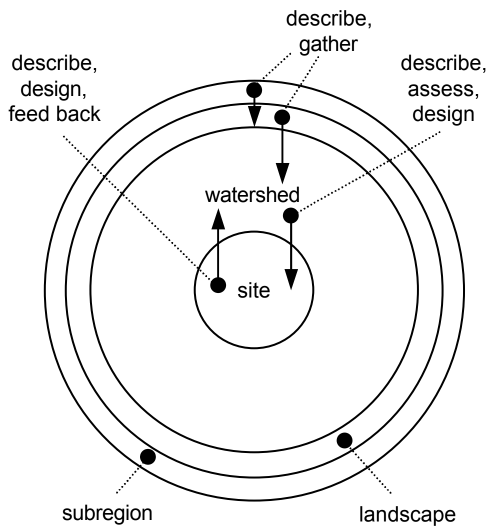
1.6 Overview of Guide

Because of the links between hydroriparian zones and entire drainage basins, and because of the relative independence of entire drainage basins, the *Hydroriparian Planning Guide* focuses on watershed-level planning. Direction is also provided to connect watershed-level plans to site-level planning. Accordingly, a set of procedures is described to help design watershed and site-level plans to manage for a consciously chosen level of risk to hydroriparian function.

Watersheds are situated in larger landscapes. Planners (both land-use planning tables and forest planners) use information gathered at four scales (**subregion,** landscape, watershed, site; Figure 1) to assess risks and opportunities associated with forest land use. At the subregional and landscape levels, steps are limited to describing the area and gathering existing information. At the watershed level, additional steps assess risk to hydroriparian functions and design a watershed plan. At the site level, steps include designing a site plan and ensuring that site information is passed back to higher levels. There is some flexibility within lower levels (watershed, site) if risks remain acceptable at higher levels (subregion, landscape), and if ecosystem representation is not undesirably changed. For example, within a landscape, low- or no-risk management options may be chosen for some watersheds, while higher-risk options are adopted in similar ecosystems elsewhere.

Similar opportunities may be available within watersheds to manage risk differently at different sites. Carefully designed variation in practices and risk can facilitate learning within an adaptive management framework. In general, more sensitive (physically and biologically) ecosystems (at any scale) will be managed for low risk.

Figure 1 **Framework of the hydroriparian planning process.** The width of each band represents the emphasis placed at each spatial scale.



LRMP tables, or equivalent bodies, and First Nations Land Use Planning teams will first set risk targets within the subregions and landscapes in their planning area to guide decisions on risk at lower levels. They may further set targets for specific watersheds or hydroriparian ecosystems (e.g., floodplains). Planning groups will also be responsible for committing to the adaptive management strategy necessary for use with the risk assessment procedures.

Consequently, although the *Hydroriparian Planning Guide* focuses on watershed-level planning, the proposed procedures require that landscape-level planning occur (as discussed in the *EBM Planning Handbook*). This Guide includes the requirement to incorporate the zoning and reserves that are created through other planning processes and other levels of planning. Although four distinct scales of activity are considered, the hierarchical organization of drainage basins means that processes and functions vary continuously over a range of scales. Landscape- and watershed-level planning activities, in particular, will tend to merge together.

Table 1 lists precautionary guidelines and planning steps for meeting hydroriparian objectives. All guidelines apply at the watershed scale unless otherwise noted and assume that information about the condition and character of the subregion and landscape has been considered before watershed-level planning.

The process described in the *Hydroriparian Planning Guide* consists of the following four stages, each of which incorporates a number of steps:

1. Define subregion
    1.1. determine subregion of interest
    1.2. describe subregion character and condition
    1.3. plan adaptive management strategy

2. Define landscape
   2.1. determine landscape of interest
   2.2. describe landscape character and condition
   2.3. identify and assess risk to **rare ecosystems,** biodiversity, and stream channel morphology
   2.4. design adaptive management procedures
3. Develop watershed plan
   3.1. develop interpretative maps of watershed character and condition
   3.2. determine targets for retention and development based on precautionary guidelines or risk assessment
   3.3. design reserves (the "hydroriparian ecosystem network") and harvestable area
   3.4. develop monitoring plan for adaptive management within the watershed
4. Develop site plan
   4.1. assess in the field, and revise the components of the hydroriparian ecosystem network as needed
   4.2. establish site-level reserves, and retention and management zones necessary to protect hydroriparian ecosystem function(s)
   4.3. identify harvest area (cutblock or multiple cutblock) components
   4.4. integrate site-level information into watershed-level plan and into monitoring and adaptive management plans
   4.5. enter specific information into a hydroriparian database

Chapters 2 and 3 of this Guide describe the risk assessment procedure, and provide a framework for adaptive management, respectively. Chapters 4 through 7 each describe a stage of the planning process.

The seven appendixes contain additional background information:

1. References
2. Characteristics of coastal hydroriparian ecosystems, including stream, wetland, and marine ecosystems
3. Recovery from disturbance: An example
4. Abundance, importance, and influence of hydroriparian ecosystems in coastal regions
5. Characteristics of ecological subregions
6. Sample watershed plan
7. Glossary

Table 1 Precautionary guidelines and planning steps for meeting hydroriparian objectives.

Objective	Indicators	Units for analysis	Precautionary guidelines	Planning steps
Maintain **hydrological regime**	rate of cut (%)	sub-drainage basin down to 1,000 ha within watershed	Rate of cut <1% per year of forested area averaged over 20 years	Summarize area harvested over time (current and planned)
Maintain **stream morphology**	index of road length + area cut in terrain classes IV and V	sub-drainage basin and watershed	Reserve all **wetlands,** active fluvial units, and floodplains of unknown activity including buffer Reserve all class IV and V terrains that are located in positions such that a surcharge of sediments may be delivered to any stream channel	Identify units Map preliminary fixed-location reserves Revise based on field assessment For risk assessment procedure,[a] estimate indicator value and reserve areas as required
Maintain bank stability	% deviation from natural proportion of standing forest along stream course	transportation and deposition zones	Reserve buffer around all streams in transportation and deposition zones	Create default GIS buffer around hydroriparian ecosystems Design windfirm buffer after field assessment For risk assessment procedure, estimate planned deviation from natural riparian forest and plan buffers as required
Provide downed wood	% deviation from natural proportion of old **riparian forest** in transportation and deposition zones % forest younger than 30 years in source zone	process zones within watershed	Maintain <20% deviation from natural riparian forest[b] in transportation and deposition zones Maintain <30% of forest younger than 30 years in source zone	None necessary if precautionary guidelines for hydrology and bank stability have been followed Otherwise, calculate deviation from natural riparian forest

[a] Risk curves for use with risk assessment are presented as Figures in Chapter 2.

[b] Sufficient information exists to calculate the amount of old riparian forest that occurs with natural disturbance (Table 2). Estimates of the natural amount of deciduous forest and of equivalent old forest require further development.

Table 1 continued

Maintain **high-value fish habitat**	presence of development activities that have impacted high-value fish habitat deviation from natural proportion of riparian forest cover; barriers to access; deviation from natural levels of sedimentation	watersheds within landscape habitat within watershed	Landscape scale: Create watershed-scale refugia until habitat recovery has occurred in other watersheds within the landscape Watershed scale: Reserve all high-value fish habitat and adjacent areas from development Limit disturbance to 10% of forest area per 3-year period in small watersheds (<1,000 ha) with high-value fish habitat Deactivate road networks after harvesting	Determine need for watershed refugia and map refugia as necessary Apply precautionary guidelines for rate of cut in small watersheds Plan for road deactivation
Provide riparian connectivity	% streams with natural cover along length	process zone within watershed	Maintain >60% of streams within a process zone with natural levels of cover	Analyze existing reserve network for connectivity and revise as necessary
Maintain characteristic **ecosystem productivity**	deviation from natural proportion of riparian forest by hydroriparian ecosystem	hydroriparian ecosystem	See coarse filter hydroriparian biodiversity	None necessary. Guidelines and risk assessment identical to those under biodiversity

Table 1 continued

Maintain **coarse filter** hydroriparian biodiversity	deviation from natural proportion of riparian forest	hydroriparian ecosystem within subregion and watershed	Subregional scale: Maintain <3% deviation from natural riparian forest on **estuaries**, in **karst** landscapes and next to small steep streams with high susceptibility to debris flow Maintain <10% deviation from natural riparian forest next to floodplains, fans, **forested swamps,** and small steep streams with distinctive **microclimate** Maintain <30% deviation from natural riparian forest around remaining hydroriparian ecosystems Watershed scale: Maintain <10% deviation from natural riparian forest on estuaries, in karst landscapes, and next to small steep streams with high susceptibility to debris flow; meet subregional target across all watersheds Maintain <50% deviation from natural riparian forest next to floodplains, fans, forested swamps, and small steep streams with unique microclimate; meet subregional target across all watersheds Maintain <70% deviation from natural riparian forest around remaining hydroriparian ecosystems; meet subregional target across all watersheds Represent site series within reserves according to their naturally-occurring proportion	Calculate area of each hydroriparian ecosystem to reserve according to precautionary guidelines or risk assessment Calculate area of reserves already mapped for other objectives and add area as necessary Design small-stream reserves within watersheds based on distribution, representation, and terrain Identify small streams with high susceptibility to debris flow or with unique microclimate during site assessment Analyze designed reserve network for representation and revise as necessary

2 Determining Risk to Hydroriparian Functions and Ecosystems

2.1 Introduction

This chapter lists the hydroriparian functions of concern in the CIT region, presents the concept of risk as used in this Guide, and provides risk curves and associated precautionary guidelines for each function or ecosystem. The information in this chapter is the basis for risk assessment of hydroriparian aspects of the *EBM Planning Handbook* at each spatial scale.

2.2 Hydroriparian Functions

As the interface between surface water and land, hydroriparian ecosystems are ecologically important in several ways. Their ecological functions can be classified into three types: maintaining environmental character, movement of materials linking portions of the landscape, and reciprocal influences of **water-on-land** and **land-on-water**. Each point in the following list describes a function, lists coastal hydroriparian ecosystems in which the function is important, presents the extent of influence of the function, and gives the time it takes to recover from disturbance. Planning tables can use the list to encourage discussion about the relative importance of each function.[6]

Hydroriparian ecosystems are important to the environment because they:

- *store water and evacuate excess water from the land*. This is the fundamental reason for the occurrence of hydroriparian zones.
- *contain* ***biodiversity hotspots,*** *with the most diverse structure, vegetation, and animal communities* of the coastal temperate rainforest. These characteristics are the consequence of their dynamic nature, due to flooding, debris flows, downed wood, animal activity, productivity, landform, and elevation. Most coastal terrestrial vertebrates use hydroriparian ecosystems; invertebrate diversity is also high. Estuaries, fans, floodplains and wetlands are the most diverse ecosystems in the area. Extent is variable (different species travel different distances); core area extends to the edge of the influence of water on the land (biogeoclimatic ecosystem classification [BEC] **site series**). Recovery after forest disturbance is variable (from <50 years for some features to >250 years for large structure).
- *contain rare ecosystems*. Several shoreline, fan, and floodplain ecosystems are listed as rare (in old structural stage) in British Columbia. Extent is easily defined by BEC site series. Recovery is long (250 years).
- *provide habitat for many rare and important species*, including plants, fish, amphibians, birds, and mammals listed by the Conservation Data Centre (**CDC**) as threatened (**blue listed**) or at risk (**red listed**). On the coast, most listed birds use estuaries; tailed frogs live in small steep streams in the Outer Coast Mountains; and grizzly bears rely heavily on floodplains, fans,

[6] See *Technical Reports 3, 4, 5,* and *7* and *North Coast LRMP Hydroriparian Background Report* for details (Appendix 1).

and estuaries on the mainland. Extent is variable; some habitat suitability models exist. Recovery can be very long; some populations may not recover.

- *deliver water of a quality characteristic of the system.* By definition, hydroriparian ecosystems are coincident with the principal flow pathways of water through the landscape. Prolonged contact of water with mineral and organic matter establishes the quality of water, including temperature, odour, colour, and dissolved mineral and organic content. In the CIT region, abundant water moves relatively quickly through most drainage basins and waters remain nutrient-poor. Lakes are dominantly **oligotrophic**. However, water quality may be significantly modified locally in wetlands and ponds. Forest disturbance accelerates both mineral and organic matter solution, but recovery normally is rapid (about 10 years for most characteristics).

Hydroriparian ecosystems, particularly stream systems, influence watersheds and landscapes by:

- *transporting water* downstream above and below the ground. Forest canopies intercept a portion of precipitation, moderating water flows to hydroriparian ecosystems. Forest soils further store water and modulate runoff. Effects extend throughout the watershed. Recovery after forest disturbance is variable (10–25 years; roads may have permanent impacts on drainage pathways and timing).
- *transporting sediment* downstream, which modifies ecosystems as it moves. Sediment can increase productivity (e.g., by creating fans and floodplains in valley bottoms, renewing moderate gravel deposits along streams) or reduce productivity (e.g., by inundating stream channels with gravel, covering stream beds with fines, hence reducing habitat). Extends throughout the watershed. Recovery is variable (increased input up to 40 years after harvest; chronic increase of fine sediment with active roads).
- *transporting small organic material* from small headwater streams to other hydroriparian ecosystems. This movement is particularly important in nutrient-poor systems like those of the coast. Extends in a ribbon along stream systems. Recovery is quick (5–15 years).
- *transporting downed wood* that accumulates in channels, on fans, and on floodplains. Influences flow and sediment dynamics, especially flood dynamics. This function is critically important to channel and floodplain complexity. Extends from unstable hillslopes to stream systems, particularly within the transport zone. Recovery is long (>100 years).
- *serving as corridors* for plant and animal movement. A variety of invertebrates and vertebrates feed and travel along hydroriparian ecosystems. Extends variable distance along stream systems. Recovery varies among organisms (5–200 years).

Land and water influence each other by:

- *providing sediment* that influences channel morphology, channel stability, and aquatic habitat quality, particularly gravel substrate in which invertebrate biota live and fish spawn. Sediment provision is important throughout the stream system, but its effect is ecologically significant in intermediate and larger channels and on **alluvial fans**, where the sediment is deposited. Recovery from disturbance is moderate and variable (10–100 years)

- *providing downed wood* that influences channel morphology, stores sediment, and provides food and shelter for a variety of organisms. The rate of input depends on the type, frequency, and intensity of disturbance in riparian forests and on steep upland slopes. This influence is important throughout the area. Extends to unstable hillslopes and two tree heights around stream systems. Recovery is long (>100 years).
- *providing organic material* in the upper watershed that supports hydroriparian food webs throughout the drainage. Organic matter recruitment is most important in small streams, but the effect is important in larger channels downstream. Extends less than one tree height from stream systems. Initial recovery is quick (5–15 years), but mid-seral closed canopy forests supply low quantities of organic material.
- *providing shade* that moderates light and climate, hence water temperature, and so influences aquatic invertebrate communities and other organisms. This influence is most pervasive in small streams, but is likely less important than in warmer climates. Extends several tree heights from stream systems. Recovery is quick (5–15 years).
- *filtering sediment and dissolved materials*. Sediment interception is important in steep terrain and on fans, and dissolved nutrient flushes are retained in riparian soils and plant communities. Effect extends variable distance from stream systems, depending on topography and water circulation pathways (usually one to two tree heights or extent of valley flat). Recovery is variable (5–50 years).
- *stabilizing banks* and reducing erosion caused by flooding. This influence is important on streams, floodplains, and fans everywhere on the coast. Direct effect extends less than one tree height but, where channels are laterally active, effective forest is coextensive with the amplitude of lateral instability. Recovery is moderate and variable (20–100 years).
- *increasing ecosystem productivity* by providing moisture and nutrients in well-drained soil. This influence is obvious in large floodplains, fans, and estuaries. Extends variable distance from 1 metre to width of valley flat, possibly over 1 kilometre. Recovery may be long, particularly if subsurface flows change (>100 years).
- *decreasing ecosystem productivity* by promoting organic matter accumulation in poorly drained soil. This influence is most noticeable in the extensive bogs of the Lowlands. Can extend over landscapes. Recovery period is unknown.
- *modifying landscape morphology* by creating depositional (fans, floodplains) and erosional (gullies, terraces) landforms along drainage systems, and by modifying the character of stream channels. This factor is strongly influenced by the mobility of sediments in stream systems. It is significant throughout the drainage system but is particularly important in intermediate and larger streams where diverse aquatic ecosystems include many fish species. Recovery is intermediate and variable (20–100 years), but some changes may be permanent.
- *modifying the microclimate* of adjacent land, influencing plant growth, soil microbes, amphibians, and other organisms. This influence is most obvious in the shoreline forests of the Hecate Lowland; in other ecosystems, it is likely less important in the CIT area than in warmer, drier climates. Extends several tree heights in some climates. Recovery is moderate (50–100 years).

Hydroriparian functions considered for risk assessment in this Guide include maintaining hydrological regime (i.e., transporting water), maintaining stream morphology, maintaining bank stability, providing downed wood, maintaining coarse filter biodiversity, maintaining rare ecosystems, serving as corridors, and maintaining characteristic ecosystem productivity. Certain functions are combined in these categories. Special or rare species are not considered; planners and managers are referred to other existing models and tools for assessing and providing appropriate protection for them. Risk of microclimatic modification is not considered because this function is less critical in the wet, cool coastal climate.

2.3 Risk Assessment Methods and Rationale

In this Guide, risk is defined as the probability that a hydroriparian function or ecosystem will be changed or lost following a particular management activity.[7] Risk curves relate the level of risk to planning indicators developed for each hydroriparian function selected for attention. These curves can be used to estimate the risk associated with a particular management activity. The level of risk can then be compared with an acceptable level of risk. Determining an acceptable level of risk is a task for planning table members who must consider social and economic as well as ecological consequences. This Guide provides precautionary guidelines based on low risk thresholds. These guidelines document the point at which either risk increases or relative certainty of low risk changes to uncertainty about risk level. The precautionary guidelines are listed as low-risk thresholds in the *EBM Planning Handbook* and are consistent with current scientific knowledge and local expert opinion.

Risk assessment might show that risks of further development are currently unacceptable throughout a watershed, unacceptable in certain process zones or hydroriparian ecosystems, or acceptable throughout the watershed. Opportunities for development can be assessed by comparing current condition either with the low-risk precautionary guidelines provided by the *Hydroriparian Planning Guide* or with results from a risk assessment based on the risk curves and thresholds. Because of uncertainties in the risk relationships, the latter option requires appropriate monitoring and establishment of a well-designed adaptive management experiment (Chapter 3). Modelling of recovery rates (see Appendix 3) may give estimates of future opportunities for development. If a decision is made to proceed with development, the levels of risk within process zones and particular hydroriparian ecosystems can be used to guide the locations of hydroriparian reserves.

2.3.1 Planning indicators

The risk thresholds and relationships are based on planning indicators developed for the hydroriparian functions listed above. Several indicators could be used for each hydroriparian function (as, for example, in the construction of a watershed disturbance index within the *Coastal Watershed Assessment Procedure Guidebook* [1995]). This Guide selects a subset of indicators to minimize complexity and redundancy. A single indicator—deviation from natural proportion of

[7] This definition follows that used by the B.C. Ministry of Water, Land and Air Protection rather than an industrial definition, which entails the probability of loss multiplied by the consequence of the loss.

riparian forest[8]—can be used for biodiversity (coarse filter), rare ecosystems, downed wood, and ecosystem productivity. Related indicators—deviation from natural proportion of **old growth forest** in the drainage basin, and deviation from natural proportion of forest along stream channels—are useful to index water transport and channel stability. These indicators are useful because a land management plan determines their future state, thus risk can be assessed before harvest.

In wetlands and the small upland streams of the source zone,[9] the Guide bases natural proportions of riparian forest on the disturbance return intervals provided for upland and wetland forests within a subregion (Table 2). For floodplains in the transportation zone, and for ocean spray forests on the outer coast, the Guide uses estimates calculated for these particular ecosystems (Table 2).

The appropriate ecological division (i.e., unit of land) to use to calculate deviation from natural riparian forest varies among functions. For biodiversity and ecosystem productivity, the hydroriparian ecosystem (Appendix 2) is the appropriate unit because risk varies among ecosystems. For rare ecosystems, site series is the appropriate division to match existing CDC lists. For downed wood, process zones (see Section 6.1.2) are appropriate divisions because downed wood functions differently in the different zones.

Precautionary guidelines are more stringent for some indicators than others. Hence, where these indicators overlap, it is possible to simplify the set of indicators considered.

Table 2 Range of natural variability in proportion of old forest in upland and wetland, fluvial, and ocean spray ecosystems.[a]

Region	Ecosystem[b]	Return interval for disturbance[c]	Proportion of forest >250 years (%)
Hypermaritime	upland and wetland	4,500–33,300	95–99
	fluvial	2,200–11,100	89–98
	ocean spray	1,000–5,600	78–96
Outer Coast North	upland and wetland	1,800–10,000	87–98
	fluvial	500–2,100	61–89
Outer Coast South	upland and wetland	900–2,500	76–90
	fluvial	400–1,400	54–84
Inner Coast	upland and wetland	500–5,600	61–96
	fluvial	300–900	43–76

[a] Price and Daust (2003).

[b] Based on groups of site series listed in small-scale Predictive Ecosystem Mapping.

[c] To nearest 100 years.

[8] Riparian forest includes forests influenced by adjacent surface water (including dry floodplain) plus one-and-a-half tree heights (to capture the influence of the land on the water).

[9] See Section 5.1.2 for full description of process zones.

2.3.2 Determining acceptable levels of risk

Generally, acceptable levels of risk will be determined at the strategic level through public processes (e.g., Land and Resources Management Plans and First Nations Land Use Planning). These planning teams will set risk targets within subregions and landscapes to guide decisions at lower scales. Planning teams may be more specific and also set targets for specific watersheds or hydroriparian ecosystems. While this is a planning table decision, it will be informed by this Guide and the *EBM Planning Handbook*. In this way, hydroriparian objectives can be balanced with other resource management objectives to best fit with different ecological characteristics and conditions at various scales. Basic information in this Guide can inform planning tables about where risk increases rapidly and about the types of risks encountered in different subregions. Table participants could then examine the current level of risk in particular areas and model changes to risk resulting from different management options. Modelling exercises could demonstrate how decisions affect activities at the watershed and site levels. Interactive watershed simulation games, with animations of future conditions, can facilitate understanding of trade-offs and identify experimental options for adaptive management.

Acceptable levels of risk should be linked to the adaptive management strategy. For example, a planning team may accept a moderate level of risk in a certain area if it is linked to a well-designed adaptive management plan that will document the consequences of the actions taken. Hence, levels of risk should be tied to the level of commitment to a well-designed adaptive management program with secure long-term funding.

Acceptable levels of risk can be modified according to an ecosystem's importance, influence, and abundance. Some ecosystems are more important for maintaining a given hydroriparian function than others (e.g., floodplains are more productive and diverse than the margins of small steep streams). Other ecosystems exert a strong influence elsewhere, particularly downstream (e.g., small steep streams supply more organic material to a system than do ponds). Finally, some ecosystems are especially abundant, defining the character of a region (e.g., bogs in the Hecate Lowland), or especially rare. More sensitive landscapes, watersheds, and ecosystems requiring a higher degree of protection will be assigned lower risk targets.

Risk targets are also influenced by the condition of the subregion, landscape, watershed, and target drainage basin. The more a particular ecosystem or cluster of ecosystems has been modified at one or more of these scales, the higher the degree of protection (i.e., lower risk) that is required.

Appendix 4 provides expert opinion on the importance, influence, and abundance of each hydroriparian ecosystem in regions of the CIT area. When undertaking a complete risk assessment procedure,[10] the values in these tables can be used to modify acceptable risk thresholds (e.g., a lower level of risk is appropriate for ecosystems with high importance and/or influence). Rare ecosystems need special consideration. **Abundant ecosystems**, characterizing a region, need consideration for cumulative impacts. The numbers will be most useful for numerical modelling developed for LRMP tables. Without such quantitative approaches, the values can be used for guidance about the relative levels of acceptable risk for each hydroriparian ecosystem.

[10] These tables will not be used if practices follow the precautionary guidelines listed in Section 2.4.

Planners at the operational scale will use the planning team targets at the subregion and landscape scales and the direction for watersheds and hydroriparian ecosystems to set targets for specific watersheds and ecosystems. Risk within watersheds may in turn be managed differently across various sub-basins using the procedures and guidelines described in this Guide, the *EBM Planning Handbook,* and the direction from the planning teams.

2.3.3 Determining actual risk

Risk is operationally defined as:

1 – (probability of maintaining a hydroriparian function)

Hydroriparian functions are listed in Section 2.2. Risk is expressed as a function of an indicator value, derived from risk curves. For indicators of terrestrial function, the Guide uses natural disturbance regimes as the reference point (or benchmark) for comparison, a generally accepted method in ecosystem-based management and consistent with the *EBM Planning Handbook.* The approach assumes that indicator values within the range of natural variation pose low risk, and that risk increases as values depart further from natural.

Risk curves are explicit hypotheses about how management activities influence ecosystems. Explicitly drawn risk curves are useful to summarize current knowledge and to force consideration of uncertainty. Without explicit risk curves, management decisions are based on hidden, implicit risk curves, often confounding values with knowledge, or on single numbers extracted from literature. Explicitly drawn curves can also help separate knowledge from values in multi-stakeholder discussions. In planning processes, different stakeholders have different implicit risk curves, complicating debate. A set of common risk curves illustrating current knowledge can facilitate discussion. Alternatively, managers could consider that current knowledge is insufficient to draw even hypothetical curves and begin with a hypothesis of no information about the relationship in question (such an assumption could still be drawn explicitly, with uncertainty bands covering all possibilities). This latter approach seems to ignore the considerable research and management experience to date.

At present, documented information about physical processes or ecological functions specific to the CIT region is insufficient to permit the construction of empirically based risk curves specific to the region. Therefore, risk curves within this Guide are based on published literature, as summarized in the technical reports listed in Appendix 1, and on expert opinion gathered at specially convened risk workshops. In some cases, expert opinion was used to modify more general curves to apply better to the ecosystems of the CIT region. In other cases, where published literature was sparse or ambiguous, expert opinion was used to draw preliminary curves based on the little information available. Precautionary guidelines correspond either with indicator values at which risk curves become steeper, uncertainty about risk increases, or, for linear curves, values between the very low and low risk categories on a five-point scale. In some instances, a forest manager may have accumulated sufficient experience locally to permit redrawing of risk curves to reflect known conditions in a particular watershed or landscape. Providing that the rationale is presented for modifying the curves and provision is made to test the newly drawn curves within an adaptive management plan, such refinements reflect the intent of the Guide. It is expected that, eventually, all risk curves used in the region will have been empirically tested against data accumulated in the region and will have been adaptively refined to reflect local variations in physical and ecological conditions within the region.

Ecologically based risk curves are often sigmoidal (S-shaped, with areas of relative insensitivity at both extremes on the x axis joined by a steep portion). Confirming this form is important, for it establishes a region of persistently low risk for low to moderate levels of disturbance. Levels of uncertainty, however, mean that evidence may be insufficient to distinguish a linear from a sigmoidal curve (in a linear curve, risk increases in simple proportion to disturbance). For management, thresholds (where the curve becomes steeper) are most crucial to identify as these represent areas where a small change in management can change risk substantially. In some cases, change may be sudden and obvious (a step function); more often, change will be more gradual and hence more difficult to detect precisely.

The curves within the Guide assume current forestry practices and assume that a given amount of harvesting will include a set length of road. For some ecosystems where harvesting is common both with and without roads, separate risk curves are developed with and without roads. Currently, risks for **variable retention** could be assessed by calculating the remaining proportion of forest and assuming equivalence of amount. As knowledge increases, specific curves can be developed. Variable retention can also be included as a factor that influences **recovery curves** (see Appendix 3).

Forest development differs from natural disturbance. Although precautionary guidelines are drawn in part from natural disturbance indications, managers must remain sensitive to indications that some real threshold has been crossed and that the system is not remaining functionally viable. This outcome would be an indication that a limit of resilience has been crossed. In ecosystem-based management, it is sufficiently important to halt development, and it would indicate the need to modify management practice in similar areas.

2.4 Specific Risk Curves and Precautionary Guidelines

2.4.1 Hydrological regime

Scale

Watershed

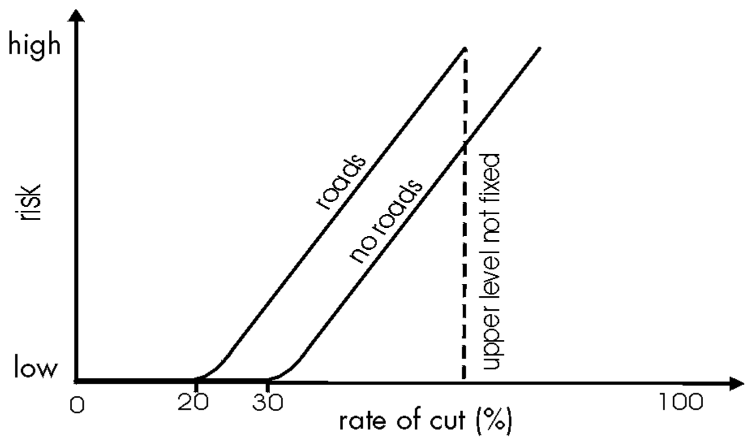
Hydrological regimes are best considered at the watershed scale.

Indicators and Risk Curves

Rate of cut (%) in watershed

The relationship between forest clearance and hydrological regime has been widely studied (see *Technical Report 3*) and is complex. Streamflow regime can be divided into three critical criteria: (1) flood flows; (2) mean flows; and (3) low flows. There is general agreement that mean flows increase in proportion to forest clearance, but there is no consensus on the other criteria. Substantial evidence, however, shows that the frequency of moderate flood flows, which stress instream ecosystems, increases following forest clearance. Hence, this criterion is considered to be most important. It has most often been related to a simple rate-of-cut criterion. A risk curve developed on this criterion is insensitive to 20% cleared (with roads) or 30% cleared (no roads), increasing thereafter to high risk for some level of clearance less than 100%, but not determined, in conformity with the majority of experience (Figure 2). Recovery occurs after about 20 years. Effect on minimum flows is considered to follow, at least qualitatively, a similar pattern.

Figure 2 Risk to hydrological regime associated with forest rate of cut.



The low-risk inflexion point at 20% clearance over 20 years (consistent with an annual rate of cut of 1%/year) shown in Figure 2 is consistent with both published scientific literature and local expert opinion. Expert opinion was used to refine the curve to include roaded and unroaded watersheds. Neither published literature nor expert opinion was able to quantify an upper inflexion point giving a high-risk threshold. Note that the effect of roads can be quite variable: where roads are designed with adequate sumps or with continuous under-draining (so-called french drains), their incremental impact may be small.

Precautionary Guidelines

The principal guideline for hydrological regime is based on the rate of cut at which the risk begins to increase (Figure 2).

- Rate of cut should not exceed 1% per year of the forested area averaged over 20 years applied to every watershed and sub-basin over 1,000 hectares. Stratify larger watersheds into sub-basins of approximately 1,000–3,000 hectares. Some watersheds divide sensibly into sub-drainages; others, particularly long, narrow watersheds, do not. It is possible to leave semi-linear mainstem portions as a single larger unit if it appears from physiography and terrain that similar features and potential problems occur everywhere. Use more conservative guidelines if a practitioner's experience indicates that a watershed may have a higher risk.
- Exercise professional discretion in smaller drainage basins. Discretion consists of recognizing that while up to 50% of very small basins may be cleared within a short time, terrain conditions that indicate potential drainage-related slope instability, or channel conditions that indicate potential for substantial erosion, should be treated conservatively. In small

basins, small openings or variable retention will nearly always represent superior practice (hydrologically), wherever they are feasible.

- See guidelines under high-value fish habitat (Section 2.4.4) in relation to smaller drainages.

2.4.2 Stream morphology and streambank stability

Scale

Watershed

Stream morphology and streambank stability are best considered at the watershed scale.

Process zones within watershed

Indicators and Risk Curves

Index of road length + area cut in terrain classes IV and V

Percent deviation from natural proportion of standing forest along stream course

Stream morphology depends largely on the calibre and quantity of sediment delivered to the stream system. In managed forests, increments to sediment delivery over and above naturally introduced amounts derive largely from road building and maintenance, from activities in unstable terrain, and from destabilization of streambanks. Therefore, useful planning indicators are considered to be:

- (planned) length of road
- area of forest cleared in Classes IV and V terrain
- percent of streambank cleared in transportation and deposition zones.

The first criterion is intended to cover the likelihood of landslides originating at roads (and reaching the riparian zone), the second to cover landslides from unstable terrain, while the third is intended to cover sediment derived from streambanks. Modification of the natural sedimentation regime, not the arrival of sediment in the channel per se, should be recognized as the concern.

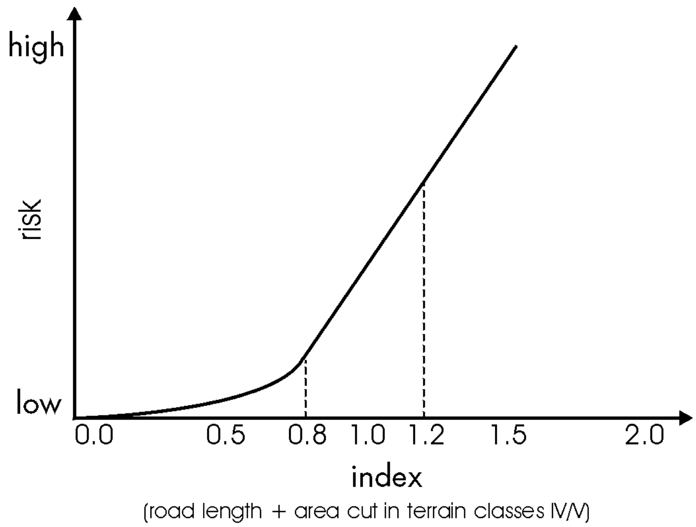
The first two criteria have been combined into one index using guidelines established in the *Coastal Watershed Assessment Procedure Guidebook.*[11]

Criterion	**Score**										
	0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
km of Class IV or V road (km/km^2)	0	0.03	0.06	0.09	0.12	0.15	0.20	0.25	0.30	0.35	>0.40
ha of Class IV or V logged (%)	0	1	2	3	4	5	6	7	8	9	>10

[11] *Coastal Watershed Assessment Procedure Guidebook* (CWAP), Level 1 Analysis, August 1995. The 1998 edition 2 of the CWAP abandons this specific index assessment technique, but it remains useful for a risk analysis because it permits direct quantification of relative sensitivity.

As the range of raw data varies, the raw data are rescaled to a score between 0 and 1.0. The table above shows the conversions from raw data to scores. The index used in the risk curve is calculated by simply adding together the score for each criterion. An index of less than 0.8 means low impact, 0.8–1.2 means potential moderate impact, and greater than 1.2 means potential high impact (Figure 3). This risk assessment should be performed for the 1,000–3,000 hectares sub-basins delineated for assessing risks to hydrological regime.

Figure 3 Risk to stream morphology associated with forest management activities.



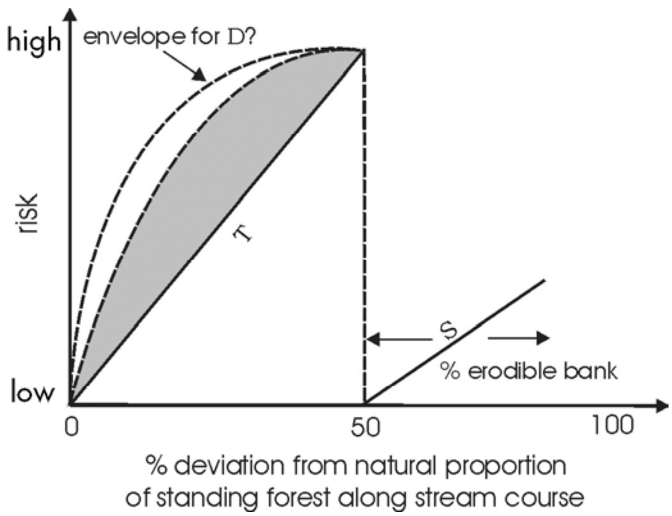
The risk curve for stream morphology is consistent with local expert opinion and with coastal experience as included in the *Coastal Watershed Assessment Procedure Guidebook*. Published literature is insufficient to draw a curve relating management activities and risk to stream morphology.

Risk curves for stream morphology vary with land attributes. An index of drainage basin sensitivity would usefully refine this general curve.

For streambank stability, percent of streambank forest cleared (hence subject to loss of critical root strength) is considered to be the relevant criterion. Application of this indicator is different in different process zones (Figure 4). In the source zone, the proportion of streambank that is erodible (many source zone streams flow in gullies confined by bedrock or other unerodible materials) influences the critical level of a forest management indicator. In the transport process zone (banks largely alluvial), a linear function is proposed extending to maximum risk at (1-fraction of naturally erodible banks). This function may actually be convex (possessing high sensitivity at small levels of forest removal) because bank erosion yields additional sediment to the stream channel, which then forms deposits around which the stream must flow. Then, additional current attack and erosion of banks may occur. The deposition process zone may be even more sensitive in this regard, because streambanks there are entirely composed of recent alluvium, but documentation is insufficient to quantify any distinction.

The risk curve shown in Figure 4 is based primarily on expert opinion, but the steep slope is consistent with published literature. The shaded area explicitly expresses uncertainty.

Figure 4 Risk to streambank stability associated with non-forested streambanks. D, T, and S indicate deposition, transport, and source zones, respectively, in the drainage basin.



Precautionary Guidelines

The guidelines listed are based on expert opinion and literature review (*Technical Report 3*). The guidelines for stream morphology are not related to the risk curve (Figure 3).

- Do not harvest hillslopes in stability class IV (detailed rating), failure of which might cause sediments to be delivered to any stream channel. Note that watershed-level terrain stability classification, based on air photo interpretation with varying levels of field checking, is subject to revision after site-level assessment. For planning purposes, empirical data for similar watersheds can be used to estimate the proportion of class IV terrain identified at the watershed level that will remain classified as potentially unstable at the site level.
- The entire **wet floodplain** and all wetlands are no-work zones. Wet floodplains should be considered to be part of the **active channel**.
- Road crossings of the wet floodplain should be minimized; roads should avoid **dry floodplains** where possible; roads crossing active fans must be constructed such that they will not influence natural processes.

The guideline for streambank stability reflects the importance of streambank cover to transportation and deposition zone channels and the potentially convex shape of the risk curve.

- In transportation and deposition zones, leave windfirm buffers. At the watershed scale, it is not possible to delineate "windfirm" buffers. Instead, for watershed planning, use a default buffer width (one-and-a-half-tree heights). Site-level planning will revise buffer design. The unconfined nature of channels on floodplains and fans means that the entire floodplain and

fan must be considered; buffering the stream channel alone is not sufficiently precautionary (see also **confined channel**).

2.4.3 Downed wood–channels and floodplains

Scale

Process zone within watershed

Downed wood is best considered within a watershed scale. Different process zones have different sources and types of downed wood.

Indicators and Risk Curves

Source zone: % forest younger than 30 years

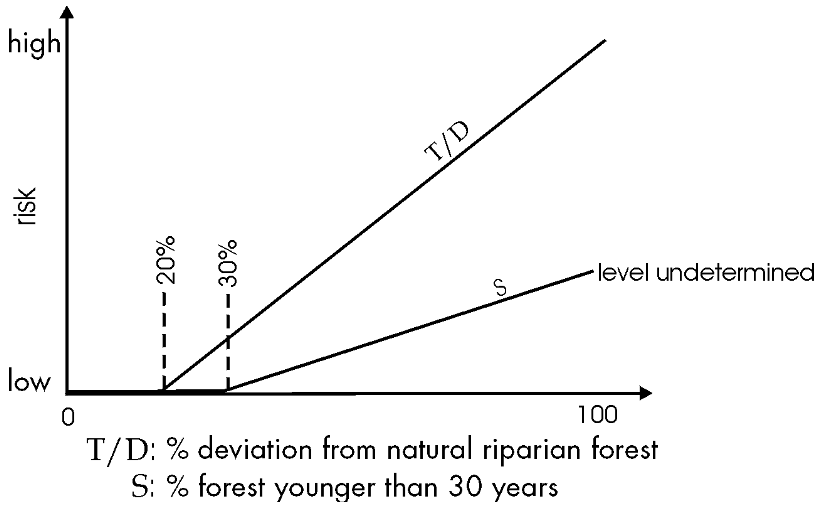
Transportation and deposition zones: % deviation from ***natural riparian forest*** *(for range of natural variation in old riparian forest, see Table 2)*

Process zones receive wood from different sources. In the source zone, most wood travels downslope during mass wasting events. In the transportation and deposition zones, most wood comes from adjacent riparian forest (though wood can still be delivered downslope to streams with a narrow valley flat). Old forest is a necessary part of the downed wood indicator in transportation and deposition zones. In the source zone, however, smaller pieces of wood may be effective. In the transportation and deposition zones, the risk to downed wood is insensitive to small deviations from natural riparian forest and subsequently increases linearly (Figure 5). In the source zone, the risk to downed wood is insensitive to forest clearance up to 30% and subsequently increases at an uncertain rate.

Although the distinction between coniferous and deciduous cover is important, published information is insufficient to distinguish between forest types.

Published studies document changes in woody input following forestry activities, but insufficient quantitative information exists to construct a curve. Hence the risk curve shown in Figure 5 is based primarily on expert opinion. The specification of separate risk curves for different process zones is also based on expert opinion.

Figure 5 Risk to downed wood functions with forest management actions.



Precautionary Guidelines

These guidelines are based on the low-risk inflexion point at which the risk curve becomes steeper.

- <30% of forest should be younger than 30 years in the source zone
- <20% deviation should occur from natural riparian forest in the transportation and deposition zones

The precautionary guidelines for downed wood match the guidelines for a 1% rate of cut (see Section 2.4.1) and for a windfirm buffer in the transportation and deposition zone (see Section 2.4.2). Hence these guidelines do not need to be considered separately. They are provided here for completeness and to allow planners and managers to focus on one or another function as appropriate to the character of different watersheds.

2.4.4 High-value fish habitat

Scale

Watershed

Although the presence of **high-value fish habitat** can be used to describe the character of different watersheds and hence is useful in landscape- and subregional-scale analyses, high-value fish habitat is primarily a concern during watershed planning.

Indicators and Risk Curves

Presence of development activities (roads, landings, log dumps, log sorts, cutblocks, etc.) in or adjacent to high-value fish habitat

Deviation from natural proportion of riparian forest cover; barriers to access; deviation from natural levels of sedimentation

For high-value fish habitat, there is no option to follow a risk assessment procedure; risk-averse precautionary guidelines must be applied

Because of the sensitivity and critical nature of high-value fish habitat, no risk curve is developed. Essentially, the risk curve can be considered a step function moving to high risk when activities do not meet the precautionary guidelines. Ensuring healthy fish habitat requires that land development practices be managed in a low-risk manner to ensure all hydroriparian ecosystem functions are maintained. The precautionary guidelines for each function, considered in other subsections, provide guidance. Additional guidelines in this section apply to identified and mapped high-value fish habitat.

Precautionary Guidelines

Precautionary guidelines are based on expert opinion and published literature.

- Reserve all high-value fish habitat and adjacent areas from development; adjacent refers to any land from which there may be direct impacts on the habitat as a result of development. These direct impacts refer to significant changes in temperature, water quality, sedimentation, and bank stability. This Guide assumes that planners and managers will refer to other documents (e.g., *Fish Stream Crossing Guidebook*) to determine how to avoid direct impacts to high-value fish habitat.

For watersheds larger than 1,000 hectares (10 square kilometres), use the management direction for Hydrological Regime (Section 2.4.1), including either precautionary guidelines or the risk management approach.

Because process characteristics differ between these systems and smaller watershed systems, a different set of precautionary guidelines apply to watersheds smaller than 1,000 hectares. Smaller watersheds are headwater-driven systems where hillslope disturbances directly affect adjacent channels. For primary watersheds (i.e., those that are not part of a larger drainage basin) smaller than 1,000 hectares (10 square kilometres) that contain high-value fish habitat zones, the following guidelines apply:

- identify all hydrologically active areas, for example hydroriparian zones, headwater seepage zones
- limit disturbance to 10% of the forest area in the watershed averaged over 3 years
- deactivate road networks after harvesting to assure the maintenance of the natural hydrological regime.

Protection of fish habitat requires that all hydroriparian functions be maintained. This section is included for completeness and to introduce guidelines for small watersheds that are not covered adequately elsewhere.

2.4.5 Biodiversity (coarse filter)

Scale

Subregion

Landscape

Watershed

For biodiversity, a subregional scale is appropriate for precautionary management, while flexibility is increasingly possible at finer scales.

Indicators and Risk Curves

Percent deviation from natural riparian forest by hydroriparian ecosystem and/or site series (site series for landscape-level assessment)

Risk curves for hydroriparian ecosystems may differ from risk curves based on biogeoclimatic site series drawn for all ecosystems. **Biogeoclimatic ecosystem classification** (BEC) was designed for classifying forested ecosystems. It does not consider hydrological features, provide landscape context, or combine sites into ecosystem complexes—all important aspects of hydroriparian ecosystems. Some hydroriparian ecosystems are particularly sensitive to disturbance; others influence ecosystems downstream. A set of curves designed specifically for hydroriparian ecosystems facilitates assessing risk for these elements.

Ideally, this indicator would examine three forest conditions: **interior old growth**, **old growth equivalent** (based on recovery curves developed for various forest types following various management activities; see Appendix 3), and deciduous. Interior old growth gives the best indication of undisturbed riparian forest. Old growth equivalent could include edge or interior forest and can include recovery from variable retention. Deciduous ecosystems provide diversity in floodplains. Estimates of the natural proportion of old riparian forest in the transportation and source zones are given in Section 2.3.1 (Table 2). Information on the natural proportion of old growth equivalent and deciduous forest is not currently available and can be collected as part of an adaptive management strategy.

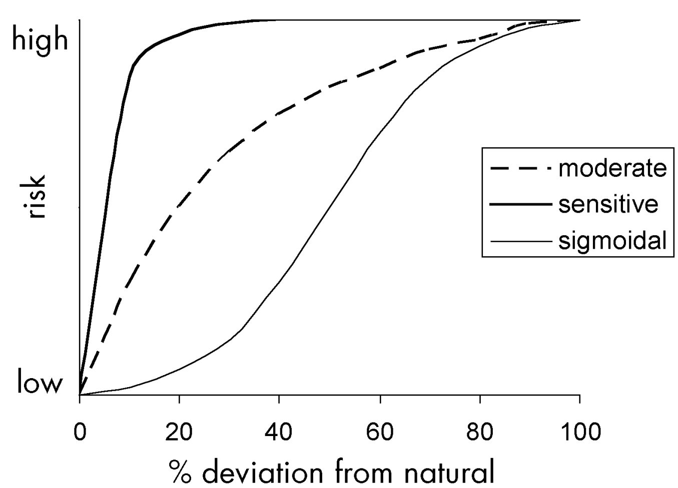
The general curve for risk to biodiversity is shown as sigmoidal based on published theoretical and empirical studies over a wide range of landscapes in many regions.[12] Local experts in coastal ecosystems considered that the risk to biodiversity within the area considered in this Guide varies by hydroriparian ecosystem. They created a suite of curves applicable to different ecosystems, but judged that information was not sufficient to draw different curves for different regions. The expert group felt that their levels of certainty were sufficient to distinguish three classes of curves for risk to biodiversity: standard, moderately sensitive, and highly sensitive (Figure 6). Different ecosystems follow different risk curves. The uncertainty band around the standard curve is broader than around the sensitive curves (uncertainty bands are not drawn) because it covers a wide range of conditions. Although the shape of the biodiversity curves does not vary by subregion, differences in natural disturbance regimes may lead to different deviations from natural, and hence different risks. These risk curves are drawn based on the assumption of conventional harvesting.

[12] See *Technical Report 7* and *Scientific Basis to Ecosystem-based Management* for a discussion of the literature.

According to expert opinion, estuaries, karst ecosystems and small (1- to 3-metre width), very steep (>20%) streams and gullies with high susceptibility to debris flow follow the highly sensitive curve. These small, steep streams are often gullied, incised in deep till, with accumulation of large organic debris, and may be glacier-headed. They are usually infrequent in a watershed, but may be concentrated in headwater scarps. They generate energy and materials to entire stream systems. Floodplains, fans, forested swamps, and small (1–3 metres), very steep (>20%) streams and gullies with distinctive microclimate follow the moderately sensitive curve. These small steep streams are located in more resistant bedrock, usually not gullied, and often bouldery with a tumbling step-pool structure. They provide a distinctive microclimate of high humidity within an envelope of trees, and house specially adapted organisms with low adaptive capability. The remaining small streams (various sizes, including <1 metre, various gradients), shoreline forests, and wetlands (lakes, ponds, sedge fens, bogs) are considered to follow the standard curve (sigmoidal to reflect literature values) because of uncertainty. In all cases, streams on unstable terrain follow the sensitive curve.

At the watershed scale it will not be possible to discriminate among types of small streams. For planning, small streams can all be included within the low susceptibility to debris flow category (streams on unstable terrain will already be reserved through stream morphology guidelines). Field checking will then identify streams with high susceptibility to debris flow and those with unique microclimates. These streams can then be treated as appropriate. Over time, information about the relative abundance of each stream type in different regions will become available for planning.

Figure 6 Risk curves for biodiversity.



Note that the biodiversity risk curves are based on the deviation from estimated natural amounts of old forest, rather than on the actual amount of old forest. For example, 50% old forest in fluvial ecosystems of the northern Outer Coast Mountains translates into 56–82% of the estimated natural amount of old forest in these ecosystems (range of natural variability = 61–89%; Table 2).

Precautionary Guidelines

Consistent with ecosystem representation thresholds in the *EBM Planning Handbook,* different guidelines apply at different scales under a cumulative risk assessment approach.[13] Subregional guidelines for the sigmoidal risk curve occur at the inflexion point at which the curve becomes steeper. For the sensitive and moderate curves, lacking an obvious lower threshold, precautionary subregional guidelines are set at the indicator value that gives 20% of total risk (i.e., at the top of the lowest of five risk categories). The guidelines allow more flexibility at more local scales provided that guidelines at more regional scales are met. Guidelines at finer scales represent upper limits (consistent with the *EBM Planning Handbook*) and are precautionary only when applied within the guidelines at higher scales.

Several hydroriparian ecosystems will be identified only at the watershed, or even site, scale. Hence several of the guidelines listed below cannot be assessed with current information.

Subregional scale

- Estuaries, karst ecosystems, small (1–3 m), very steep (>20%) streams with high susceptibility to debris flow or on unstable terrain: <3% deviation from natural riparian forest.
- Floodplains, fans, forested swamps, small, very steep streams with low susceptibility to debris flow, but distinctive microclimate: <10% deviation from natural riparian forest.
- All other small streams, shoreline forests, and wetlands (lakes, ponds, sedge fens, bogs): <30% deviation from natural riparian forest

Landscape scale

- Estuaries, karst ecosystems, small (1–3 m), very steep (>20%) streams with high susceptibility to debris flow or on unstable terrain: <5% deviation from natural riparian forest. Average over landscapes meets subregional guidelines.
- Floodplains, fans, forested swamps, small, very steep streams with low susceptibility to debris flow, but distinctive microclimate: <20% deviation from natural riparian forest. Average over landscapes meets subregional guidelines.
- All other small streams, shoreline forests, and wetlands (lakes, ponds, sedge fens, bogs): <50% deviation from natural riparian forest. Average over landscapes meets subregional guidelines.

Watershed scale

- Estuaries, karst ecosystems, small (1–3 m), very steep (>20%) streams with high susceptibility to debris flow or on unstable terrain: <10% deviation from natural riparian forest. Average over watersheds meets landscape guidelines.
- Floodplains, fans, forested swamps, small, very steep streams with low susceptibility to debris flow, but distinctive microclimate: <50% deviation from natural riparian forest. Average over watersheds meets landscape guidelines.

---

[13] See *EBM Planning Handbook* for description of Cumulative Risk Assessment.

- All other small streams, shoreline forests, and wetlands (lakes, ponds, sedge fens, bogs): <70% deviation from natural riparian forest. Average over watersheds meets landscape guidelines.
- In any hydroriparian ecosystem, determine areas for reserve and harvest by site series according to their representation in the watershed.

2.4.6 Rare ecosystems

Scale

Subregion

Landscape

Watershed

In general, planning for rare hydroriparian ecosystems will be conducted at the same time as planning for rare upland ecosystems (see the *EBM Planning Handbook*). In the CIT region, the vast majority of listed ecosystems, and most other rare ecosystems, are hydroriparian.

2.4.7 Corridors

Scale

Process zone within watershed

Although corridors between watersheds are also important, hydroriparian corridors are most important to consider within watersheds. The source zone allows consideration of corridors linking the valley bottom with the steep upland area of watersheds.

Indicators and Risk Curves

% streams with natural levels of cover

The corridor function requires a different indicator to deal with connectivity. Overall abundance values would not discriminate between a watershed with half of the streams with all of their riparian forests harvested, and half undeveloped and a watershed with all streams riparian forests harvested along half of their length. Modifying the indicator to describe the percentage of streams with natural riparian forest captures watershed patterns at a gross scale. This indicator is the only one within this Guide to consider pattern.

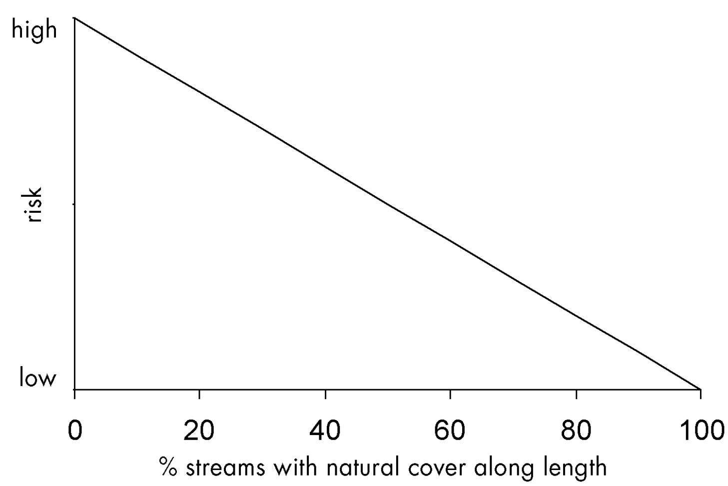
Due to high uncertainty in the published literature about the use of **riparian corridors,** risk to this function is considered to decrease linearly as the proportion of streams with natural levels of cover increases (Figure 7). Although natural levels of connected cover vary across the coast (e.g., Skidegate Plateau has streams with naturally connected forest from head to mouth; whereas mainland streams usually cross avalanche tracks, bogs, and other non-forested ecosystems), a local expert group considered that a single curve for all regions reflects the current state of knowledge. The curve does not apply at the level of individual streams, but to the population of streams within a watershed.

Calculating the corridor indicator involves counting streams within a process zone. In the source zone, it is relatively easy to count the number of channels crossing the boundary between the source and transportation zones. These channels include mainly first- and second-order streams with seasonal or perennial flow. In the transportation zone, it is possible to count the number of channels joining the main channel. With forest cover overlaid, it is possible to count the number of these streams in each zone with at least a certain proportion having forest cover over a given age.

Challenges are associated with the corridor indicator. Most source streams will not be marked on 1:20,000 maps in watersheds without harvesting history. Streams are difficult to count and vary tremendously in their character. However, a simple rule, counting the number of streams entering the transportation zone (and ignoring stream order or persistence), still provides novel information.[14]

Apart from the valley-bottom, mainstem stream, the transportation zone generally contains short stream sections. Precautionary guidelines under bank stability require that these short portions have windfirm buffers—hence a corridor guideline is redundant in the transportation zone if precautionary guidelines are followed. The indicator is of primary importance in the source zone.

Figure 7 Risk to corridor function with proportion of streams with natural amounts of riparian forest.



Precautionary Guidelines

Because of uncertainty over the value of corridors, the precautionary guideline adopts a low-moderate risk in relation to the linear curve.

- >60% of streams within a process zone have natural levels of cover

[14] See Price (2003).

2.4.8 Ecosystem productivity

Scale

Watershed

Indicators and Risk Curves

The biodiversity curves (Figure 6), reflecting current practices (including access), apply equally to ecosystem productivity.

Relative to upland ecosystems, risk to productivity in all hydroriparian ecosystems posed by increased road density follows a highly sensitive curve. This curve needs further development.

Precautionary Guidelines

See Section 2.4.5 (Biodiversity).

2.4.9 Organic material

Organic material initially recovers quickly, but then declines as the canopy closes. The biodiversity curves, examining deviation from natural forest cover, apply to this function.

Precautionary Guidelines

See Section 2.4.5 (Biodiversity).

2.4.10 Further work on risk curves

All of the risk curves presented above represent explicit hypotheses about how management activities are related to hydroriparian functions. All curves have associated uncertainty, which is not shown. Many of the curves are general and do not include the risk in watersheds of different character. Ideally, all curves should develop into suites of curves representing different responses to management in different watersheds or ecosystems. The curves are presented as the best initial hypothesis about risk. Adaptive management, monitoring, and application of local knowledge and experience will be necessary to revise or refine the curves. In essence, the curves set up opportunities for learning and for discussion among stakeholders. Further investigation of appropriate metrics for hydroriparian ecosystems (mean, 1 SD, range of natural disturbance), particularly ecosystems with highly variable disturbance regimes (e.g., floodplains), is needed. The long-term effectiveness of the *Hydroriparian Planning Guide* presupposes that such investigations will be pursued through adaptive management.

3 Adaptive Management

3.1 Introduction

Because this section is not based upon a background report, workshop or team discussions, it includes literature citations.

"Adaptive management" is a systematic approach to improve management and accommodate change by learning from the outcomes of management interventions (Taylor et al. 1997). Adaptive management emerged as a means to reconcile conservation of natural systems with sustainable economies (Lee 1999). With adaptive management not only are objectives and policies adjusted in response to new information, but also management policies are deliberately designed and implemented as experiments to enhance the rate of improvement (Holling [editor] 1978; Walters 1986; Taylor et al 1997). In this way learning is promoted as a high priority in resource stewardship.

The focus on deliberately designing management to enhance learning differentiates true adaptive management from trial-and-error approaches often promoted as adaptive management. In addition, because adaptive management requires documentation of objectives, assumptions, decisions, and outcomes, it increases the chances that knowledge gained through experience will be passed on to others.

Although adaptive management has elements in common with traditional research (e.g., hypothesis testing, use of controls and replicates), it differs in several important respects: managers play an integral and often lead role; and policies are implemented at an operational scale, in an operational setting. A key element is to bring managers and researchers together with the common goal to learn something about ecosystem processes and structures. Management context is a critical element. However, experiments can often provide surprises, and require experienced scientists to recognize surprise and pursue its full implications (Lee 1999).

The central focus of adaptive management is to formulate management approaches and policies as experiments that probe the responses of ecosystems as management activities change. Careful design, monitoring, evaluation, and feedback are critical components of this process. Because management time frames are long and the associated ecological questions are complex, imagination and creativity in applying these steps are important to deal effectively with change and complexity.

The *Hydroriparian Planning Guide* was designed to be part of an adaptive management program. Adaptive management is valuable whenever there is significant uncertainty about the outcomes of management activities, such as those recommended by this Guide. While existing research provides some direction for this Guide, data for local ecosystems are lacking and considerable uncertainty exists around the development of some of the risk curves. Accordingly, uncertainty increases as planners choose increased risk in their management strategy. A commitment to adaptive management is therefore an essential element in the successful implementation of the *Hydroriparian Planning Guide* over time if hydroriparian functions are indeed to be maintained in the most effective and efficient manner.

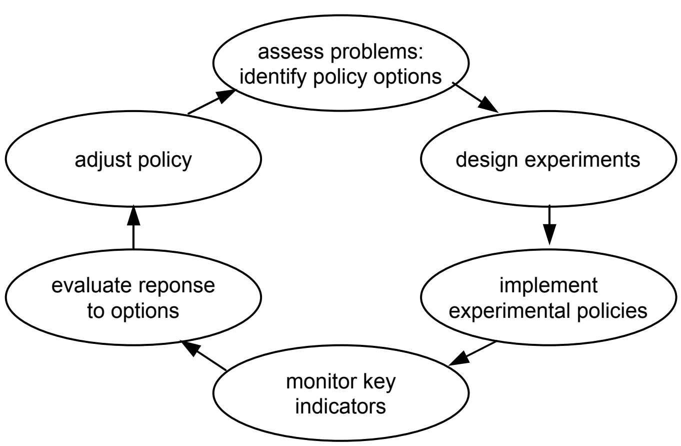
A commitment to true adaptive management is no small undertaking. It may be technically challenging to design powerful experiments and effective monitoring schemes at large spatial scales, for indicators with long response times and high levels of natural variability. Managers and stakeholders must be convinced that the long-term benefits of adaptive management are worth the additional costs and effort involved in design, layout, monitoring, and data storage. Ensuring continuity of funding and support over the long time scales at which forest ecosystems operate will be a challenge, and will require continued collaboration and leadership. Two approaches can reduce monitoring costs. First, up-front investment in automated monitoring technologies increases future efficiency. Second, stakeholders already in the field can conduct monitoring activities. This approach has successfully reduced the monitoring burden in fisheries research, where resort owners, local residents, and interest groups collect information on fish and streams.

With these considerations in mind the general structure of the adaptive management program for the *Hydroriparian Planning Guide* is presented with recommendations for its implementation. The final adaptive management program will be built with input from managers and stakeholders at a strategic level. Above all, the program requires a solid commitment and a strong dose of realism in terms of time frames and budgets.

A structure for designing an adaptive management program is described with some suggestions for program content. The final design will require thoughtful input and consideration by managers and stakeholders.

Adaptive management programs follow several steps (Figure 8).

Figure 8 The steps in an adaptive management program, shown as a loop to promote continual learning, adaptation, and re-examination of the management situation (modified from Nyberg 1999)**.**



3.2 Assessing the Problem

3.2.1 Securing a commitment to adaptive management; identifying budgetary constraints

Adaptive management is frequently discussed, but few sound examples are evident. Weyerhaeuser's adaptive management program for their "Forest Project" is considered by many to be one of the best local examples (Beese, 2002, pers. comm.). It involves collaboration with the scientific and stakeholder communities and a significant commitment to long-term funding. The Weyerhaeuser program was developed, and is directed, by an Adaptive Management Working Group that includes representatives from the University of British Columbia Centre for Applied Conservation Biology, the B.C. Ministry of Forests, the B.C. Ministry of Water, Land and Air Protection, the environmental consulting sector, and Weyerhaeuser BC Coastal Group. Support for this group requires a significant ongoing commitment from upper management and leadership within the company at the strategic level.

Based on the options available and the identified priorities and potential outcomes, the adaptive management program for the *Hydroriparian Planning Guide* needs a similar long-term commitment to be successful. This commitment should occur at the LRMP strategic level where it can bring stakeholders, managers, and scientists together in a suitable collaborative framework to ensure continuity and consistency of implementation and funding across all scales over appropriate time periods. At the same time, long-term budget requirements should be explored and discussed. This discussion should be viewed as a reality check rather than a stumbling block and will help prioritize, focus, and perhaps refine the program to be effective within the bounds of what is feasible.

3.2.2 Identifying the key questions that will be explored within the program

The *Hydroriparian Planning Guide* defines the challenge of managing riparian ecosystems in terms of clear goals. The goals are then translated into indicators explicitly related to ecosystem function. This is the necessary initial step in adaptive management.

Next the key management questions that hold the greatest potential to enhance learning, and tease out surprises are identified. The key questions to be explored were developed by the *Hydroriparian Planning Guide* team by reviewing risk curves and thresholds for the range of hydroriparian functions to determine where the greatest uncertainty exists; by determining which indicators with a reasonable degree of uncertainty have the most potential to impact management decisions; and by examining other assumptions regarding the indicators themselves or the *Hydroriparian Planning Guide* decision-making process. The team also tried to consider the relationship between actions and indicators over a range of conditions, and the sensitivity of forecasts and management choices to alternative hypotheses.

The Weyerhaeuser experience stresses the importance of not trying to tackle all important questions at once. This can quickly become untenable in its magnitude and associated cost. The Weyerhaeuser Adaptive Management Working Group considered many focus questions for the Forest Project, but finally selected five key questions that would maximize learning in the short to medium term. Accordingly, the *Hydroriparian Planning Guide* team tried to combine questions from interrelated indicators and *Hydroriparian Planning Guide* process steps to focus on a few questions most likely to enhance learning. The priority is to address first those questions that can yield answers more quickly and have the greatest impact on learning.

The *Hydroriparian Planning Guide* isolated the following questions to explore for riparian management.

1. What are appropriate ECA criteria in roaded and in non-roaded watersheds to assure maintenance of hydroecological functions?

   ECA remains a controversial topic. It is unlikely that the precautionary specifications that can be drawn from current research literature are appropriate everywhere on the coast. The risk curve presented in this Guide represents only an arbitrary (although expert) extrapolation of those guidelines. Forest management deliberately designed to be sensitive to, and to monitor, ECA and hydrological effects, through an experimentally articulated program of comparative gauging, will eventually allow more secure and more flexible guidelines to be developed to govern rate of cut.

2. What criteria reliably identify watersheds that are "high risk" in the sense that high sediment delivery is apt to compromise the function of hydroriparian ecosystems?

   Because geology, topography, and landscape history all vary, certain parts of the landscape are more prone to yield excessive amounts of sediment to stream systems than others, especially under certain land use practices. It is important to identify these areas before development occurs. This *Hydroriparian Planning Guide* proposes a method based on the occurrence of terrain of stability classes IV and V, which is available from **terrain mapping**, and is consistent with criteria of *Coastal Watershed Assessment Procedure Guidebook* (1998). The method needs to be critically tested, and the possibility for more refined means to identify "high risk" areas needs to be examined. It is probable that initial work on this problem would constitute research (rather than adaptive management) but, eventually, means need to be tested and adapted in the operational environment of forest land management.

3. What are the impacts to biodiversity (at site and downstream) of various management practices around small streams? Is biodiversity best conserved through narrow buffers on most streams, or by reserving selected patches including several streams, or by applying alternative harvesting practices to streams? Are continuous strips of riparian vegetation valuable as corridors?

   The impacts of forest management around small streams remain controversial. Although harvesting around single streams likely has negligible downstream impacts, cumulative impacts can be high. Conversely, leaving buffers around all small streams can remove most harvest opportunity in some watersheds. In addition, some buffers are susceptible to blowdown and may not achieve their aim.

   This topic includes questions about impacts on the hydrology of very small, intermittently flowing streams. A relatively simple study looking at the number of weeks of flow of ephemeral, intermittent, and perennial small streams throughout the summer before and after harvest would be very useful. If flow patterns change and intermittent streams become ephemeral, plant and animal (primarily invertebrate) communities may change.

The value of remnant strips remains contentious. Unfortunately, this area of study is highly complex and frequently troubled by ambiguous results; some recent research programs, however, have met with success.

3.3 Identifying Policy Options

For each question, the next task is to develop a set of alternative strategic options representing a range of risks to the relevant function. The risk curves included in this Guide provide prior information in the form of initial hypotheses that can be used to assist in identifying options.

3.4 Designing the Program: Choosing the Adaptive Management Options to Address the Key Questions

Two adaptive management implementation options have been described (Nyberg 1999).

3.4.1 Active adaptive management

Active adaptive management is considered by most as the foundation of an effective adaptive management program. Active adaptive management involves deliberate experiments designed to discriminate between alternate management hypotheses developed to address key questions. As is typical with experimentation, active adaptive management involves setting hypotheses, controlling extraneous factors, and replicating to increase reliability. Replicated and/or paired treatment/control comparisons are most effective in teasing apart the multiple confounding factors common in large-scale management situations.

Active adaptive management is important for reliable knowledge, yet it may not always be easily achieved or most efficient with the types of questions posed. For this reason, passive adaptive management is often considered as well.

3.4.2 Passive adaptive management

With passive approaches, the manager evaluates existing information and implements the policy that is "best," assuming that the most likely hypothesis about ecosystem function is indeed correct. Outcomes are monitored and compared to predictions and pre-treatment conditions. For an effective program, it is essential that *specific predictions* about the expected outcome be made *before* activities are begun.

Passive approaches must be used with a great deal of caution. They are attractive because they are less costly and onerous than active adaptive management. However, passive approaches may reduce adaptive management to simple trial and error — this certainly is what will happen without specific predictions -- potentially leading to erroneous inferences and connections between cause and effect. Strong reliance on passive approaches therefore could hinder rather than advance learning.

Nyberg (1999) suggests that passive adaptive management may be a reasonable alternative where:

- it is impossible or impractical to design a powerful experiment;
- the ecological costs of testing a range of actions is unacceptably high;
- there is a high level of certainty and agreement about which hypothesis is true, and thus which action is best; and
- past actions or natural disturbances provide reliable information about response over a range of conditions.

The Weyerhaeuser Adaptive Management Working Group uses passive adaptive management to supplement, rather than replace, active adaptive management while exploring their focus questions. They are testing predictions related to their five adaptive management questions through carefully designed and replicated variable retention experiments in their operations.

Also, an experimental landscape unit is being used to address the relevant questions at the landscape scale. At this scale the working group realized that many questions would not be answerable by simple comparisons, when long time frames and large areas are involved. To address this problem they are developing predictive models and working to find effective means to assess and validate those models.

To supplement the active adaptive management program, passive adaptive management is being used at the stand level to address the questions related to habitat structure retention and impacts on local populations of selected organisms. Permanent sample plots were established after logging within a range of standard operational variable retention cutblocks and corresponding baseline information was collected to monitor differences over time between operational treatments. It is hoped that together the active and passive approaches will yield more comprehensive data more quickly.

3.4.3 Recommendations for the *Hydroriparian Planning Guide* questions

Applying adaptive management to resolve the questions posed above presents difficulties related both to time scale and spatial variability within the landscape. To tackle the question of ECA most directly, a series of drainage basins should be identified and subjected to different harvest rates (including zero harvest controls), with monitoring of water outputs. Time constraints suggest that some form of community–industry–public sector partnership will have to plan and execute the program (it has proven difficult to maintain institutional focus on programs of this kind for the requisite time). However, the greatest difficulty will lie in selecting basins that can be reasonably compared, so unequivocal lessons can be learned. Recent developments in hydrological scaling theory may help to resolve the problems, but this circumstance suggests that the program may have to begin with a specialist (scientific) review.

To address the biodiversity questions, initial work should document "natural" levels of connectivity along streams. This can be viewed as baseline data collection. Subsequent active studies and passive monitoring should examine how a variety of organisms (not just birds) use these corridors. This question will involve research (field- and landscape-level modelling experiments) as well as adaptive management.

Also, stakeholders, scientists, and managers have realized the inadequacy of practices to protect small streams over the past decade, and research and adaptive management have begun to address this question already (e.g., Weyerhaeuser's small stream retention program). Further studies, preferably active, in other geographic areas are necessary.

In contrast, the question of identifying high risk basins might be pursued by compiling operational experience for analysis in a statistical experiment. In this case, the focus would have to be on defining operational measurements that are sufficiently standard to permit construction of a database that can be properly evaluated statistically.

3.5 Implementing, Monitoring, and Evaluating: Monitoring and Data Analysis Protocols

Three types of monitoring are associated with adaptive management programs. A form of all three may be required in either active or passive approaches, depending on the key questions being explored.

3.5.1 Implementation monitoring

This monitoring ensures that the management prescribed by the adopted land management plan is actually being implemented correctly. If implementation is incorrect, outcomes will not be meaningful. Depending on the management action being explored, correct implementation may at times be obvious, requiring only a cursory check. Others will need more rigorous monitoring.

3.5.2 Effectiveness monitoring

Effectiveness monitoring answers the question of "did it work for what we intended it to do?" This type of monitoring looks at whether the prescribed management action is attaining the objectives for each indicator.

3.5.3 Validation monitoring

Validation monitoring tests the assumptions associated with the *Hydroriparian Planning Guide* model parameters and relationships. This monitoring attempts to test areas of uncertainty.

3.5.4 Monitoring and data analysis requirements

At this point the following will be determined for each question being examined in the adaptive management program:

- the type and amount of baseline (pre-treatment) data required;
- frequency, timing, and duration of monitoring;
- indicators to be monitored at each interval;
- appropriate spatial scales for monitoring different indicators;
- identification of who is responsible for undertaking different aspects of monitoring;

- specific method(s) that will be used to analyze data;
  - set up system for managing data over the long term (e.g., storage, analysis, access);
  - agree who will interpret data and who will have access to it;
- specific protocols for prompt analysis and reporting as soon as useful information and trends are evident. The emphasis should be to provide feedback to the manager as rapidly as possible.

Deciding the methods for analysis is a key step for, without it, inappropriate or insufficient information may be collected and meaningful analysis may not be possible.

3.5.5 Cost effectiveness

All of these requirements must be carefully considered to maximize efficiencies and meet budget expectations. Developing cost-effective monitoring for adaptive management is one of the most important aspects of adaptive management. It is particularly important to avoid measuring everything and to focus on key indicators. Approaches to cost-effective monitoring include using automated monitoring (e.g., satellite imagery, remote water quality stations) and changing institutional arrangements to allow people in the field (e.g., resort owners, local residents, interest groups) to perform monitoring. Monitoring requirements have increased recently with the introduction of certification schemes, hence improving cost effectiveness.

3.6 Adjusting Management Actions or Objectives

- At the start of the adaptive management program, it may be useful to identify who needs what information, and when it is needed to make timely changes.
- Define the intensity and degree of response in an indicator that will trigger a change in management actions or objectives.
- Establish a system to communicate results.

As analysis of monitoring results starts to suggest adjustments in management actions, those adjustments will reflect the trade-off between the costs of acting if preliminary results later prove to be incorrect, and the costs of not acting if they later prove to be correct. Careful analysis and discussion with scientists, managers, and stakeholders at the strategic level will be required.

Timely communication of emerging results and information to all practitioners and stakeholders is critical to complete the feedback loop. The Weyerhaeuser Program uses an annual meeting of an international panel of scientists to communicate with the scientific community and environmental non-governmental organizations outside their adaptive management working group. As well, they have an operational working group within Weyerhaeuser with membership from all Timberland divisions to communicate results to the field. Responsibility for coordination of the entire program and the associated communication rests with designated staff at the Nanaimo Coastal Timberlands office.

4 Subregional-Level Analysis (Map Scale 1:250,000)

Within this Guide, planners determine the subregion and associated natural disturbance regime of an area of interest, and assess risk to biodiversity. Specific planning measures are not specified at the subregional scale, but it is assumed that land management planning at this scale has been guided by the *EBM Planning Handbook*. The *Hydroriparian Planning Guide* incorporates the zoning and reserves that are created through other planning procedures.

4.1 Determine Subregion of Interest

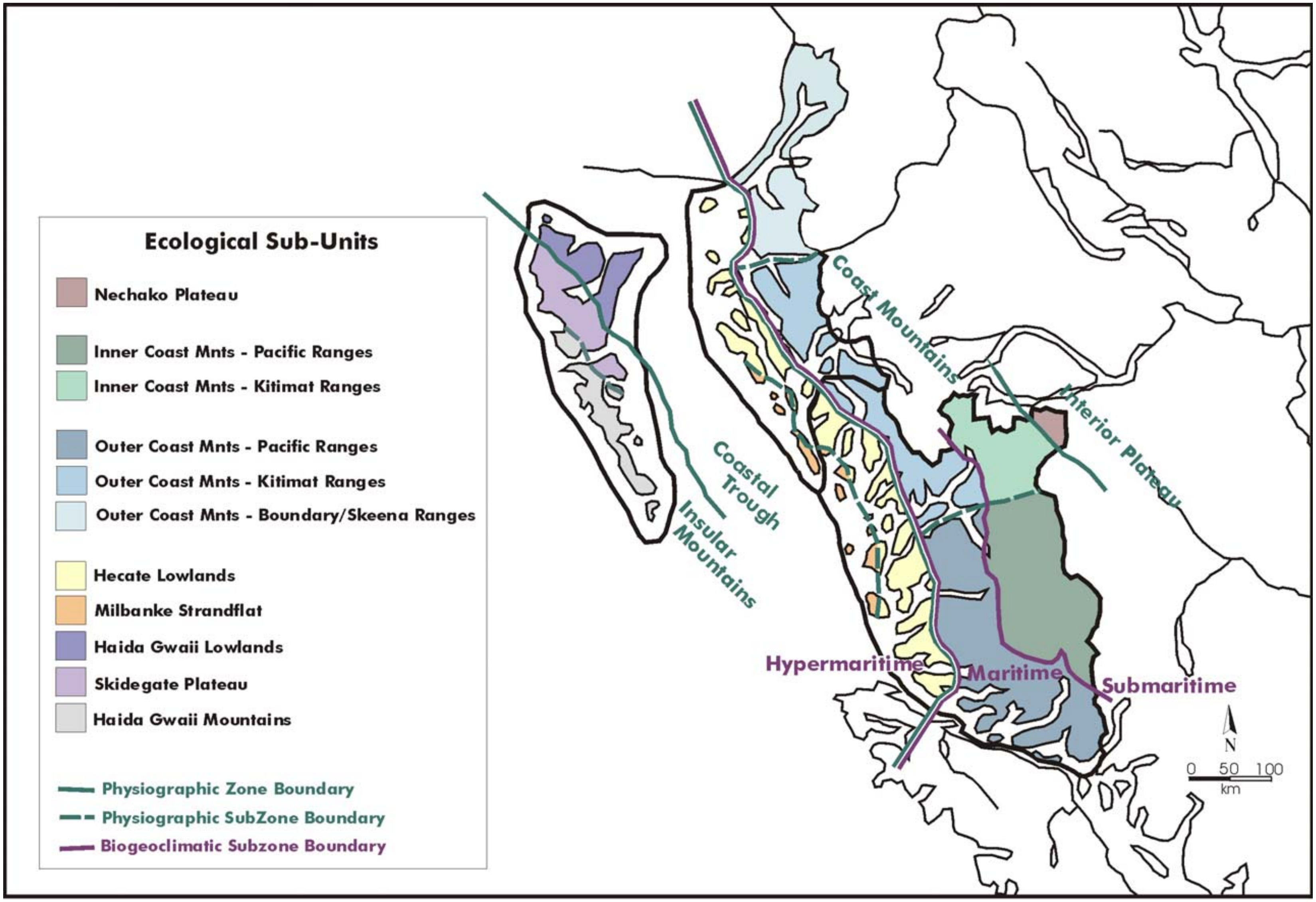
Use Figure 9 to locate subregion of interest.

Use Appendix 5 to determine specific management concerns for subregion.

British Columbia's coast is geologically, climatically, and ecologically diverse. Hydrology, disturbance regimes (Table 2), and ecosystems vary across subregions. Watershed processes and impacts of forest management likely also vary. Therefore, the first step is to locate a watershed or site of interest within an ecologically and hydrologically homogeneous subregion. Eleven subregions are defined within four regions, based on relative uniformity of hydrology, slope conditions, and ecosystems (Figure 9; Appendix 5; *Technical Report 1;* Pojar et al. 1999). Current information often does not distinguish all 11 subregions. However, as information improves, resolution will increase. The 11 subregions also provide the basis for careful design of adaptive management experiments (e.g., controls and treatments should be within the same subregion).

Because the abundance and ecological importance of the hydroriparian ecosystems described in this Guide (Appendix 2) vary among subregions (Appendix 5), the level of acceptable risk to a particular ecosystem may vary among subregions.

Figure 9 **Physiographic sub-units of the Central Coast, North Coast, and Haida Gwaii/Queen Charlotte Islands.** Physiographic and major biogeoclimatic boundaries have been superimposed.



4.2 Describe Character and Condition of the Subregion

List natural disturbance regime either from Table 1 or based on more specific information.

Gather information from higher-level plans and relevant databases and regional reports on hydroriparian ecosystems.

In addition to the characteristics of each subregion listed in Appendix 5, natural disturbance regimes vary among subregions. Natural disturbances create patterns of ecosystem type, age, and structure on the land. Ecosystem-based management uses the range of natural variability in these patterns to inform development activities. The most useful estimates for range of natural variability are calculated for areas with relatively consistent physiographic, climatic, and ecological conditions. The subregions described in Section 4.1 fulfill this criterion. Hence, estimates of natural disturbance regimes based on analyses of the 11 subregions are provided (clustered into four larger regions, with separate estimates for upland and wetland ecosystems, fluvial ecosystems, and ocean spray ecosystems; Table 2 in Section 2.3.1). These disturbance regimes provide essential context for assessing risk to several hydroriparian functions at the landscape and watershed scales. If more detailed and reliable information is available, it should be used.

Higher-level plans contain information on reserves and special management zones that may be relevant to planning hydroriparian management. Information from relevant databases will likely have been collated during ecosystem-based management planning; the activity is included to ensure that all hydroriparian information has been collated and is available for planning.

4.3 Assess Risk to Hydroriparian Functions

Use the information presented in Chapter 2 to assess the risk to hydroriparian biodiversity.

Although most rare ecosystems are hydroriparian, this Guide assumes that planning for rare ecosystems will follow guidelines in the *EBM Planning Handbook*. Many hydroriparian functions are appropriately considered at the subregional scale. Consistent with the *EBM Planning Handbook*, however, biodiversity is considered at all scales, allowing for increased flexibility at lower scales.

At the subregional scale, consideration of site series will suffice for assessing risk to biodiversity in hydroriparian ecosystems. Due to the influence of hydroriparian ecosystems on ecosystems downstream and their sensitivity to disturbance, the precautionary guidelines for hydroriparian ecosystems follow the specific curves listed in Chapter 2.

4.4 Plan Adaptive Management Strategy

Identify adaptive management coordinator or group.

Facilitate design of adaptive management based on framework in Chapter 3.

Provide support for collaboration on adaptive management projects.

Adaptive management entails implementing experiments designed to compare the response to a range of policy options (see Chapter 3). Development of strategic adaptive management experiments will affect the range of options that can be applied in different landscapes and watersheds within a subregion.

For efficiency, such experiments require collaboration among agencies and companies over large areas. The design of adaptive management strategies and guidelines must begin at the subregional level and must involve planning groups with a subregional overview (e.g., LRMP tables and First Nations land use planners). Effective collaboration requires coordination by an oversight authority.

5 Landscape-Level Analysis (Map Scale 1:50,000)

5.1 Introduction

Landscapes are interacting, interdependent geographic areas that are bounded by physical features and that contain similar patterns of watersheds and vegetation cover. In the *Hydroriparian Planning Guide,* landscapes provide the context for watershed planning. Landscapes, therefore, are chosen to surround a watershed within which forest development is proposed (a "**target watershed"**). The landscape must be defined sufficiently comprehensively to encompass all environmental considerations that may influence land management decisions within the target watershed.

Practical sizes for landscapes in a forest planning context on British Columbia's coast generally range from 50,000 to 250,000 hectares. Much smaller landscapes may be appropriate to consider when target watersheds are small (e.g., for a 1,500-hectare **primary watershed** flowing into the ocean, an appropriate landscape may be 5,000 hectares). Because landscapes, for hydroriparian planning purposes, are defined according to the target watershed, different landscapes may overlap geographically according to the location of the watershed. These landscapes will not necessarily be congruent with "Landscape Units" as defined during forest planning. Ecological landscapes are preferable to jurisdictional landscapes. This is the only scale of analysis for which such overlap may happen.

The condition of watersheds in similar situations in the immediate vicinity of a target watershed (i.e., within the landscape) will influence the level of risk and of development-related disturbance deemed acceptable within the target watershed.

Hydroriparian biodiversity risk assessment at the landscape scale may offer flexibility to watershed plans if risks are sufficiently low within the landscape as a whole.

5.2 Determine Landscape of Interest

Delineate target watershed.

Map landscape of interest; consider using ecological landscapes (e.g., watershed groupings defined by CIT Ecosystem Spatial Analyses) rather than "Landscape Units" as defined through planning processes.

Delineate watersheds on landscape map.

The landscape of interest is delineated to surround the target watershed. Watershed groups developed for the CIT Ecosystem Spatial Analyses (specifically, freshwater watershed classification based on physical characteristics) contain information about ecologically based landscape boundaries and about the consistency of physical features among watersheds within a landscape. The characteristics used to group watersheds in these analyses are relevant to stream morphology and aquatic biodiversity. In some cases, ecological landscapes will be congruent with already-developed "Landscape Units." However, particularly for watersheds on the edge of a "Landscape Unit," it may be necessary to modify the landscape to provide appropriate context for hydroriparian planning.

5.3 Describe Character and Condition of Landscape

Gather existing information from maps, air photos, and reports (e.g., terrain mapping, ecosystem mapping, age-class distribution by ecosystem, rare ecosystem mapping, CDC listings, cutblock and road locations, landslide occurrence).

Many of these data will already have been collated for other ecosystem-based management planning activities. Describing the landscape around a target watershed provides the context for decisions made at the watershed level. Important issues to consider include the defining characteristics of the watershed within the landscape, its relative importance to biodiversity, and the condition (including level of development) of surrounding watersheds. For example, if an adjacent landscape or watershed has an extensive road system and/or has been extensively logged, there may be a need for greater precaution within the watershed or landscape of interest. The information gathered will help identify key features (for example, whether the major risk to stream morphology is debris flows or fine sediment) and will be used to assess risk to biodiversity.

In particular, stream morphology is considered at this scale because major processes affecting morphology that will assist in risk assessment at lower levels can be identified.

5.4 Assess Risk to Hydroriparian Functions

Use the information presented in Chapter 2 to assess the risk to stream morphology, hydroriparian biodiversity, and high-value fish habitat.

Three hydroriparian management concerns (Chapter 2) are relevant for landscape-level assessment: maintaining characteristic stream morphology and processes, maintaining coarse filter biodiversity, and maintaining high-value fish habitat.

A landscape may consist of several discrete primary watersheds or of several watersheds all within a larger drainage. In the latter case, risk to stream morphology should be assessed at the landscape level, but quantitative indicators relating to stream channel morphology should not be averaged over more than one discrete drainage within a landscape.

The information from landscape-level biodiversity risk assessments will be used during watershed planning (Chapter 6), and may either constrain options or provide added flexibility. For example, some ecosystems will be completely reserved from harvest during watershed planning because of an unacceptable level of risk at the landscape scale. Conversely, if landscape-level risk to biodiversity is low, higher risk levels may be acceptable in a component watershed of the landscape, provided that ecosystems are represented adequately elsewhere within the landscape. At the landscape scale, it will be difficult to map hydroriparian ecosystems in detail, although floodplains, deltas, estuaries, and alluvial fans can be mapped. Where identification of hydroriparian ecosystems is incomplete, risk assessment for coarse filter biodiversity is based on site series instead. Site series will often approximately delineate hydroriparian ecosystems; hence specific risk curves and guidelines for each hydroriparian ecosystem can be used.

Without sufficient information at the landscape scale, risk can be assessed for each watershed independently, but this reduces opportunities for flexibility in levels of acceptable risk.

5.5 Design Experimental Units for Adaptive Management

Landscapes containing a group of ecologically similar watersheds can be used to bound site selection for adaptive management experiments. For example, watersheds within a landscape can be subjected to a range of activities (including controls).

6 Developing the Watershed Plan (Map Scale 1:20,000)

This chapter describes the development of a plan for the target watershed of interest as delineated on the landscape-level map. Within the landscape, a watershed is the area drained by a river or stream and its tributaries. Obviously, the size of the watershed depends on the size of the main stream or river considered; on the coast, size varies from a few to over 100,000 hectares. However, watersheds are hierarchical, so that smaller ones are component parts of larger ones. From a practical planning standpoint, watersheds generally are selected to range from 1,000 to 50,000 hectares (so that a very large watershed will include sub-watersheds). This Guide is focused on the watershed level because watersheds are defined by surface water flow (with the exception of some karst ecosystems). Therefore, the watershed is the appropriate scale at which to consider hydroriparian function (see *Technical Reports 3, 4*, and *7*).

A watershed plan zones the watershed into areas available and unavailable for harvest over the short and long terms. The areas unavailable for harvest must be selected first to determine the operable timber landbase. The goal of this stage, then, is to develop a plan for the watershed that focuses on a **hydroriparian ecosystem network**, and includes reserves specified at higher scales. The rationale for including reserves from other scales within a hydroriparian ecosystem network is to develop a complete watershed-level ecosystem-based plan to improve operational planning efficiency, to recognize the high density of small, unmapped streams in most coastal watersheds, to recognize the widely variable influence of land on water within a watershed and between watersheds, and to meet overall ecosystem-based management goals at the watershed scale.

Developing a watershed plan involves collating and developing a series of maps (Section 6.1), assessing the current and proposed risk to hydroriparian functions associated with development (Section 6.2), and finally, designing zoning for the watershed (Section 6.3). Appendix 6 shows an example of a watershed plan based on precautionary guidelines developed for a watershed on the North Coast.

6.1 Collate and Develop Interpretative Maps of Watershed Character and Condition

There are eight such maps. Most will be already created for other ecosystem-based planning activities; two are created as part of the *Hydroriparian Planning Guide.*

6.1.1 Terrain map

Consult terrain and terrain stability maps (developed by a registered geomorphologist or geotechnical engineer).

Highlight areas of sensitive (Class IV and V) terrain determined from terrain stability mapping.

These maps should already exist.

Terrain mapping categorizes and delineates characteristics and attributes of **surficial materials,** landforms, and geological processes within the natural landscape. Terrain mapping is used to delineate the transportation and deposition zones (see Section 6.1.2) and to help delineate hydroriparian ecosystems.

Terrain stability mapping uses map **polygon** attributes of terrain mapping to zone slope stability within a particular landscape. Slope failures that reach hydroriparian areas can affect a variety of hydroriparian functions. Terrain stability mapping is used to identify slope failures and zones where slope failures potentially may be initiated to assess risk to stream morphology, and to aid in the design of areas for harvest.

Both procedures involve stereoscopic interpretation of aerial photographs (supplemented with field checking) by a qualified geomorphologist or geotechnical engineer. The criteria used to separate terrain stability classes are defined in terms of slope gradient, genetically classified surficial materials, material texture, material thickness, slope morphology, moisture conditions, and ongoing geomorphic processes. Terrain stability maps are *not* to be used in lieu of a terrain stability field assessment for making site-specific prescriptions (see Chapter 7). Nor are they to be used to pre-judge or overrule the conclusions or management recommendations of a qualified registered professional who has made a terrain stability field assessment of a potential problem area.[15]

Existing terrain mapping varies considerably in quality, but floodplain and fan delineation should be sufficiently accurate in most cases to apply the Guide. Terrain mapping does not exist for parts of the CIT region. Management without terrain mapping, given current levels of understanding, is not sufficiently precautionary.

6.1.2 Hydroriparian process zone map

Map source, transportation, and deposition zones on watersheds and sub-drainages down to 1,000 hectares using terrain mapping.

Where necessary for refinement or revision, conduct walk-through inspections to permit completion of mapping (but note that zoning will be verified or revised following site-level surveys: see Chapter 7).

This map is created as part of the *Hydroriparian Planning Guide.*

The watershed is further delineated into three "process zones," areas within which material transfers—especially sediment and wood—between the land surface and stream channels occur in distinctly different ways. Hydroriparian functions, processes, and consequent risks to these vary among the three zones. This map will be used to define the areas within which to assess risk to streambank stability, downed wood, and corridors.

The **source zone** comprises upland areas, including all hillslopes within the watershed. Source zone channels are small upland/headwater streams where channeled drainage begins. Channels in source zones receive material directly from hillslopes via mass wasting processes (debris slides, landslides, rockfall) and snow avalanches. They deliver fine sediments and nutrients to larger channels continually, and large sediment and organic debris episodically via debris flows. In wetland source zones, streams may receive mainly organic materials, and may transport only

15 B.C. Ministry of Forests (1999).

fine organic material. Source zone channels comprise the majority of channel length within the watershed.

The **transport zone** occurs in valleys that include a **valley flat**. The term refers to the fact that stream channels here receive material from source zone channels and directly from adjacent riparian zones and transport them to deposition zones. However, transport zone channels may be partly confined by hillslopes, migrate across valley floors, or alternate between confined and unconfined, so they may still receive some inputs directly from hillslopes. They are associated with a discontinuous or continuous floodplain.

The **deposition zone** is the unconfined valley bottom where rivers are characterized by horizontal migration across floodplains and deposition of sediments is persistent. Deposition zones include alluvial fans and deltas. Deposition zone channels receive material from origin and transport zone channels as well as from adjacent riparian zones and, of course, they continue to transport some material onward as well. Deposition zones are small but disproportionately important. In many cases, management in the transportation and deposition process zones may be similar, but there will be cases where management should differ.

There will be some overlap in processes among zones. For example, material will be both transported and deposited on alluvial fans. The process zones are designated to indicate the primary processes that affect stream morphology and habitat character. At finer scales, pockets of transportation or deposition (e.g., wetlands) may be detected in the source zone. Process zones are a conceptual planning tool rather than hard and fast lines on the ground.

Methodology for mapping hydroriparian process zones

Terrain mapping provides the information required to classify areas into the deposition, transport, and source process zones. Table 3 identifies the terrain symbols commonly used to designate landforms in the deposition and transport zones—hence providing a key to initial delineation of these zones from a terrain map. The source process zone is simply defined as the area not included in the deposition and transport zones.

Variants (including **composite**[16] and **stratigraphic**[17] **symbols**) exist and some familiarity with the B.C. Terrain Classification System will aid in accurately identifying which terrain symbols are associated with a given process zone. The table is intended as a guide, to be used with the descriptions of the three process zones given above. To illustrate the method, Figure 10 shows a small watershed located in the Hecate Lowland region with terrain stability mapping and process zone delineation.

Because of the complexity of terrain symbols, drawing process zones simply by using GIS queries can result in area missed from the transportation and deposition zones because of the high number of possible combinations of descriptors. A terrain map should be used in conjunction with GIS queries.

[16] Two or three types of terrain are present within a polygon.

[17] One or more kinds of surficial materials overlie a different material.

Basing the transportation zone purely on the location of floodplain and fan landforms results in patches of transportation zone within a source zone matrix and can miss areas that are influenced by water (e.g., extensive organic plains). Adding polygons with a terrain slope class of 2–3 (<49%) that are adjacent to floodplains and fans creates continuity, but includes areas that are not within the transportation zone. In particular, when terrain mapping quality is deficient, adjacent zones may extend for a considerable distance away from hydroriparian ecosystems. An alternative approach adds a fixed strip (one-and-a-half tree heights as a default until field checking) to mapped floodplain and fan polygons. Either method can be used; the latter is less conservative but will usually be more realistic. Both methods capture over 80% of hydroriparian ecosystems as defined by site series and timber "Analysis Unit."[18]

No reliable procedures exist to map process zones in watersheds with no, or questionable, terrain mapping. Designation of landform in the current version of **small-scale Predictive Ecosystem Mapping (ssPEM)** does an extremely poor job of capturing floodplains and fans. Slope criteria could identify major floodplain units, but would lose pocket units, particularly fans, which could represent important habitat islands. However, hydroriparian process zones are easily delimited directly from air photography of scale 1:20,000 or better by an experienced air photo analyst.

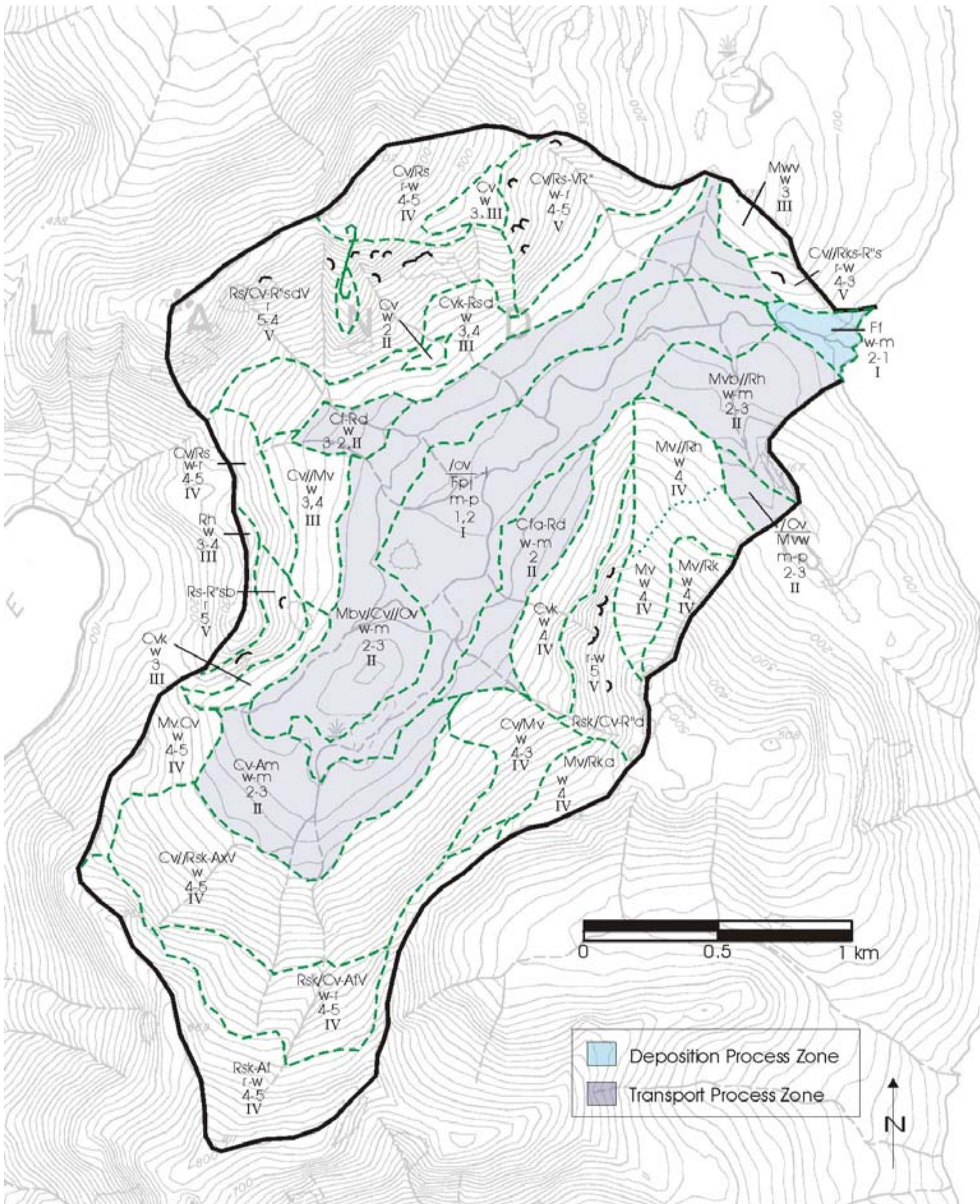
Table 3 Terrain symbols associated with transportation and deposition zones

Process zone	General terrain symbol	Comments
Deposition	Ff (fluvial fan)	A low gradient (0–7%) alluvial fan/delta situated at the outlet of the watershed (usually a sub-watershed within a larger one)
	Fp (floodplain) or F^{A}p (**active floodplain**)	Extensive floodplain polygons found near the outlet in larger systems may also be included
Transportation	F^{A}p, F^{A}f, F^{A}b, F^{A}v, F^{A}j	All active fluvial polygons (plain, fan, blanket, veneer, gentle slope) (most fluvial fans have gradient <15%)
	Fp or Ft (fluvial terrace)	Flood surfaces of unknown activity
	Cf (colluvial fan)	These landforms typically flank valley sides in mountainous subregions (gradient >14%)
	L^{A}j, L^{A}p (lacustrine gentle slope or plain)	Former lake bed
	Op, Ov (organic plain or veneer)	When found in composite or stratigraphic symbols with Fp

[18] Price (2003).

Figure 10 Example of hydroriparian process zone definitions.

Example: Hecate Lowland Subregion



6.1.3 Hydroriparian ecosystem map

Use terrain mapping, ***terrain resource inventory mapping (TRIM),*** *forest cover maps, and air photos to locate hydroriparian ecosystems (floodplains, alluvial fans, wetlands, lakes, steep and gentle small streams).*

Map terrestrial extent of hydroriparian ecosystems.

This map is created as part of this Guide using existing information. Operationally, the map involves drawing a GIS buffer around water features (streams, rivers, wetlands, lakes) and terrain-derived hydroriparian features (floodplains, fans). It is, in effect, an extension of the hydroriparian process zone map (Section 6.1.2).

This map will be used to assess risk to biodiversity and to design reserves and harvestable areas. The terrestrial extent of hydroriparian ecosystems will be examined to calculate amounts of riparian forest in natural condition for use in risk assessment and to define default reserve width prior to field surveys.

The biogeoclimatic ecosystem classification (BEC) was designed for classifying forested ecosystems at the stand level for areas of similar growing conditions for regeneration of trees. Hydrological connectivity and landscape context are not considered, nor are sites combined into ecosystem complexes. These characteristics are all important aspects of riparian ecosystems. Hence, information for specific hydroriparian ecosystems that commonly occur in the North and Central Coast and Haida Gwaii is in Appendix 2. Hydroriparian ecosystems include small, very steep streams, torrented gullies, small steep streams, small low gradient streams, fans, floodplains, karst landscapes, forested swamps, sedge fens, **slope/blanket bogs,** wetland ponds, lakes, shoreline saltspray forests, and estuaries. These ecosystems have different functions, sensitivities to disturbance, and influences on downstream systems.

For watershed planning, a simpler list of hydroriparian ecosystems, including floodplains, fans, wetlands, lakes, streams >20% and streams <20%, can be used unless more detailed information exists.

Definition of the Hydroriparian Zone
To maintain the functions of hydroriparian ecosystems (Chapter 1), hydroriparian zones must be defined with these functions in mind. Hydroriparian zones are therefore delineated as extending to the edge of the influence of water on land defined by plant community (including **high-bench** or **dry floodplain** communities) and/or landform (e.g., gullies) plus one-and-a-half site-specific tree heights (horizontal distance) beyond. In general, hydroriparian zones and hydroriparian ecosystems are coextensive but, if landform and plant communities delineate different areas, the feature extending farthest from water is adopted as the limit. In the transportation and deposition hydroriparian process zones, the entire valley flat plus one-and-a-half tree heights is considered the hydroriparian zone (this will correspond exactly with the transportation or deposition zone if it was drawn with a fixed strip but not necessarily if it was drawn to include adjacent terrain polygons with a gentle slope; see process zone map). Physical functions are influenced by at least one tree height (*Technical Report 4*); biological functions are influenced over much greater distances (*Technical Report 7*). In many respects, hydroriparian zones and hydroriparian ecosystems are coextensive, but it is not possible to define a distinct boundary for animals because most riparian organisms also use upland areas. To this extent, the protection of riparian biodiversity must be integrated with the protection of general watershed-level biodiversity. The

additional half tree height serves to protect conditions within the buffer. Wider buffers may be necessary in some cases.

In test watersheds, hydroriparian features defined by terrain mapping plus a fixed buffer included over 80% of hydroriparian site series (as determined by the intersection of ssPEM aggregated ecosystems and Timber Analysis Unit).[19] However, until further work in a variety of watersheds confirms this overlap, it is important to continue to examine site series and to add area to the hydroriparian ecosystem map as necessary.

6.1.4 High-value fish habitat, including marine habitats

Identify and map high-value fish habitat including, if applicable, estuarine and marine habitats on a watershed map. Information can be gathered from fish habitat inventory databases, stream classification inventories, consultation with federal and provincial fisheries agencies, First Nations, and stewardship groups. In areas with no inventory data or no available local knowledge, a qualified fisheries biologist must complete an overview fish habitat assessment to identify high-value fish habitat zones.

In landscapes where land development has affected high-value fish habitat, identify candidate habitat refugia at the watershed scale.

Note the presence of rare and/or endangered fish species.

High-value fish habitat

This map is not created for the *Hydroriparian Planning Guide,* but relies on existing information. High-value fish habitat will often occur in areas identified in interpretative map 3 (hydroriparian ecosystems: Section 6.1.3). Assembly of a separate map ensures that fish values, important in coastal British Columbia, will not be missed.

High-value fish habitat includes critical spawning and rearing areas for anadromous and non-anadromous fish. These areas are "biological hotspots"—specific places within aquatic systems where aquatic animals and their predators concentrate their activities and numbers. They usually receive salmon-derived nutrients and are highly productive ecosystems where nutrients are transferred from aquatic to terrestrial ecosystems. Alteration to the structure and composition of these areas may reduce the reproductive success for salmonids.

Working at the watershed scale (1:20,000) requires assessment of fish habitat at a reconnaissance level. High-value fish habitats that should be mapped for effective watershed-level planning are:

- all estuaries (including eelgrass beds, and salmonid and eulachon rearing areas)
- wet floodplains (including main channel salmonid and eulachon spawning habitats, and **off-channel habitats** used for rearing and spawning).

In watersheds with a marine interface, the following zones should also be mapped.

- high-value marine habitats (including shallow intertidal areas, kelp beds, herring spawn areas, and other nearshore habitats used by marine invertebrates for reproduction and rearing).

[19] Price (2003).

Sources vary for identifying high-value fish habitat. Small-scale maps exist based on Department of Fisheries and Oceans salmon escapement data. These maps, however, show known salmon-bearing systems, rather than mapping high-value fish habitat, and do not consider resident fish. As data improve, they should be included. Many small streams with valuable habitat are not shown at 1:20,000 scale. Field checking will be used to revise the watershed map.

The Guide provides a method for assessing risk to coarse filter biodiversity, but not for assessing risk to rare species. This Guide assumes that other processes will guide planning for listed fish.

Identify suitable habitat refugia in developed landscapes

The objective of defining and protecting riverine refugia habitats in developed landscapes (on the watershed scale) is to protect remaining salmonid populations disproportionately dependent on these habitat pockets for short-term survival. Long-term recovery will be aided by managing these areas for the primary purpose of salmonid conservation until habitat restoration in other areas has occurred.

Many types of refugia exist within a watershed, including localized habitats, unique reaches, and escape terrain (flood channels). These areas function as source areas for natural recolonization of an area after a disturbance. All components of the food chain that have been impacted must be considered in addressing the needs of species at the community level.

At the watershed scale, refugia include rivers. As rivers are open, directional systems, protection of any segment requires that planning decisions consider the entire upstream network and surrounding landscape. Within a larger drainage basin certain sub-basins should be left undisturbed to provide refugia for fish stocks.

6.1.5 Terrestrial ecosystem maps

Map site series (or surrogate – small-scale Predictive Ecosystem Mapping [ssPEM] or Timber Analysis Units, as available).

Map stand age, leading species, derived from forest cover information.

Map rare ecosystems by site series, using CDC lists or other available reports.

These three maps will have been created for other ecosystem-based planning processes.

The hydroriparian ecosystem map will partly duplicate information contained in the map of terrestrial ecosystems; for example, floodplain units will be similar. Small, steep streams in the source zone, however, can flow through many different terrestrial ecosystems. The terrestrial ecosystem map will facilitate planning for protection of all ecosystems adjacent to small streams.

In the watersheds of the British Columbia coast, riparian plant communities change fairly predictably from steep headwaters to valley bottoms. Small streams in the source zone influence moisture regimes relatively little, and plant communities near these streams may be those found in any upland ecosystem. Conversely, channels in the transportation and deposition zones influence riparian ecosystems considerably. Vegetation patterns can be used to delineate the extent of the influence of water. For example, different plant communities indicate high, **middle**, and **low benches** within floodplains, reflecting differences in flood frequency, duration, and seasonality as a function of bench height (*Technical Report 7*).

Information about forested riparian ecosystems is provided through terrestrial ecosystem mapping of biogeoclimatic site series or some surrogate (e.g., ssPEM or Timber Analysis Units). Site series from the biogeoclimatic ecosystem classification are not just descriptions of plant communities. Because they integrate differences in climate, topography, and soil, and represent habitat for other organisms, they indicate more general ecological units.

SsPEM is developed from computer modelling of spatial data using knowledge of ecological–landscape relationships, which are then used to define specific but highly variable ecological characteristics. Hence, ssPEM must be used with caution, but also with the recognition that it is the best approximation existing at the moment. If applied with caution, ssPEM provides a preliminary basis for describing site series, subject to field assessments. Site-level verification can be used to upgrade ssPEM to **TEM** (**Terrestrial Ecosystem Mapping**) over time.

Timber Analysis Units, based on descriptions of tree species and productivity, are another potential surrogate. Timber Analysis Units are not based on descriptions of ecosystems and can change over time (e.g., as an ecosystem passes through a deciduous **seral stage,** or when harvesting alters the leading tree species). Without terrestrial ecosystem mapping or field-checked predictive ecosystem mapping (PEM) designed and calibrated to the watershed in question, ssPEM combined with Analysis Units can serve to identify terrestrial hydroriparian ecosystems. As the level of risk planned for a watershed increases, the reliability of information should also increase; hence further field checking may be necessary.

Seral stage is also an important variable, defining the structural attributes and age of forest ecosystems. Stand age (by site series or by hydroriparian ecosystem) will be used to assess risk to various hydroriparian functions (Chapter 1). In general, site productivity should be captured by site series representation; hence it does not need to be mapped separately. Examination of a rare ecosystem map will help efficient design of hydroriparian reserves. Without rare ecosystem mapping, it is possible to estimate the occurrence of rare ecosystems using a combination of Timber Analysis Units and tables that link site series to Analysis Units, slope position, and ssPEM.

6.1.6 Development map

Map existing and planned timber and non-timber development within the watershed using forest cover information, forest development plans, and aerial photography as required.

This map will have been created for other ecosystem-based planning processes.

This map will be used to assess the risk to hydroriparian function posed by current levels of development and to assess opportunities for further development within the watershed.

Examination of air photos is important along floodplains and shorelines to identify old logging not recorded in databases[20] and is also useful to identify disturbance type.

[20] For example, Pearson (2003).

6.2 Determine Targets for Retention and Development Based on Precautionary Guidelines or Risk Assessment

Follow either the precautionary guidelines or risk assessment procedures (both provided in Chapter 2) to determine targets for watershed-level retention.

If risk assessment shows that opportunities for harvesting exist within acceptable risk levels, note the current risk level within each process zone and hydroriparian ecosystem for use in planning hydroriparian ecosystem reserves (Section 6.3).

If the risk assessment procedure is chosen, develop monitoring and adaptive management plan (Section 6.4).

Where reliable, detailed maps of small streams are not available, estimate the proportion of the source zone that is in cutblocks (e.g., as determined from forest history maps) to determine the proportion of small streams that have, or will have, harvesting around them.

This step follows the risk assessment procedure detailed in Chapter 1.

Small streams in the source zone provide a particular challenge. Most small streams cannot be identified by remote means, and field surveys of entire watersheds are not feasible. In addition, in parts of the source zone, small streams will be so dense that hydroriparian zones will overlap. For watersheds over 1,000 hectares, the proportion of the forested area in the source zone that has been harvested will provide a minimum estimate of the proportion of small streams affected by harvesting. Because of the typical pattern of harvesting in coastal watersheds (relatively narrow bands running along the watershed), this calculation will underestimate the proportion of harvested streams, particularly in mountainous subregions. For example, in a test watershed, in one sub-basin with 13% of the source zone harvested, 73% of source zone streams had experienced some harvesting.[21] Further work is needed to design a more effective indicator.

6.3 Design Reserves and Harvestable Area

Combine interpretative maps to create the foundation for a hydroriparian ecosystem network.

Apply reserves from subregional and landscape plans (via the Hydroriparian Planning Guide, EBM Planning Handbook, and/or other processes).

Identify and map spatially constrained reserves that are prescribed by this Guide (e.g., wet floodplain).

Design the hydroriparian ecosystem network, including spatially constrained and flexible reserves, applying mapping and information collected above. This will include application of default hydroriparian reserves and reserves identified by air photos, both subject to refinement with field planning.

From the EBM Planning Handbook, *identify watershed reserves for connectivity, rare ecosystems, representation, special elements, and human use (e.g., cultural, visual) to complete reserve design for watershed.*

[21] Price (2003).

Ground truth selected watershed reserves and refine watershed reserve design based on field assessments. Overlay map of potential operable areas on the map of the hydroriparian ecosystem network and watershed reserves.

Determine area of the timber management landbase, characteristics of timber within timber management landbase, and rate of cut for watershed.

This step maps hydroriparian ecosystem networks using the interpretive maps created in Section 6.1 and the precautionary guidelines or risk assessment applied in Section 6.2.

Thoughtful design integrates reserves, sensitive sites, and the hydroriparian network to maintain hydroriparian ecosystem functions. Reserves planned for various reasons may protect hydroriparian functions. Mapping hydroriparian ecosystem networks will occur in both watershed- (1:20,000) and site-level (1:5,000) planning. Delineation at the watershed level will be flexible until confirmed by ground-truthing at the site level. Site-level assessments will provide the opportunity to design more ecologically relevant boundaries. The hydroriparian ecosystem network includes reserves and special management areas.

There are no general rules for how much of a watershed's hydroriparian zone should be retained. The guidelines or risk assessment in the Section 6.2 exercise can be used to define how much of a particular process zone, hydroriparian zone, or site series should be

- reserved at any given time to maintain an acceptable risk level and to delineate special portions to be reserved from harvest;
- harvested with special management considerations (e.g., 50% retention of structure and function); or
- available for harvest.

A hydroriparian ecosystem network will likely include essentially linear reserves around channels in the transportation and deposition zones, and patches of reserves in the source zone around unstable terrain and concentrations of small streams. Linear reserves in the source zone may still be found where these streams are susceptible to debris flows or contain distinctive habitats. For example, a hydroriparian ecosystem network might include reservation of a red-listed floodplain community, designation of two stable fans for 50% structural retention, and reservation of patches of unique and/or representative small steep streams for connectivity, while other patches will be designated for partial retention and possible harvest. Under the biodiversity guidelines (Chapter 2), areas for reserve and harvest will be determined by site series according to their representation in the landscape. The qualities of some reserved areas will dictate that they remain reserves in perpetuity (e.g., an area of high natural instability), whereas others may become available for harvest in the long term when recovery is well advanced in contemporary harvest areas (e.g., source zone patches for preservation of representative forest). The decision about permanence of reserves will be made in development of an ecosystem-based plan for the subregion and landscape that contains a particular watershed.

Modelling of recovery from various management activities (Appendix 3) can be used to calculate the change in development opportunities over time.

The design of hydroriparian reserves, and the resultant identification of harvestable area at the watershed and sub-drainage basin levels, cannot be separated from subregional- and landscape-level reserve designs. In particular, landscape-level reserve design, coupled with assessment of landscape character and condition, provides information and constraints for watershed-level reserve design, including hydroriparian reserves. Also, subregional and landscape levels of reserves may include entire watersheds, eliminating the need to plan hydroriparian and other reserves at the watershed level.

Similarly, hydroriparian reserve design in a watershed needs to be connected with a planned overall reserve design for the watershed. While hydroriparian reserves can be designed in isolation, without considering other scales and/or watershed reserves, this approach does not respect the basic tenet of ecosystem-based management that requires interconnected planning and reserve design at multiple spatial scales. It is also inefficient, as it likely leads to more area being withdrawn from the harvestable landbase than if an integrated approach is taken. Appropriate reserve design at multiple spatial scales results in interdependent reserve designs at differing scales. Reserves for protection of cultural and historical sites are included in an ecosystem-based plan. These reserves are generally added in the process of human use zoning as described in the *EBM Planning Handbook* but could be added during development of the hydroriparian ecosystem network.

Therefore, the process described below to design hydroriparian reserves assumes that they will be designed as part of a broader process to identify reserves at multiple spatial scales.

Selection of hydroriparian ecosystem reserves may be based either on precautionary guidelines or on a risk assessment procedure, accompanied by appropriate monitoring and adaptive management. It is most efficient to design a network of precautionary hydroriparian reserves, based on precautionary guidelines, first. Then, if there is a rationale to move beyond the precautionary guidelines (e.g., specific local knowledge that risks are lower than in the general risk curves presented, or of unacceptably high risks to other values), it is easy to choose a subset of functions for application of the risk assessment procedure.

A rationale for the hydroriparian ecosystem network will be written as part of an ecosystem-based watershed plan, so that First Nations, community members, planners, and managers understand the basis for the reserves and special management areas. The rationale will provide an important reference for people engaged in ongoing planning processes to approve, or revise the plan.

The steps below result in a mapped hydroriparian ecosystem network.

Step 1: *Consider subregional and landscape information and constraints.* In landscapes that have been moderately to highly modified, the appropriate level of risk acceptable for hydroriparian reserves and upland reserves in the watershed will be low. For landscapes that have been only slightly modified to unmodified, the appropriate level of risk applied to a watershed will generally be moderate, but could under some limited circumstances be high. Generally speaking, however, high risk management options do not fall within the range of ecosystem-based management plans and practices.

Step 2: *Map spatially constrained reserves based on the precautionary guidelines in Chapter 2, using the interpretative maps***.** These reserves are derived from the precautionary guidelines for maintaining stream morphology, bank stability, downed wood, and high-value fish habitat. On a base map showing water features, contours, and process zones, reserve:

a) all terrain polygons classified as slope stability IV or V;

b) all terrain polygons classified as active fluvial units (including F^Ap, F^Av, F^Ab, F^Aj, F^Af) or as floodplain of unknown activity (Fp);

c) all wetlands;

d) default buffers (one-and-a-half site-potential tree heights wide) around all streams and rivers within the transportation and deposition zones;

e) any extra area required to protect high-value fish habitat (this step may require checking other sources); and

f) red-listed and blue-listed and other rare ecosystems (these will be available through other ecosystem-based planning exercises).

Step 3: *Determine locations for watershed refugia, as required.* In landscapes where development has affected high-value fish habitat in other watersheds, candidate watershed-level refugia will be selected from analysis of interpretative map 4, that synthesizes high-value fish habitat. These watershed refugia will be added to the hydroriparian ecosystem network, and mapped accordingly. Note that refugia created to protect fish habitat are reserved only until ecological/hydrological recovery is considered to be satisfactory elsewhere.

Step 4: *Design preliminary reserves to maintain hydroriparian biodiversity.* Calculate the area of each hydroriparian ecosystem (floodplains, fans, steep streams, other streams, wetlands, lakes) to reserve (based on deviation from amount of natural riparian forest; see guidelines under biodiversity Chapter 2). Add preliminary reserves as necessary, considering ecosystem representation. In the source zone, identify small fish-bearing streams and their direct tributaries and map default reserves of one-and-a-half tree heights for these streams. Select small stream reserves to protect the target area of source zone streams, considering site series representation, geographic distribution of reserves, terrain sensitivity, and stand age. Initial reserves are subject to review according to the level(s) of acceptable risk, to site-specific terrain/ecological features, and to representation analysis.

Step 5: *Complete representation analyses.* Check that all site series (or their surrogates) are proportionally represented and modify designed reserves as necessary.

Step 6: *Analyse riparian connectivity.* Review reserve and modify, as necessary, to meet the targets for riparian corridors listed in Chapter 1.

6.4 Develop Monitoring Plan for Adaptive Management within the Watershed

Follow guidelines in Chapter 3 to develop adaptive management and monitoring plan.

In the absence of an adaptive management and monitoring plan, follow precautionary guidelines for watershed planning.

The *Hydroriparian Planning Guide* was designed to be part of an adaptive management program. Adaptive management is valuable whenever there is significant uncertainty about the outcomes of management activities, such as those recommended by this Guide. While existing research provides some direction (summarized in the risk curves presented in Chapter 2), data for local ecosystems are lacking and considerable uncertainty exists around the development of the risk curves. Accordingly, uncertainty increases as planners choose increased risk in their management strategy. The procedures specified in this Guide *require* that an adaptive management and monitoring plan be adopted whenever development levels exceed the precautionary guidelines. Adoption of adaptive management procedures, even when precautionary guidelines are followed, will more rapidly improve knowledge and decrease the uncertainties associated with management, and will submit the precautionary guidelines to critical evaluation. It is *recommended* that adaptive management always be considered.

Planning at the subregional level (Chapter 4) should have initiated the development of a coordinated, collaborative adaptive management plan. The central focus of adaptive management is to formulate management approaches and policies as experiments that probe the responses of ecosystems as management activities change. Careful design, monitoring, evaluation, and feedback are critical components of this process (see Chapter 3)

Within watersheds, reserves and habitat refugia may serve as control sites, so long as they meet the experimental criteria for a control site. Sites undergoing continuing monitoring (e.g., monitored streams used to measure fish populations) should be considered for inclusion in reserves.

Chapter 3 gives an introduction to adaptive management, provides a general approach, and lists some important questions specifically related to this Guide.

7 Developing the Site Plan (Map Scale 1:5,000 or Larger)

At this stage, fieldwork is undertaken. Field assessment leads to revision, as required, of the components of the hydroriparian ecosystem network and the hydroriparian ecosystem network map. Site-level reserves, retention, and management zones necessary to protect hydroriparian ecosystem functions are established and recorded on a site plan map. Then the harvest area (cutblock or multiple cutblock) components (i.e., road locations, landing locations, drainage structures, and cutblock boundaries) may be identified and mapped.

7.1 Assess in the Field, and Review as Required, the Components of the Hydroriparian Ecosystem Network

Key aspects of this step are the following:

- Carry out field inspection to evaluate the hydroriparian ecosystem network and other watershed reserves, considering
  - process zones, terrain units, hydroriparian ecosystem functions, hydrologically active areas related to high-value fish habitat, site series, and **microterrain features**; and
  - boundaries of the hydroriparian reserves as defined at the watershed level. Important factors to consider in this step are downed wood, anadromous and resident fish and fish habitat, windfirmness, microterrain sensitivity, natural slope breaks, and the importance of adjacent ecosystems to biodiversity of hydroriparian reserves.
- Correct information on watershed reserves map and revise watershed plans as necessary.
- Provide a technically verifiable rationale for changes (i.e., site conditions confirmed to vary from those inferred in watershed-level analysis), including additions and deletions made to the hydroriparian ecosystem network, other reserves, watershed features, and/or watershed plans.

Field surveys will be used to verify or revise watershed features, including process zones, terrain units, hydroriparian ecosystems, and site series mapped at the watershed level.

Through field surveys, it will be possible to delineate ecologically more appropriate, effective, realistic and feasible boundaries for hydroriparian ecosystem networks and other watershed reserves. Particular attention should be paid to drainage conditions near slope base, where mapped hydroriparian reserves are likely to need adjustment.

Ideally, this step would be carried out for the entire watershed. However, operational constraints likely will limit this assessment to the portions of the watershed where active development planning is occurring.

7.2 Establish Site-level Reserves, Retention, and Management Zones Necessary to Protect Hydroriparian Ecosystem Functions

NB: This step is carried out within the area of interest for location and design of a specific cutblock.

Prepare the site plan map showing reserves, retention, and management zones. Key aspects of this stage are the following:

- Identify and map small streams and other hydroriparian ecosystems (e.g., wet slopes, springs, seeps, wetlands).
- Establish, mark in the field, and map reserves, retention, and management zones, as required to protect hydroriparian functions by:
  - identifying the hydroriparian functions that are most relevant to the reserve under consideration and applying precautionary guidelines appropriate to those functions to determine site-level reserves, retention, and management zones, including small sensitive areas as determined from microterrain features. For example, within a particular floodplain hydroriparian zone, the precautionary guideline allows for 10% deviation (by area) from natural levels of old forest. Note: In ecosystem-based management the 10% removed must be representative of a stand's profile (i.e., it does not allow for removal of all of the big spruce trees);
  - determining small stream protection requirements based on level of protection required for locations within the watershed (i.e., process zone, terrain sensitivity, site series/forest cover representation);
  - considering the dependence of small stream channels on downed wood, and considering anadromous and resident fish/fish habitat, windfirmness, microterrain sensitivity, natural slope breaks, and the importance of adjacent ecosystems to biodiversity of hydroriparian reserves; and
  - establishing reserves around high-value fish habitat.

The results of this step are a site plan map and rationale for site-level hydroriparian reserves, retention, and management zones necessary to protect hydroriparian ecosystem functions at the site scale. This map will be used to plan development in step 7.3 of the development of a site plan.

7.3 Identify Harvest Area (Cutblock or Multiple Cutblock) Components

Note: This step uses the site plan map developed above that shows site reserves, retention, and management zones.

Key aspects of this stage include the following:

- Use site-level reserves, retention, and management zones to guide road location, landing location, and cutting unit boundary to protect hydroriparian functions. This is a key aspect of ecosystem-based management. Locations of reserves direct the location of harvesting.

- Design and locate in the field harvest system components.
- Add the harvest system components to the site plan map.
- Specify construction standards for roads, and management practices for treatment units within the site to protect hydroriparian functions. These standards will be established in conformity with the need to maintain hydroriparian functions. This step includes provision of a rationale for the harvest system design that explains how the site plan provides an appropriate level of protection for hydroriparian ecosystems that is within the range of ecosystem-based management, and meets targets set by higher-level plans.

Site-specific features are important factors in selecting the best location for the target levels of retention and harvesting within a watershed. For example, within a watershed, risk assessment might provide for 20% harvesting of fans. The areas available to harvest will depend upon the frequency and extent of disturbance events. Because the extent may vary from 30 metres to over 1 kilometre from the active channel, field assessments are required to best locate reserves on fans.

Important elements of site-level design include the following:

- Establish reserves and retention as required to protect rare ecosystems and fish habitat, and to meet representation targets.
- Identify important fish habitat features such as deep pools, undercut banks, and downed wood complexes and ensure that they are undisturbed by management practices. For example, retain trees rooted in the streambanks to maintain undercut banks; manage for recruitment of downed wood into wood-dependent reaches; and maintain shade over streams.
- Concentrate retention around downed wood-dependent reaches, tributaries to fish bearing streams, and confluences.
- Design retention to be resistant to windthrow, considering where windward boundaries of retention patches are located (topographic exposure, rooting restrictions, etc.), the nature of the patches (tree species, density, height), and the pattern of retention close by (which may reduce or increase exposure to damaging winds). A reserve of one-and-a-half tree lengths allows for moderate endemic blowdown in the first tree length. If more blowdown is expected, reserves will need adjustment. Retain windfirm patches, and design windfirm buffer widths and shapes, as opposed to just using fixed buffer widths around hydroriparian ecosystems. The key here is to strive to have effective buffers. In some portions of stream reaches, there may be small areas without buffers, but such situations will be compensated for with wider buffers in other locations, and/or through reserves of patches of small streams in areas near to, or adjacent to the area in question.
- Protect fans by following this approach: If the channel is not laterally confined, go to the edge of recent sediment deposits (current disturbance extent), then go another 50 metres to establish the edge of the protective buffer. Check the age of cohorts next to the channel to determine frequency of disturbance. Plan roads and bridges appropriately.

- Prohibit machine traffic in reserves and retention areas, and minimize machine traffic in management zones. In most instances, machine traffic will not be necessary to carry out partial harvesting that may occur in management zones.
- Prohibit mechanical disturbance to streambank.
- Prevent overland flow of sediment to streams (for example, avoid disturbance to understory vegetation adjacent to streambanks; designate machine-free zones).
- Maintain fish passage by preventing the creation of obstructions to migration.
- Follow all Best Management Practices listed in guidebooks associated with the Forest Practices Code.

7.4 Apply Adaptive Management

Site-level plans must consider the adaptive management strategies designed at higher levels. Some adaptive management experiments will be focused at the site level, with sets of paired sites or sub-basins within replicated watersheds.

Detailed information collected during site-level surveys should not be lost. It is critically important to ensure effective recording of information and data gathered through adaptive management experiments. To set up opportunities for passive adaptive management, it is also necessary to record information from other areas of work and other operations.

To increase the chances of learning while managing, it is recommended that a hydroriparian database be established to record specific information on ecosystems and management plans. This database will eventually be a major resource for passive adaptive management analyses.

7.5 Feed Information Back to Higher Scales

Incorporate site-level information into the watershed plan, modifying boundaries mapped at watershed level on the basis of site-level information. Use site-level information to revise ecosystems as appropriate.

A final, critical, step integrates the detailed information collected at the site into watershed plans and into monitoring and adaptive management plans.

Appendix 1 References

Technical and Background Reports

Prior to the development of this *Hydroriparian Planning Guide,* the Work Team commissioned a series of technical reports to review the relevant literature and make recommendations in relation to the condition and management of hydrological, aquatic, and terrestrial aspects of hydroriparian ecosystems, with particular focus on the Pacific Northwest. These reports represent internal working papers of the HPG Work Team. Accordingly, they have been reviewed by experts selected by the authors, but have not been externally peer reviewed. Background reports produced for LRMP processes in the North and Central Coast and Haida Gwaii/Queen Charlotte Islands have also provided information. Primary literature is not cited in the Guide, but interested readers are referred to the reports listed below, where citations of the primary literature are found.

Technical Report #1: Trainor, K. 2001. *Geomorphological/hydrological assessment of the Central Coast plan area.*

Technical Report #2: Trainor, K. 2001. *Ecosystem sub-units: Central Coast, North Coast & Haida Gwaii Plan Areas.*

Technical Report #3: Church, M and B. Eaton. 2001. *Hydrological effects of forest harvest in the Pacific Northwest.*

Technical Report #4: Young, K. 2001. *A review and meta-analysis of the effects of riparian zone logging on stream ecosystems in the Pacific Northwest.*

Technical Report #5: Bunnell, F.L., G.D. Sutherland, and T.R. Wahbe. 2001. *Vertebrates associated with riparian habitats on British Columbia's mainland coast.*

Technical Report #6: Zielke, K. and B. Bancroft. 2001. *A comparison of riparian protection approaches in the Pacific Northwest and British Columbia.*

Technical Report #7: Price, K. and D. McLennan. 2002. *Impacts of forest harvesting on terrestrial riparian ecosystems of the Pacific Northwest.*

Holt, R. and G. Sutherland. 2001. *Environmental risk assessment: base case coarse filter biodiversity. Background report for the North Coast LRMP.*

Pojar, J., C. Rowan, A MacKinnon, D. Coates, and P. LePage. 1999. *Silvicultural options in the Central Coast. Background Report for the Central Coast LCRMP.*

Price, K. and D. McLennan. 2001. *Hydroriparian ecosystems of the North Coast. Background report for the North Coast LRMP.*

Other References

B.C. Ministry of Environment, Lands and Parks. 2000. Environmental risk assessment: an approach for assessing and reporting environmental conditions. Habitat Branch, Victoria, B.C. Technical Bulletin 1.

B.C. Ministry of Forests. 1999. Mapping and assessing terrain stability guidebook. Victoria, B.C. 2nd ed.

B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. 1995. Biodiversity guidebook. Victoria, B.C. Forest Practices Code guidebook.

B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. 1995. Coastal watershed assessment procedure guidebook. Victoria, B.C. Forest Practices Code guidebook.

Holling, C.S. (editor). 1978. Adaptive environmental assessment and management. John Wiley and Sons, New York.

Lee, K.N. 1999. Appraising adaptive management. Conservation Ecology 3(2):3.

Nyberg, B. 1999. An introductory guide to adaptive management for project leaders and participants. B.C. Ministry of Forests, Forest Practices Branch, Victoria, B.C.

Pearson, A. 2003. Natural and logging disturbances in the temperate rain forests of the Central Coast, British Columbia. Report to B.C. Ministry of Sustainable Resource Management, Victoria, B.C.

Price, K. 2003. *Testing the Hydroriparian Planning Guide*. Report for the North Coast LRMP and CIT.

Price, K. and D. Daust. 2003. The frequency of stand-replacing natural disturbance in the CIT region. Report prepared for the CIT.

Taylor, B., L. Kremsater, and R. Ellis. 1997. Adaptive management of forests in British Columbia. B.C. Ministry of Forests, Forest Practices Branch, Victoria, B.C.

Walters, C. 1986. Adaptive management of renewable resources. MacMillan, New York.

Appendix 2 Characteristics of coastal hydroriparian ecosystems, including stream, wetland, and marine ecosystems

Hydroriparian ecosystem	Ecosystem characteristics	BEC site series
Small, very steep streams gradient >20%; width <3 m; flow perennial, seasonal or ephemeral	network of perennial, seasonal and ephemeral[a] streams expanding and shrinking with precipitation seepage ecosystems often occur along the stream; range of site conditions and understory vegetation, including devil's club, salmonberry, or red alder some streams may be highly susceptible to debris flow; others have special microclimates abundant in mountain zones; infrequent in lowlands in-channel sedimentation restricted to forced deposits behind jammed logs or boulders	CWHvh2/04,06 CWHvm/01,05,08 CWHws/01,04,06 CWHwm/01,03,04
Torrented gullies gradient >20%; flow perennial or seasonal	steep, confined channels, often cut into deep glacial till or bedrock unique vegetation community within gully due to continuously cool and damp microclimate; gully walls may be unstable glacial deposits, bedrock, or productive seepage ecosystems dominated by western hemlock and Sitka spruce with devil's club and a rich herb community; lower gradient gully bottoms may have small floodplain with abundant shrubs, herbs, redcedar, and amabilis fir may be clear of sediment or filled with organic and mineral slide deposits common along larger valleys throughout mountain zones; rare in lowlands	CWHvh2/04,06 CWHvm/01,05,08 CWHws/01,04,06 CWHwm/01,03,04
Small, steep streams 4% < gradient <20%; width <3 m; flow perennial or seasonal	adjacent vegetation varies from dry to wet sites frequent log jams; mineral sediments structured abundant on lower slopes; often connected to a range of small- and medium-sized lakes and pools; further inland, infrequent as seasonal streams in backchannel areas on fans; common in Insular Mountains	CWHvh2/01,11,12,13 CWHvm/variable CWHws/variable CWHwm/variable
Fans gradient 4–20%; width <10 m; flow perennial or seasonal	characteristic fan formations that develop where streams reach the valley floor and deposit mineral sediment and organic debris; channels subject to frequent shifting on active fans consequently, highly dynamic ecosystems support coniferous or deciduous forests of various ages depending on disturbance history; very large Sitka spruce and western hemlock common in less active areas of the fan; conifer stands often feature wide spacing and large tree crowns, red alder and slide alder the most common deciduous species feature abundant berries and herbs and are important wildlife habitat common in mountain zones where they form a characteristic valley floor complex with floodplains; infrequent in lowlands	CWHvh2/06,07 CWHvm/05,08 CWHws/04,06 CWHwm/03,04

[a] **Perennial streams** flow year round and have rich communities of aquatic invertebrates; **seasonal streams** are dry for a season, but have a stable source of water and have rich communities of aquatic invertebrates; **ephemeral streams** flow for a short period after storms and change routes periodically.

Hydroriparian ecosystem	Ecosystem characteristics	BEC site series
Small and intermediate, low gradient streams gradient <4%; width <10 m; flow perennial or seasonal	adjacent vegetation varies from dry to wet sites may be associated with significant floodplain abundant in lowlands, draining organic terrain in forested and non-forested ecosystems; often connected to a range of small- and medium-sized lakes and pools; occur as seasonal streams in backchannel areas on major floodplains or fans	CWHvh2/08,09,10 CWHvm/09,10,11 CWHws/07,08,09 CWHwm/05,06,07
Floodplains gradient <4%; width variable; flow perennial or seasonal	complex ecosystems built from sediment deposited in low gradient reaches; constantly created and eroded; range from very narrow along small streams to 1 km wide or more changing mosaic of high productivity ecosystems; forests range from stands of widely spaced, large Sitka spruce and western hemlock, to red alder or black cottonwood stands on younger surfaces, and willow, black cottonwood/red alder stands on the lowest benches; areas of poor drainage or beaver- and debris-dammed areas may support shrub and sedge wetlands; forested swamps occur in depressions, often along the base of the valley walls or at the toes of fans feature abundant berries and herbs and are important wildlife habitat rare (high-bench) to infrequent (low-bench) and small in lowlands; low- and high-bench floodplains common in Inner and Outer Coast Mountains on valley floors of larger valleys; where they meet the seas, floodplains on medium and large rivers often grade into estuaries; high-bench floodplains rare in Insular Mountains due to small channel size	CWHvh2/08,09,10 CWHvm/09,10,11 CWHws/07,08,09 CWHwm/05,06,07
Karst landscapes gradient and width variable; some entirely underground	complex three-dimensional landscape with water travelling underground through channels and caves nutrient-rich soil and well-developed drainage on limestone supports very productive forests relative to neighbouring stands underlain by other bedrock; pH buffered, even temperature, streams support diverse and abundant invertebrate communities and rapidly growing fish found only in Lowlands and Haida Gwaii	CWHvh2/05

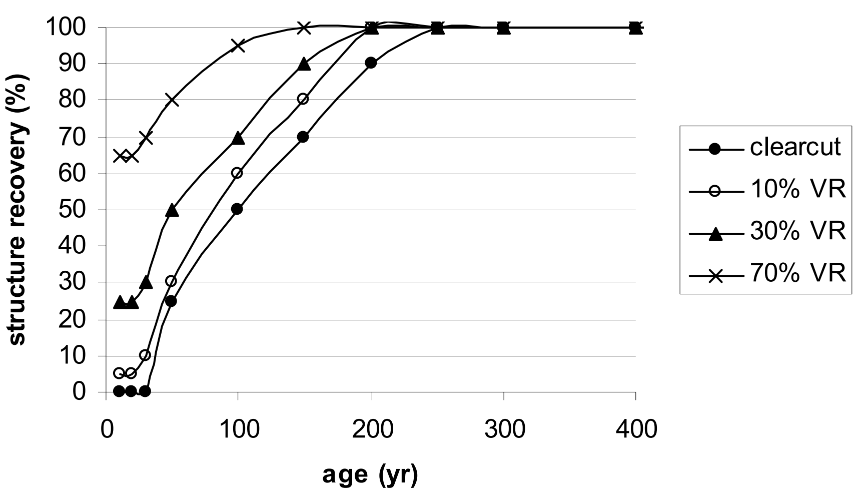
Riparian system	Ecosystem characteristics and notes	BEC site series
Forested swamps	forested wetland ecosystems with mineral seepage that increases productivity compared with other wetlands support western hemlock, Sitka spruce, and western redcedar on elevated mounds, skunk cabbage in depressions; open canopies with dense herb and shrub communities infrequent in lowlands on lower slopes and depressional areas; common in mountain regions on depressions on larger floodplains adjacent to valley walls or at the base of fans	CWHvm/14
Sedge fens	sedge-dominated wetlands occurring in landscape depressions with variable amounts of mineral seepage; soils mostly fibric and mesic peat over fluvial deposits fringed by low and tall shrub communities, grading into forested swamp or upland ecosystems infrequent in lowlands near river channels and small lakes where lateral seepage occurs; infrequent in mountain regions in depressions on floodplains, as fringes around lakes, at fan bases or back channels	CWHvh,vm,ws,wm/31
Slope/blanket bogs	level to sloping, large bogs; mostly organic veneers and blankets over bedrock and till supports sphagnum, sedges, and heath shrubs, with scattered stunted western and mountain hemlock, and yellow-cedar at higher elevation abundant and characteristic of lowlands, covering >50% of the landscape, and forming a mosaic with forested ecosystems on organic soils; infrequent further inland in transitional areas; common in Insular Mountains	CWHvh2/31
Wetland ponds	small, shallow freshwater ecosystems, often with organic banks; forms complex of ponds and streams; hydrology determined by flows in adjacent organic soils abundant algal and macrophytic vegetation abundant in lowlands in forested and bog landscapes; infrequent further inland, associated with slope wetlands (CWHvm2, MHmm1) and infilling stream meanders; common in Insular Mountains	not classified
Lakes	freshwater ecosystems providing an important component of regional biodiversity abundant small lakes in lowlands, often connected with ponds and small, low gradient streams; larger lakes infrequent throughout area; several deep, medium-sized lakes occur in faulted bedrock structures in Outer and Inner Coast Mountains	not classified
Shoreline saltspray forests	seaside forests that differ from other upland forests because of the effects of salt spray and strong winds, tidal flooding and marine-related landforms such as beaches, estuaries, and glaciomarine sediments Sitka spruce dominates; understory varies with landform and marine effects; unique and productive epiphytic lichen communities because of wind and salt spray infrequent in lowlands and common on Insular Mountains on windy, unprotected shores	CWHvh2/14,15,16,17
Estuaries	extremely rich and productive ecosystems created where tidal marine water and sediment mix with freshwater and river sediment mosaic of unique forest wetlands; shrub thickets; sedge and grassland ecosystems; salt, brackish, and freshwater marshes; and mudflats infrequent in lowlands (small because of small contributing areas and low sediment transport); infrequent in mountain regions (very small to very large; large estuaries occur in conjunction with floodplain-fan valley systems; small occur where fans empty directly into the ocean)	CWHvh2/18,19 similar site series in CWHvm

Appendix 3 Recovery from disturbance: An example

After disturbance, ecosystems tend to recover to a viable state closely related to the original state. Recovery time following a disturbance depends on the intensity, extent, and legacy of the disturbance. In sensitive ecosystems, or following intense disturbances, some elements may not recover. Curves describing the recovery of ecosystem elements (e.g., stand structure, vegetation, soil biota, epiphytic biota) over time can be used to assess the functional integrity of a disturbed stand. Curves can be developed based on different types of disturbance (natural vs. managed; clearcutting vs. 50% retention).

Curves describe the recovery (from clearcutting) of structure (large live, dead, and downed trees), tree composition, understory vegetation, soil biota, and epiphytes for 10 analysis units (based on leading species and site index) within the BEC variants of the North Coast (developed for the environmental risk assessment of the North Coast LRMP). Some of these analysis units are relevant to hydroriparian ecosystems (e.g., the spruce leading, high productivity analysis unit is a floodplain ecosystem). Initial curves have been developed describing recovery from 10, 30, and 70% variable retention for structure, vegetation, and soil biota for high and medium productivity spruce leading sites (Figure A3.1).

Figure A3.1 Expert-based recovery curves for structure in the spruce-leading, high site index (floodplain) analysis unit in the CWHvh2. Curves are based on initial management activities of clearcutting, and 10%, 30%, and 70% variable retention.



Development of an old growth equivalency index based on forest age and levels of structural retention requires further work. For the example shown, recovery of structure to a fully functioning, late seral stage on a floodplain in the Hecate Lowland takes 250 years following clearcutting, 200 years following 30% retention, and 150 years following 70% retention. Such an index will facilitate comparisons of risk among different management options (e.g., variable retention, long rotation). Although recovery curves based on analysis units can be applied to some hydroriparian ecosystems, curves for site series or hydroriparian ecosystem would be more appropriate. Similar recovery curves might in principle be constructed for physical characteristics of the hydroriparian system but there is, in general, insufficient collated evidence to allow this to be achieved.

Appendix 4 Abundance, importance, and influence of hydroriparian ecosystems in coastal regions

Table A4.1 Landscape abundance of hydroriparian ecosystems in coastal regions (rare = 1, infrequent = 2, common = 3, abundant = 4)

Hydroriparian ecosystem	Lowland	Outer Coast Mountains	Inner Coast Mountains	Insular Mountains
small steep stream[a]	2	4	4	4
torrented gullies	1	3	3	3
small low gradient streams	4	2	2	3
fans	2	3	3	3
dry floodplain	1	3	3	1
wet floodplain	2	3	3	3
karst	1	n/a	n/a	2
bogs	4	2	2	3
forested swamps	2	3	3	3
sedge fens	2	2	2	2
ponds	4	2	2	3
lakes	2	2	2	2
shoreline forests	2	n/a	n/a	3
estuaries	2	2	2	2

[a] Includes small, very steep streams and small, steep streams as per Appendix 2.

Table A4.2 Importance of hydroriparian ecosystems for maintaining terrestrial hydroriparian function in coastal regions (low = 1, moderate = 2, high = 3, very high = 4)

Hydroriparian ecosystem	Lowlands	Outer Coast Mountains	Inner Coast Mountains	Insular Mountains
small steep streams[a]	3	4	4	4
torrented gullies	3	4	4	4
small low gradient streams	4	2	3	3
fans	4	4	4	4
dry floodplain	3	4	4	2
wet floodplain	4	4	4	4
karst	4	n/a	n/a	4
bogs	4	2	2	3
forested swamps	3	3	3	3
sedge fens	1	2	2	2
ponds	2	1	1	1
lakes	1	3	3	3
shoreline forests	2	n/a	n/a	3
estuaries	4	4	4	4

[a] Includes small, very steep streams and small, steep streams as per Appendix 2.

Table A4.3 Influence of hydroriparian ecosystems on other hydroriparian ecosystems in a watershed in coastal regions (low = 1, moderate = 2, high = 3, very high = 4)[a]

Hydroriparian ecosystem	Lowlands	Outer Coast Mountains	Inner Coast Mountains	Insular Mountains
small steep streams[b]	4	4	4	4
torrented gullies	4	4	4	4
small low gradient streams	2	1	2	3
fans	3	3	3	3
dry floodplain	2	4	4	2
wet floodplain	3	4	4	4
karst	4	n/a	n/a	4
bogs	2	1	1	2
forested swamps	2	3	3	3
sedge fens	2	2	2	2
ponds	1	1	1	1
lakes	2	3	3	3
shoreline forests	2	n/a	n/a	3
estuaries	4	4	4	4

[a] Data derived from expert judgements. Each value has an associated uncertainty level (0–10) and rationale recorded in expert workshop proceedings (but not presented) to allow inclusion in a Bayesian Belief Network.

[b] Includes small, very steep streams and small, steep streams as per Appendix 2.

Appendix 5 Characteristics of ecological subregions

British Columbia's Coast can be divided into four regions—Coastal Lowlands, Haida Gwaii Uplands, Outer Coast Mountains and Inner Coast Mountains—differing in topography, climate, hydrology, natural disturbance regimes and ecosystems (Pojar et al. 1999; Price and McLennan 2001; *Technical Report 1*). The Lowlands form narrow, low-lying, boggy strips along the coast and islands. The Insular, Outer Coast and Inner Coast Mountains feature steep, rugged mountains, large watersheds, and ocean fjords, and are distinguished primarily by climate. Geomorphic disturbances (avalanches, debris flows, and landslides) and flooding are common in the Inner and Outer Coast Mountains; fire is significant only in the Inner Coast Mountains; wind is a minor disturbance agent except in the Insular Mountains. The planning area also contains a small section of an interior region, the Nechako Plateau. The four major regions are further subdivided into 11 subregions according to physiography and hydrology.

Table A5.1 Characteristics of physiographic subregions

Subregion	Biogeoclimatic subzone	Physiographic region	Climate	Landscape pattern	Principal stand-replacing disturbances	Specific management concerns
Hecate Lowland	Hypermaritime	Coastal trough	Very wet, cool, little snow	Small patches of scrubby forest in matrix of non-forested bogs	Very rare wind, debris flows, and landslides	**Sensitive terrain** re: bogs, organic soils; wind hazard
Milbanke Strandflat	Hypermaritime	Coastal trough	Very wet, cool, little snow	Small patches of scrubby forest in matrix of non-forested bogs	Very rare wind, debris flows, and landslides	Sensitive terrain re: drainage; wind hazard
Haida Gwaii Lowlands	Hypermaritime	Coastal trough	Very wet, cool, little snow	Small patches of scrubby forest in matrix of non-forested bogs	Very rare wind, debris flows, and landslides	Sensitive terrain re: bogs, organic soils; wind hazard
Skidegate Plateau	Hypermaritime	Insular Mountains	Very wet, cool, little snow	Old forest matrix	Debris flows, landslides, flooding, wind	Wind hazard; slope stability
Haida Gwaii Mountains	Hypermaritime	Insular Mountains	Very wet, cool, little snow	Old forest matrix	Debris flows, landslides, flooding, wind	Slope stability; wind hazard

Subregion	Biogeoclimatic subzone	Physiographic region	Climate	Landscape pattern	Principal stand-replacing disturbances	Specific management concerns
Outer Coast Mountains – Pacific Ranges	Maritime	Coast Mountains	Very wet, cool summer, heavy snow	Old forest matrix (amabilis fir, hemlock, cedar, Sitka spruce) interrupted by slide tracks, wetlands, and rock; glaciers present	Debris flows, landslides on steep terrain; flooding in valleys	Slope stability; flood hazard; channel stability; avalanche hazard; glacial runoff (some rivers)
Outer Coast Mountains – Kitimat Ranges	Maritime	Coast Mountains	Very wet, cool summer, heavy snow	Old forest matrix (amabilis fir, hemlock, cedar, Sitka spruce) interrupted by slide tracks, wetlands, and rock	Debris flows, landslides on steep terrain; flooding in valleys	Slope stability; flood hazard; avalanche hazard
Outer Coast Mountains – Boundary/Skeena Ranges	Maritime	Coast Mountains	Very wet, cool summer, heavy snow	Old forest matrix (amabilis fir, hemlock, cedar, Sitka spruce) interrupted by slide tracks, wetlands, and rock; glaciers present	Debris flows, landslides on steep terrain; flooding in valleys	Slope stability; flood hazard; channel stability; avalanche hazard; glacial runoff (some rivers)
Inner Coast Mountains – Pacific Ranges	Sub-maritime	Coast Mountains	Relatively dry to wet, warm summer, heavy snow	Old forest matrix (hemlock, cedar, some Douglas-fir) interrupted by slide tracks, wetlands, and rock; glaciers present	Debris flows, landslides on steep terrain; flooding in valleys; rare fire	Slope stability; flood hazard; channel stability; avalanche hazard; glacial runoff (some rivers)
Inner Coast Mountains – Kitimat Ranges	Sub-maritime	Coast Mountains	Relatively dry to wet, warm summer, heavy snow	Old forest matrix (hemlock, cedar, some Douglas-fir) interrupted by slide tracks, wetlands, and rock	Debris flows, landslides on steep terrain; flooding in valleys; rare fire	Slope stability; flood hazard; avalanche hazard
Nechako Plateau	Continental	Interior Plateau	Moderately dry, warm to cool summers, and cold winters	Old forest matrix (subalpine fir, spruce, lodgepole pine)	Fire; debris flows, landslides on steep terrain	Slope stability

Appendix 6 Sample watershed plan

This appendix provides a sample watershed plan based on a simple procedure following precautionary guidelines.[22]

Chambers Creek empties into Nass Bay on the North Coast. It includes a single third-order watershed of 8,911 hectares. Development of Chambers Creek has only recently started, allowing for creation of a hydroriparian ecosystem network with few constraints.

Procedure (based on Chapter 6)

On a base map showing water features, contours, and process zones

1. Reserve all terrain polygons classified as slope stability IV or V; use terrain map/data
2. Reserve all terrain polygons classified as active fluvial units (including $F^{A}p$, $F^{A}v$, $F^{A}b$, $F^{A}j$, $F^{A}f$) or as floodplain of unknown activity (Fp); use terrain map/data
3. Reserve all wetlands; use hydroriparian ecosystem map/data
4. Draw preliminary buffers (one-and-a-half tree heights wide) around all streams within the transportation and deposition zones; use base map; GIS buffering exercise
5. Determine if extra reserves are required to protect high-value fish habitat; use high-value fish habitat map/data
6. Reserve rare ecosystems; use rare ecosystem map/data
7. Calculate the area of each hydroriparian ecosystem (floodplains, fans, steep streams, other stream, wetlands, lakes) to reserve based on guideline giving precautionary deviation from natural area. Add preliminary reserves as necessary, considering ecosystem representation; use hydroriparian ecosystem map/data and site series map/data
8. Select small stream reserves to protect the area of source zone streams. Consider ecosystem representation in designing areas; use base map and site series map/data
9. Check that all site series (or their surrogates) are proportionally represented and modify as necessary; base map with reserves and site series map/data
10. Check that requirements for corridors are met within the reserve system and modify as necessary; base map with reserves

The first six steps are spatially constrained and provide the backbone of the hydroriparian ecosystem network, protecting stream morphology, bank stability, downed wood, and rare ecosystems. The remaining steps are flexible in location, though constrained to meet representation requirements, and focus on maintaining biodiversity.

[22] Based on Price (2003). The test includes a second watershed, Paril River.

The entire procedure takes about a day to complete for a 10,000-hectare watershed, once all data are collated into a usable format and process zones have been defined, using a combination of paper maps and GIS databases.

This process delineates a precautionary watershed-level hydroriparian ecosystem network (Table A6.1). Site-level assessment will revise boundaries. Risk assessment procedures can be used to move beyond the precautionary guidelines for any or all of the hydroriparian functions examined in this Guide.

Steps 1 to 5 reserved sufficient proportions of every hydroriparian ecosystem except for fans (144 hectares still needed to meet precautionary guidelines). Representation by Analysis Unit within each hydroriparian ecosystem was adequate for all but Hemlock High units around steep streams and within floodplains (only tiny amounts of this analysis unit exist in the watershed). Adding several fans and a small stream protection area, and including inoperable Hemlock High communities to the network, addressed the representation needs. The small stream protection area also created several corridors within the hydroriparian ecosystem network. Overall, few modifications were necessary once the spatially constrained areas had been reserved.

The hydroriparian ecosystem network covers 2,737 hectares of forest, of which 1,249 hectares are operable. Almost all of the operable forest within the network (1,235 hectares) is over 140 years old. Most of the forest is low productivity hemlock forest matching the pattern in the entire watershed. The hydroriparian ecosystem network based on precautionary guidelines covers 56% of the 2,238 hectares of operable forest in the Chambers Creek watershed. There are 989 hectares of operable forest remaining, constituting 11% of the entire watershed.

Elements of the network overlap. Reserves designed to maintain stream morphology (unstable terrain and active floodplains and fans) have the highest impact (Table A6.2), removing almost half of the operable forest. Reserving Class IV terrain from harvest overlaps the least with other elements of the network (306 hectares are removed solely because they are unstable); most other elements overlap. In particular, areas reserved to maintain biodiversity, with the possible exception of fans, overlap almost completely with areas reserved to maintain stream morphology. Small additional areas including patches of small streams have a small relative impact.

Table A6.1 Area of hydroriparian ecosystem network added to maintain each hydroriparian function in Chambers Creek.

Step	Function	Area of operable forest in hydroriparian ecosystem network (ha)	Incremental area of operable forest (ha)	Incremental % of operable forest in watershed
Class IV/V terrain	Stream morphology	745	745	33
Active fluvial units	Stream morphology	338	338	15
Wetlands	Stream morphology	45	29	1
Streams in transportation and deposition zone	Bank stability, downed wood	383	98	4
High-value fish habitat	Fish	unknown	0	0
Rare ecosystems	Rare ecosystems	65	1	0
Floodplains	Biodiversity	447	12	1
Fans	Biodiversity	194	25	1
Streams >20%	Biodiversity	179	4	0
Streams <20%	Biodiversity	264	1	0
Lakes	Biodiversity	0	0	0
Wetlands	Biodiversity	45	0	0
Small stream reserves	Biodiversity, corridors	21	19	1
Representation	Biodiversity	0	0	0
Total		n/a	1,272[a] ha	56%

[a] There are 23 ha of unaccounted overlap within this total (total network is 1,249 ha).

Appendix 7 Glossary

Abundant ecosystems: Ecosystems that are especially common, that define the character of a region (e.g., bogs in the Hecate Lowland). See Appendix 2 for a list of abundant ecosystems in each subregion.

Active channel: The area within the lower limit of continuous terrestrial vegetation, which is more or less well defined on most streambanks. Within the active channel, vegetation is restricted to species able to survive extended periods of inundation. (*Technical Report 3*)

Active floodplain: Areas adjacent to a stream channel that are flooded frequently. Some analysts describe the active floodplain as the wet floodplain (q.v.). (*Technical Report 3*)

Adaptive management: A formal process of "learning by doing," where management practices are designed to increase understanding about the impact of management on the system being managed. Adaptive management ("active" adaptive management) uses formal experimental techniques. "Passive" adaptive management has been defined as adaptive management that does not use formal experimental techniques. Although active adaptive management is more powerful; "passive" adaptive management may also be useful. (*Technical Reports* 6 and *7; North Coast Background Report*)

Alluvial fan: Cone-like sediment accumulations that develop where streams reach the valley floor and deposit sediment and organic debris. From apex to toe, fans have a slope gradient up to and including 26%. (*Technical Reports 1* and *7*)

Biodiversity: The diversity of organisms in all their forms and levels of organization, including genes, species, ecosystems, and the evolutionary and functional processes that link them. (*Technical Reports 5* and *7*)

Biodiversity hotspots: Particularly diverse ecosystems (e.g., floodplains).

Biogeoclimatic ecosystem classification (BEC): A system that groups similar segments of the landscape (ecosystems) into categories of a hierarchical classification system. An ecosystem is the product of a complex interaction of vegetation, animals, micro-organisms, and the physical environment. The BEC defines an ecosystem as a particular plant community and its associated topography, soil, and climate

Blue-listed species: In British Columbia, the designation of an indigenous species, sub-species, or population as being vulnerable or at risk because of low or declining numbers or presence in vulnerable habitats. Included in this classification are populations generally suspected of being vulnerable, but for which information is too limited to allow designation in another category. (*Technical Reports 5* and *7*)

CDC listings: The British Columbia Conservation Data Centre (CDC) systematically collects and disseminates information on the rare and endangered plants, animals, and plant communities of British Columbia. This information is compiled and maintained in a computerized database, which provides a centralized and scientific source of information on the status, locations, and level of protection of these rare organisms and ecosystems. (*Technical Reports 5* and *7*)

Coarse filter: An approach to managing biodiversity using broad ecosystem types to assess consequences of management. Coarse filter strategies aim to capture sufficient habitat to maintain most ecosystems, species, and genes through time. In contrast, fine filter approaches deal with species or other elements that may not be managed adequately through a coarse filter approach (e.g., rare species). The *Hydroriparian Planning Guide* addresses risk only to coarse filter biodiversity and refers managers to other processes and models for fine filter considerations.

Composite symbol: In the British Columbia Terrain Classification system, symbols (separated by a slash) indicating that two or three types of terrain are significantly present within a single polygon. Used when the terrain types alternate at too small a scale to permit designation as separate, individual polygons.

Confined channel: A stream channel flowing against a high bank that confines its ability to change position by lateral erosion, in particular, a gully channel or any other channel that is incised into pre-existing deposits. A channel may be confined on only one bank.

Deposition zone: Deposition zone channels receive material from source and transport zone channels as well as from adjacent riparian zones. Situated at drainage basin outlets, deposition zones include alluvial fans and deltas. Deposition zone channels are unconfined valley bottom rivers characterized by horizontal migration across floodplains and valley bottoms or channels on active alluvial fans. (*Technical Report 1*)

Disturbance regime: Disturbance regime encompasses the type, extent, frequency, and intensity of events that disturb or displace ecological processes. They create characteristic spatial and temporal patterns on landscapes and leave structural legacies within stands. In the *Hydroriparian Planning Guide,* most disturbance events are due to flooding, debris flows, slides, and snow avalanches with some wind and rare fire disturbances.

Downed wood: Dead wood in various stages of decay that provides habitat for fungi, micro-organisms, plants, animals, and their predators, and structures aquatic systems. Process zones receive wood from different sources. In the source zone, most wood travels downslope during mass wasting events. In the transportation and deposition zones, most wood comes from adjacent riparian forest. (*Technical Reports 3* and *4*)

Drainage basin: The area drained by a river or stream and its tributaries. See watershed.

Dry/high floodplain: Floodplain that is higher than wet floodplains, flooded infrequently (approximately once in 6–30 years), and does not exhibit wetland vegetation types (unless flooded from the valleyside). Within the biogeoclimatic ecosystem classification, "high fluvial bench" corresponds to dry floodplain. (*Technical Reports 3* and *7*)

Ecosystem-based management (EBM): 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 and processes of whole ecosystems such that component species and ecological processes can be sustained, and human social, economic, and cultural activities can be enhanced. (*CIT EBM Planning Handbook*).

Ecosystem productivity: The ability of an ecosystem to produce, grow, or yield organisms.

Ephemeral streams: Streams that flow for only a short time. Ephemeral streams carry only storm runoff, derived from saturation seepage or from overland flow. They may change route periodically. (*Technical Report 3*)

Estuary: The embayed mouth of a river where the tide meets the river flow, creating brackish water zones with a range of salinity. Extremely rich and productive ecosystems exist where tidal marine water and sediment mixes with freshwater and river sediment. (*Technical Report 7*)

Fan: See alluvial fan.

Forested swamp: Wooded mineral wetland or a wooded peatland with standing or gently flowing water in pools and channels. The water table is usually at or very near the surface. Waters are nutrient-rich. (*Technical Report 7*)

High (fluvial) bench: See "Dry floodplain."

High-value fish habitat: These are specific places within aquatic systems where aquatic animals (and their predators) concentrate their activities, including critical spawning and rearing areas for anadromous and non-anadromous fish.

Hydrological regime: The pattern of occurrence in time of water at or near the surface of the Earth (e.g., temporal changes in stream flow, soil moisture, groundwater levels, precipitation). (*Technical Report 3*)

Hydroriparian ecosystem: Aquatic ecosystems plus adjacent terrestrial ecosystems that are influenced by, or influence, the aquatic system. They extend vertically, below ground in the soil (especially in near-stream gravels), and above ground toward the vegetation canopy. (*Technical Reports 3* and *7*)

Hydroriparian ecosystem network: A geographically distributed system of riparian reserves and management areas that provides both habitat and corridor functions.

Hydroriparian functions: Hydroriparian functions can be classified into three types: (1) maintaining environmental character (e.g., containing rare ecosystems); (2) movement of materials linking portions of the landscape (e.g., transporting water downstream, above and below the ground); and (3) reciprocal influences of water and land (e.g., providing sediment, downed wood, shade).

Hydroriparian process zone: Discrete zone in a watershed where the movement of water, sediment, and organic material toward and through streams and standing water occurs in distinct ways. Hydroriparian process zones include *source zone*, consisting of upland and slope areas; *transport zone*, the trunk valley through which sediment is moved with storage in a floodplain; and *deposition zone*, where sediments are stored for a long term (typically alluvial fans, downstream floodplains and deltas).

Hydroriparian zone: Area that extends to the edge of the influence of water on land defined by plant community (including high-bench or dry floodplain communities) or landform (e.g., gullies) plus one and a half site-specific tree heights (horizontal distance) beyond. In the transportation and deposition process zones, the hydroriparian zone includes the entire valley bottom plus one-and-a-half-tree heights. (*Technical Reports 3* and *6*)

Indicators: Indicators are measures that index the state of complex functions that are difficult to assess. Sound indicators respond to management actions, are related clearly to the function considered, can be measured or described simply, are relatively insensitive to factors beyond the management actions considered, and are appropriate for the purpose and scale considered. Indicators can be developed for planning, for monitoring management actions (e.g., seral stage distribution along streams), and for monitoring the effects of actions (e.g., populations of riparian-associated organisms). Planning indicators usually describe landscape state and include spatial summaries (e.g., equivalent clearcut area) that can be read from maps and projected through time. These indicators can be used as the basis for risk assessment. (*North Coast Background Report*)

Interior old growth: Old growth forest situated away from the effect of open areas. Forest interior conditions include particular microclimates and organisms found within large forested areas, and exclude edge species.

Intermediate stream/channel: Larger than a small channel (q.v.), but capable of being spanned and blocked by individual pieces of introduced organic debris; in general, less than 30 metres in width on the British Columbia coast. For classification purposes in this Guide, channels less than 10 metres wide (see Appendix 2).

Karst: Pertains to landforms and processes associated with dissolution of soluble rocks such as limestone, marble, dolomite, or gypsum; characterized by underground drainage, caves, and sinkholes. *(Technical Report 7)*

Land-on-water influences: Land influences adjacent water by providing downed wood (q.v.), organic material, and shade; filtering sediment and dissolved materials; stabilizing banks; and providing sediment. Land-on-water influences extend at least one tree height from the water. *(Technical Reports 4* and *7)*

Landscapes: Interacting geographic areas that are bounded by physical features and that contain similar patterns of watersheds and vegetation cover. Ecological landscapes have no fixed size; practical sizes for landscapes in a forest planning context on British Columbia's coast generally range from 50,000 to 250,000 hectares. Describing the landscape around a watershed of interest provides the context for decisions made at the watershed (q.v.) level.

Low (fluvial) bench: See "wet floodplain."

Microclimate: The climatic conditions (wind, temperature, humidity, etc.) of a local area. Microclimatic effects of streams can extend to several tree heights beyond the bank. *(Technical Report 3)*

Microterrain features: Small-scale terrain features not easily described using the range of surface expressions found in the B.C. Terrain Classification System (e.g., karst hollows, tree-throw mounds).

Middle (fluvial) bench: See "wet floodplain."

Natural disturbance regime: The disturbance regime (q.v.) in a landscape not significantly affected by post-colonization human activity, including, for example, landslides and other episodic mass wasting events, windthrow, diseases, and, more rarely, fire. *(Technical Reports 1* and *3; North Coast Background Report)*

Natural riparian forest: The amount and type (deciduous, old growth coniferous, etc.) of riparian forest (q.v.) that would occur under natural disturbance regimes (q.v.). The actual amount and type varies over time within the range of natural variability.

Off-channel habitat: In streams, minor channels and pools in the floodplain, wetlands, and low areas adjacent to the channel that provide escape areas and habitat during seasonal or storm high flows.

Old growth equivalent: Forest that has been managed, but has recovered age and structure sufficiently to be considered of value equal to unmanaged old forest. Forests achieve old growth equivalence more quickly following high levels of retention.

Old growth forests: Old forests that are defined by a group of attributes, including age, multi-layered canopies, canopy gaps, high levels of decayed wood, and large trees for ecosystem productivity. Due to a lack of inventory for these attributes, old growth forests are considered to be those forests mapped as older than 250 years. On British Columbia's coast, most of these forests are actually much older than 250 years and likely much older than the age of individual trees because stand-replacing disturbances are rare. Old growth forests contain the highest level of biological diversity, compared with other seral stages.

Oligotrophic: Nutrient poor. Containing few nutrients and few organisms.

Perennial stream: Stream that flows year round. *(Technical Report 3)*

Polygon: A closed, irregular geometric figure. In this report, polygon refers to terrain polygons, areal units on the land surface that are uniform with respect to landform, surficial materials, and slope, hence identified and classified on a terrain map. Terrain polygons are typically comparable in area with forest development sites.

Precautionary guidelines: Guidelines that follow the precautionary principle (q.v.). In this report, guidelines that are used when a risk assessment is not completed.

Precautionary principle: The adoption of measures to reduce potential harm resulting from human activities or environmental change even if some cause and effect relationships are not fully established scientifically. It includes taking action in the face of uncertainty; shifting burdens of proof to those who create risks; and analysis of alternatives to potentially harmful activities. *(Technical Reports 4* and *7)*

Primary watershed: A watershed that drains directly to the ocean; the term is usually applied to small, coastal watersheds that do not form tributaries within larger watersheds.

Process zone: Watersheds can be split into three process zones (source, transport, and deposition [q.v.]), among which hydroriparian functions, processes, and risks (q.v.) vary. *(Technical Report 1)*

Rare ecosystems: Uncommon ecosystems that require special consideration when determining acceptable levels of risk (q.v.). The Conservation Data Centre compiles lists of rare ecosystems for British Columbia. Red-listed ecosystems typically have 20 or fewer suitable examples in British Columbia, blue-listed have fewer than 100. Not all rare ecosystems are listed by CDC. *(Technical Report 7, North Coast Background Report)*

Recovery curves: Curves describing the recovery of ecosystem elements (e.g., stand structure, vegetation, soil biota, epiphytic biota) over time. They can be used to assess the functional integrity of a disturbed stand.

Red-listed species: In British Columbia, the designation of an indigenous species, sub-species, or population as endangered or threatened because of its low abundance and consequent danger of extirpation or extinction. *(Technical Reports 5* and*7)*

Riparian corridor: An area composed of continuous riparian habitat (e.g., the land on either side of a river bank or around a lake). *(Technical Report 7)*

Riparian forest: Forests influenced by water (including high-bench floodplain) plus an area extending one-and-a-half tree heights beyond.

Risk: In ecological terms, risk denotes the possibility for ecosystem features or functions to be changed or lost—in effect, exposure to potential loss. In the context of land management, it is interpreted as the probability (i.e., relative exposure) that an undesired outcome (loss) will result from a particular management action. *(Technical Report 6)*

Risk assessment: Consists of calculating the exposure by use of an indicator (q.v.) value for a hydroriparian ecosystem, watershed, or landscape, determining the indicated risk from indicator-risk curves, determining acceptable levels of *risk*, and comparing the resulting values with acceptable levels. *(North Coast Background Report)*

Seasonal stream: Stream that flows throughout most of the year but may dry up during portions of the dry season. This stable source of water may have rich communities of aquatic invertebrates, including some specialist species found less frequently in perennial streams, which are useful discriminators between seasonal and ephemeral (q.v.) status. *(Technical Report 3)*

Sedge fen: Sedge-dominated wetland (q.v.) occurring in a landscape depression with mineral seepage. *(Technical Report 7)*

Sensitive terrain: Terrain units with a stability class rating of IV (potentially unstable) or V (unstable) in the British Columbia Terrain Classification. Class IV terrain is expected to contain areas with a moderate to high likelihood of landslide initiation following timber harvesting or road construction by conventional means. Class V terrain exhibits evidence of instability and is expected to contain areas with a high likelihood of landslide initiation following timber harvesting or road construction.

Seral stage: Any stage of development of an ecosystem from a disturbed, unvegetated state to a climax plant community. It defines the structural attributes and age of a plant community. *(Technical Reports 5* and *7)*

Site: One or more discrete units, typically one hectare to several tens of hectares. The appropriate mapping scale for site-level planning ranges from 1:2,000 to 1:5,000.

Site series: Describes all land areas capable of producing the same late seral or climax plant community within a biogeoclimatic subzone or variant. Site series can usually be related to a specified range of soil moisture and nutrient regimes within a subzone or variant, but other factors, such as aspect or disturbance history, may influence it as well. Site series form the basis of ecosystem units. In this report, site series is equivalent to "plant community." *(Technical Report 7)*

Slope/blanket bog: A peatland with the water table at or near the surface, sustained by precipitation. The bog surface (which my be raised or flat) is unaffected by minerotrophic ground water. Bogs are nutrient-poor and home to specialized species. Bogs may be treed or treeless, and they are usually covered with sphagnum moss and ericaceous shrubs. *(Technical Report 7)*

small-scale Predictive Ecosystem Mapping (ssPEM): Surrogate for terrestrial ecosystem mapping (q.v.) that does not require fieldwork, but instead uses existing maps, data, and knowledge of ecological–landscape relationships.

Small stream/channel: One in which the size of individual elements (cobbles, boulders) on the channel boundary is comparable in size to the channel dimensions (width or depth); practically, channels less than 3 metres in width.

Source zone: The upland area of the watershed, constituting the majority of channel length. Source zone channels will generally be small upland/headwater streams. Channels in these steep source zones receive material directly from hillslopes via snow avalanches and landslides, deliver fine sediments and nutrients to larger channels continually, and large sediment and organic debris to larger channels episodically via debris torrents, avalanches, and landslides. In wetland (q.v.) source zones, streams may receive mainly organic materials, and may transport only fine organic material. *(Technical Report 1)*

Stratigraphic symbol: In the British Columbia Terrain Classification system, symbols (separated by a bar) indicating that one kind of surficial material overlies a second kind. Used dominantly when the underlying member may significantly influence the terrain performance.

Stream morphology: The characteristics of a stream including width, depth, gradient, step-pool, and riffle sequences and bank characteristics. Stream channel morphology reflects the concentration and calibre of sediment moving down the channel. *(Technical Reports 3, 4,* and *6)*

Subregion: An extended area that is homogeneous with respect to the defining criterion. In this Guide, ecological and hydrological criteria define homogeneous subregions. Subregional analysis is carried out on 1:250,000 scale maps. This Guide currently defines 11 such regions (Appendix 5). This division is based on similarity of hydrology, slope conditions, and ecosystems within the subregions. It is expected that regional information describing hydrology, slope stability and ecosystems within each unit may lead to further subdivision. *(Technical Reports 1, 2,* and *7; Central Coast Background Report)*

Surficial materials: Defined as non-lithified, unconsolidated sediments, these materials are produced by weathering, sediment deposition, biological accumulation, human and volcanic activity. In general, surficial materials are of relatively young geological age and they constitute the parent material of most soils. Other terms virtually synonymous with "surficial material" are "Quaternary sediments" and "unconsolidated materials." Surficial materials are usually classified as to their genesis (e.g., fluvial sediments, colluvium, glaciolacustrine sediments). *(Technical Report 1)*

Target watershed: A watershed within which forest development is proposed.

TEM (Thematic ecosystem mapping): The division of a landscape into map units, showing biogeoclimatic site series, defined by a combination of ecological features, primarily climate, physiography, surficial material (q.v.), bedrock geology, soil, and vegetation. It provides a biological and ecological framework for land management.

Terrain mapping: A method to categorize, describe and delineate characteristics and attributes of surficial materials (q.v.), landforms, and geological processes within the natural landscape. *(Technical Report 1)*

Transport zone: These channels receive material from source zone (q.v.) channels and directly from adjacent riparian zones. This zone is typically situated in major valleys, with a valley flat and channels of intermediate size. Transport zone channels may be confined by hillslopes, migrate across valley floors, or alternate between confined and unconfined. They are associated with a discontinuous or continuous floodplain. *(Technical Report 1)*

TRIM (Terrain resource inventory mapping): The system of largest scale topographic mapping issued by the Province of British Columbia (scale 1:20,000). The complete mapping system includes overlays for terrain and cultural attributes.

Valley flat: Ground area with low gradient in the valley bottom, usually a river floodplain, but possibly also including low terraces or undissected Pleistocene outwash deposits.

Variable retention: Harvesting regime that retains a portion of the original stand, including live and dead standing trees and downed wood. The amount and pattern of retention varies. In this report, variable retention is referred to in the context of meeting ecological goals. *(Technical Report 6)*

Water-on-land influences: Water influences adjacent land by increasing/decreasing ecosystem productivity, modifying landscape morphology and modifying the microclimate (q.v.) of adjacent land. Water-on-land influences extend a variable distance depending upon landform and surficial materials (q.v.). *(Technical Report 7)*

Watershed: The area drained by a river or stream and its tributaries. The size of the watershed will depend on the size of the stream or river considered. For practical planning, a watershed generally ranges from 500 to 50,000 hectares. Equivalent to drainage basin in North American usage, but also used to mean “drainage divide” (European usage).

Wet/low floodplain: Area adjacent to a stream channel that is flooded more frequently than once in five years and commonly exhibits wetland vegetation. Wet floodplains include old, filled channels and low floodplain surfaces. They form part or all of the active floodplain (q.v.). Within the biogeoclimatic ecosystem classification, wet floodplains correspond to “low and middle fluvial benches.” *(Technical Reports 3* and *7)*

Wetlands: Semi-terrestrial sites where the water table is at, near, or above the soil surface and soils are water-saturated for a sufficient length of time that excess water and resulting low soil oxygen levels are principal determinants of vegetation and soils development. Wetlands must have either plant communities characterized by species that normally grow in soils water-saturated for a major portion of the growing season (hydrophytes) or soils with surface peat horizons or gleyed mineral horizons within 30 cm of the soil surface. *(Technical Reports 5* and *7)*