Fish Habitat Assessment Procedures

by

N.T. Johnston and P.A. Slaney

Watershed Restoration Technical Circular No. 8
revised April 1996

BRITISH COLUMBIA

Funded by:

FOREST RENEWAL BC

Watershed Restoration Program
Ministry of Environment, Lands and Parks
and Ministry of Forests

The formatting and images in this document may vary slightly from the printed version.

Fish Habitat Assessment Procedures

by

N.T. Johnston[1] and P.A. Slaney[2]

[1] Ministry of Environment, Lands and Parks, Fisheries Branch, Fisheries Research and Development Section, 2204 Main Mall, University of British Columbia, Vancouver, BC V6T 1Z4

[2] Ministry of Environment, Lands and Parks, Watershed Restoration Program, 2204 Main Mall, University of British Columbia, Vancouver, BC V6T 1Z4

Watershed Restoration Technical Circular No. 8
revised April 1996

Tech Circ. #8, FHAP Errata

(3 January 1997)

1. Please note the following in the text:

- pg. 26, Fig. 2, definition for "D" is incorrect. It should read, "D" is the size (the b-axis diameter, also called the intermediate axis diameter) of the largest sediment particle (stone) on the channel bed moved by flowing water.

- pg 56-57, Table 5, in the row: “LWD pieces per bankful channel width”, the second column should read “< 20 m wide” rather than “all”.

2. The following edits / corrections are required in the forms:

- pg. 89, Form 1 is missing chum salmon in its headings. If working on a chum salmon stream simply scratch out another (not present) species and pencil in “chum”.

- Forms 4 and 6 are missing column two which should be labelled "Section Number" for those wishing to break their reach into more than one section. To be consistent, Forms 2 and 5, 2nd column should read "Section number", rather than "Section Code" and "Section". Finally, Form 3, 1st and 2nd column should read "Reach number" and "Section number", respectively, and not just "Reach" and "Section".

Form 6 is based on Table 5. In Form 6, change the heading "% Wood Cover" to "% Wood Cover in Pools"; and change the heading “Dominant Substrates” to “Substrate,” as per Table 5.

Contents

Introduction

The Watershed Restoration Program

There is an urgent need to renew the forest resources upon which an environmentally-sustainable British Columbia economy depends. Past land management practices have lessened the productive capacity of both forest lands and, especially, fish-producing waters. The Watershed Restoration Program (WRP) is a provincial initiative under Forest Renewal BC to restore the productive capacity of fisheries, forest and aquatic resources that have been adversely impacted by past forest-harvest practices. The Watershed Restoration Program hastens the recovery of degraded environmental resources in logged watersheds by identifying the need for, designing, and implementing projects to re-establish conditions more similar to those found in unimpacted watersheds.

The **major goals** of the Watershed Restoration Program to 1999 are:

- *to restore, maintain and protect fisheries, aquatic and forest resources that have been adversely impacted by forest harvesting practices,*
- *to provide community-based training, employment, and stewardship opportunities, and*
- *to provide a mechanism to bridge historical forest harvesting practices and the new standards established by the Forest Practices Code.*

An important goal of the WRP is to encourage working partnerships among local stakeholder groups to ensure that the whole range of logging-related resource impacts are identified and rehabilitated in a systematic, coordinated manner at the watershed level. Restoration activities funded under the Watershed Restoration Program should adopt a process-oriented approach that:

- reduces the generation and delivery of sediments from hillslopes to stream channels,
- re-establishes natural drainage patterns and water quality,
- replaces lost channel-structuring elements within streams to increase the amount and quality of fish habitat, and
- restores habitat within selected terrestial, riparian and stream ecosystems towards pre-logging conditions.

The intent of your restoration work should be to return the processes that cause the adverse impacts to their natural levels rather than simply treating the symptoms of the impacts. By altering the rates of processes that control the physical and biological structure of watersheds, we hope to re-establish more productive, normally-functioning ecosystems in the future.

About This Circular

What Is the Purpose of This Circular?

This circular is one of a series of Technical Circulars (see Appendix A) designed to assist in planning watershed restoration projects. The purpose of this circular is to assist local groups (forest licensees, First Nations, community groups, stewardship organizations) to develop and implement integrated, effective, cost-efficient projects at the watershed scale to rehabilitate or restore fishery resources that have been adversely-impacted by past forestry practices. The circular provides a standard framework for identifying the needs and opportunities for fish habitat restoration through systematic resource assessments, and for prescribing and implementing effective activities to improve fishery and aquatic resources.

Why Should You Use This Circular?

Watershed restoration deals with the results of complex, interconnected processes that often cannot be partitioned into independent sub-components when devising effective corrective actions. Proponents of projects that are submitted for funding under the WRP should use the series of Technical Circulars to ensure that their proposals consider all important aspects of watershed restoration, that they have planned their proposed activities in an efficient manner, that their procedures and methods are technically sound, and that any data that may be collected by their projects will be compatible with Provincial data standards.

This manual should be used with the following related manuals:

- Guidelines for planning watershed restoration projects,
- Coastal (or Interior) watershed assessment procedure (CWAP or IWAP),
- Channel assessment procedure,
- Riparian assessment procedure, and
- Fish habitat rehabilitation procedures.

Note that the riparian assessment, stream channel assessment and fish habitat assessment procedures form an integrated set whose data collection should be combined wherever possible.

Background

Impacts of Forest Harvest on Aquatic Resources

In order to assess the need for fish habitat restoration, you must have a basic understanding of the impacts of poor forest harvest practices on biophysical resources. Numerous studies document the impacts of forest harvest activities on fishery and other aquatic resources. Instructive recent summaries include:

- Hartman, G.F. and J.C. Scrivener. 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Canadian Bulletin of Fisheries and Aquatic Sciences 223, Ottawa, Ontario.

- Koski, K.V. 1992. Restoring stream habitats affected by logging activities. pp. 343-403 *In* G.W. Thayer [ed.] Restoring the nation's marine environment. Maryland Sea Grant College, University of Maryland, College Park.

- Meehan, W.R. 1991. [ed.] Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, Bethesda, Maryland.

- Slaney, P.A. 1995. The Watershed Restoration Program of British Columbia: an opportunity and a challenge. pp. 117-133 *In* W.T. Dushenko, H.E. Poll and K. Johnston [eds.] Environmental Impact Assessment and Remediation: Towards 2000. Canadian Society of Environmental Biologists, Toronto.

The adverse impacts of forest harvest practices on fishery and aquatic resources arise primarily through:

- **increases in the rate of sediment generation and delivery to the stream network**, which reduces the productivity of the aquatic ecosystem through deleterious changes to the physical structure of the stream channel as well as through direct physiological effects on the biota. Fine sediment, which often originates from road running surfaces or cut-and-fill slopes, is particularly damaging. In coastal B.C., mass wasting in logged areas or from poorly-sited or poorly-maintained road networks is also a common sediment source. In interior B.C., surface erosion after the exposure of fine-textured mineral soils is an important sediment source. The interception and concentration of natural drainage by road networks often exacerbates the erosion and delivery of fine sediments to the stream channel. The geomorphic impacts of increased sediment delivery to the stream channel depend on the ability of the channel to transport and store the material. Where sediment sources are directly connected to the stream channel, large changes to stream channel structure may occur. In extreme cases, aggradation and channel widening can cause channel de-watering at low flows.

- **altered patterns of discharge**, from changes to the hydrologic regime (such as altered patterns of: rainfall interception and storage, snowmelt, and evapo-transpiration) and flow concentration by road networks, which alter the timing and amounts of water delivered to the stream channel (e.g., increasing peak flood flows).

- **removal of the natural riparian vegetation and its replacement by vegetation with very different stand characteristics**, both of which may impair the functional role of the riparian zone in establishing physical and biological conditions within the stream ecosystem. Ecological functions of the riparian vegetation may include:

    - regulation of stream temperature by controlling the direct input of solar insolation,
    - regulation of instream algal production by controlling the amount and quality of photosynthetically active radiation reaching the stream,
    - regulation of instream biological production by determining the inputs of allochthonous organic carbon (leaves, detritus, terrestial insects, large woody debris, dissolved organic carbon) to the channel,
    - regulation of the physical structure of the stream channel by determining the input and characteristics of large woody debris (LWD) that partly controls sediment storage and transport and local flow characteristics (and thus fish habitat),
    - the maintenance of bank stability, and
    - buffering the stream from contaminants, pollutants and fine sediments by intercepting surface flow and altering subsurface flow.

The characteristics of the riparian vegetation thus can strongly influence the diversity and productivity of the aquatic biota. Changes from the typical seral stages for the site often alter the ecological functioning of the riparian zone in ways that produce undesirable changes to the composition and abundance of the pre-logging fauna, (e.g., by decreasing the abundance of economically-valuable salmonid fishes). Changes to riparian function such as decreased LWD generation may take 40-50 years post-harvest to be fully expressed (Scrivener and Brown 1993) and 75-150 years subsequently to recover (Koski 1992). You should consult the references and experienced professionals for further information on the adverse impacts of forest harvest on aquatic resources.

Overview of the Fish Habitat Assessment Procedure

The WRP fish habitat assessment procedure attempts to identify opportunities and appropriate techniques to increase depressed stocks of salmonids in streams. The assessment provides a standard methodology for reviewing existing information, conducting field surveys at the reconnaissance level, and interpreting the results consistently. The procedure is based on that of the Washington State Forest Practices Board (Anonymous 1993).

The assessment **procedure** consists of four steps:

1. *identification of fish species at risk in the watershed,*
2. *a quantitative description of fish habitat conditions,*
3. *evaluation of fish habitat conditions, and*
4. *identification of opportunities for effective fish habitat rehabilitation.*

We implement the description and evaluation of fish habitat conditions in three distinct steps: (1) an **overview summary** of existing information and/or air photo interpretation, (2) a reconnaissance **(level 1) field survey**, and (3) more-detailed, site-specific **(level 2) field surveys** where these are needed to plan restoration work.

We identify physical limitations to salmonid production by quantifying and characterizing the physical habitats used by the different stream-resident life stages. We then compare these amounts and characteristics against standards for similar, undisturbed streams to identify degraded habitats or habitats that have limited availability and which may be corrected by fish habitat restoration projects. We give special attention to degraded habitats, to habitats that are (or were) heavily used, and to habitats that are limited in availability. We consider the habitats used during several life phases:

- migrating adults and juveniles,
- adults holding instream for long periods prior to spawning,
- spawning adults,
- incubating eggs,
- summer rearing by juveniles and resident adults, and
- overwinter shelter and rearing.

The fish habitat assessment procedure thus considers sequentially: what species are present, their abundance, habitat conditions, limitations to production, and opportunities for habitat rehabilitation.

Assumptions and Limitations

The procedure reported here for assessing fish habitats is limited in scope and application. The fundamental assumptions of the method are: (1) that fish distribution and abundance are limited by the quantity and quality of physical habitats present within the watershed, and (2) that the limiting habitat(s) can be identified correctly by comparison to similar undisturbed watersheds. Anonymous (1993) lists other assumptions.

The ability of habitat capability models to predict observed abundances of juvenile salmonids from physical habitat conditions (see Fausch et al. 1988) suggest that such factors often may be the principal limitations to fish production. While the assumption that physical habitat limits fish production may be plausible in watersheds that show gross morphological changes to the stream channel or the riparian zone subsequent to timber harvest, you should also consider other factors, such as predation (including human harvest), food availability, disease and other biotic interactions as potential limitations to fish production before concluding that habitat conditions impose the principal limitation. You should also consider the role of natural disturbance (such as fire, glacial conditions, natural landslides or debris flows) in determining physical habitat conditions.

Unfortunately, there are no simple methods for objectively determining the factors that limit the production of stream-dwelling salmonids. Reeves et al. (1989) propose a formal procedure to identify physical habits that limit coho production in coastal streams, but, in general, the correct identification of limiting factors for stream-dwelling salmonids depends strongly on *the skills and experience of the person doing the assessment*. A quantitative comparison of observed physical conditions to conditions in undisturbed watersheds, which are assumed to represent the average conditions to which salmonid communities have adapted over evolutionary time, appears to be the best general method available at the moment.

The adequacy of this comparative approach depends partly upon the information about habitat conditions in undisturbed watersheds, which is sparse for most ecoregions, and partly on the degree to which the average habitat conditions in undisturbed watersheds match the habitat requirements of the target species or assemblage of species. Because different salmonids differ in their use of physical habitats, “average” conditions in undisturbed watersheds may not adequately diagnose limitations for a given target species.

The present assessment procedure emphasizes the physical habitat requirements of salmonids, in part because they often dominate stream fish communities in British Columbia, in part because they are highly vulnerable to the adverse impacts of poor forest harvesting practices, and in part because of their high economic and cultural values. The emphasis on salmonids ignores issues such as the maintenance of biodiversity or multispecies management, and may not adequately protect or restore other taxa in areas where salmonids were not historically the dominant component of the fish assemblage. If non-salmonids are the target species for fish habitat restoration, then the diagnostics used to assess habitat condition must be modified to reflect the habitat requirements of the target species.

Project Scope

Whole **watersheds** are the units for which restoration plans should be developed.

The assessment procedures in WRP Technical Circulars No. 2-9 emphasize the potential impacts of forest harvest on aquatic resources. To assess the cumulative effects of forest harvest, you will usually first complete the appropriate watershed assessment procedure (CWAP or IWAP) or a similar review. You would then examine the state of roads, hillslopes, gullies, riparian areas, stream channels or fish habitat, as appropriate, to identify specific problems that may be treated through restoration projects.

The appropriate spatial scale for applying the assessment and restoration procedures from Technical Circulars No. 2-9 is, approximately, third to fourth order basins on 1:50,000 National Topographic series (NTS) maps. Watersheds of this size are logistically tractable for integrated restoration projects. Because lower order watersheds are nested hierarchically within higher order watersheds, large watersheds can usually be subdivided into sub-basins of a size that is appropriate for our assessment procedures. (refer to the CWAP or IWAP guidebooks for details on identifying sub-basins; the “point of interest” is the junction of the third-order channel with a higher order channel). In coastal areas with high precipitation, use smaller (i.e., third order) watersheds, while in drier interior locations, you can normally use larger watersheds. To apply the fish habitat assessment procedure, you will normally subdivide the portions of the watershed used by fish into homogeneous reaches (see Appendix B for definitions) whose fish habitat conditions are separately surveyed.

Related Assessment Procedures

The amount, distribution, and quality of fish habitat are influenced by the geophysical processes that control channel morphology and by the bio-physical processes within the riparian zone that regulate the inputs of heat, organic carbon, and nutrients to the channel. The riparian and stream channel assessments (Technical Circulars No. 6 and 7) provide information that is useful to the evaluation of fish habitats. All three assessments should be closely coordinated, to ensure consistency in common methods (e.g., the definition of stream reach boundaries), to ensure the exchange of information and to avoid duplication in field surveys, especially for remote sites. Where possible, air photo analyses and field surveys should simultaneously gather data for all assessments that are indicated as necessary by the results of the watershed assessment procedure.

Who Should Do the Assessments?

The overview fish habitat assessment and the Level 1 field assessment are designed to be done by experienced fisheries technicians with a working understanding of fish habitat restoration options and methods. Level 2 procedures generally can be completed by experienced fisheries technicians working, if necessary, under the supervision of a professional biologist. Some Level 2 geotechnical assessments and structural prescriptions must be done by an experienced licensed professional with the appropriate background (e.g., registered professional engineers or geoscientists). The assessment procedures are not a substitute for training and experience: *consult specialists for particularly complex situations*.

The fish habitat assessment procedure provides a standard methodology for reviewing existing information, conducting field surveys, and interpreting the results consistently to identify opportunities for effective fish habitat rehabilitation projects. To use the methodology effectively, you must have a good knowledge of the life histories and habitat requirements of salmonids. You should also be familiar with the standard field methods outlined in the BC Ministry of Environment, Lands and Parks “Lake and stream inventory standards and procedures” manual (Anonymous 1995), which is available from:

Inventory and Data Systems Section
BC Fisheries Branch
1106 Cook Street, 3rd floor
Victoria, British Columbia, V8V 1X4.

Other Sources of Information

Useful sources of information on the life stages and habitat requirements of salmonids include:

Anonymous. 1980. Stream enhancement guide. British Columbia Ministry of Environment and Canada Department of Fisheries and Oceans, Vancouver.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. pp. 83-138. *In* W.R. Meehan [ed.] Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, Bethesda, Maryland.

Groot, C. and L. Margolis. 1991. Pacific salmon life histories. UBC Press, Vancouver.

Other approaches to fish habitat assessment that you might wish to review include:

Anonymous. 1993. Fish habitat. pp. F1-F36. *In* Standard methodology for conducting watershed analysis. Version 2.0. Washington Forest Practices Board, Washington State Department of Natural Resources, Olympia.

A particularly clear description of the two-stage sampling procedure that is recommended below for quantitative fish habitat assessment is:

Dolloff, C.A., D.G. Hankin and G.H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. United States Department of Agriculture, Forest Service, General Technical Report SE-83, Asheville, North Carolina.

Approved survey methods are discussed in:

Anonymous. 1995. Lake and stream inventory standards and procedures. British Columbia Ministry of Environment, Lands and Parks, Fisheries Branch, Victoria.

Useful guides to fish habitat restoration or rehabilitation include:

Anonymous. 1980. Stream enhancement guide. British Columbia Ministry of Environment and Canada Department of Fisheries and Oceans, Vancouver.

Adams, M.A. and I.W. Whyte. 1990. Fish habitat enhancement: a manual for freshwater, estuarine, and marine habitats. Canada

Department of Fisheries and Oceans, Vancouver.

Slaney, P.A. [ed.] 1996. Fish habitat rehabilitation procedures. British Columbia Ministry of Environment, Lands and Parks and British Columbia Ministry of Forests, Watershed Restoration Program, Technical Circular No. 9 (available May 1996).

Fish Habitat Assessment Procedure

If the watershed assessment (CWAP or IWAP) or a similar review of the cumulative impacts of forest harvest in the watershed suggests potential impacts on fish or fish habitat, then you will undertake a fish habitat assessment (FHAP) to further identify the nature, locations, and magnitude of impacts on fish, and the opportunities for effective rehabilitation.

The FHAP (Figure 1) begins by identifying the species and stocks at risk to the effects of poor logging practices in the watershed. The species at risk are usually the economically important salmonids whose abundance has declined following timber harvest or which are known to be sensitive to the effects of logging. These are the potential **target species** for habitat restoration efforts. The early identification of target species can increase the efficiency of the FHAP by focusing analyses on the particular habitats used by these species in the watershed and by providing more precise criteria for evaluating the status of their habitats.

Office analyses and field surveys provide quantitative descriptions of fish habitats which are evaluated by comparing them to pre-logging conditions in the watershed or to standards derived from similar undisturbed watersheds. The comparison of observed habitat conditions with diagnostic values suggests the factors that limit fish production in the watershed. You will base your plans to restore the target fish species on the limiting factors that the FHAP identifies.

These surveys and analyses attempt to answer the following questions:

1. what fish species are present in the watershed, where are they, and in what numbers by life stage?

2. what is the amount, type, actual and potential use of habitat within the watershed by species and life stage?

3. what degraded habitats do you find, where and in what quantity by species and life stage?

4. what, where and in what quantity are the habitats that limit salmonid production?

5. what are the most likely options for the effective rehabilitation of logging-impaired fish habitat?

In practice, you will usually implement the FHAP as an iterative process. The first stage of FHAP is an **overview assessment** to identify areas of potential concern and to indicate the general nature of impacts. The second stage is a more-detailed quantitative **field assessment** of particular areas of concern, leading to precise statements of restoration plans to improve logging-impaired habitats.

Overview Fish Habitat Assessment

Aims of the Overview Fish Habitat Assessment

The **objectives** of the overview assessment are:

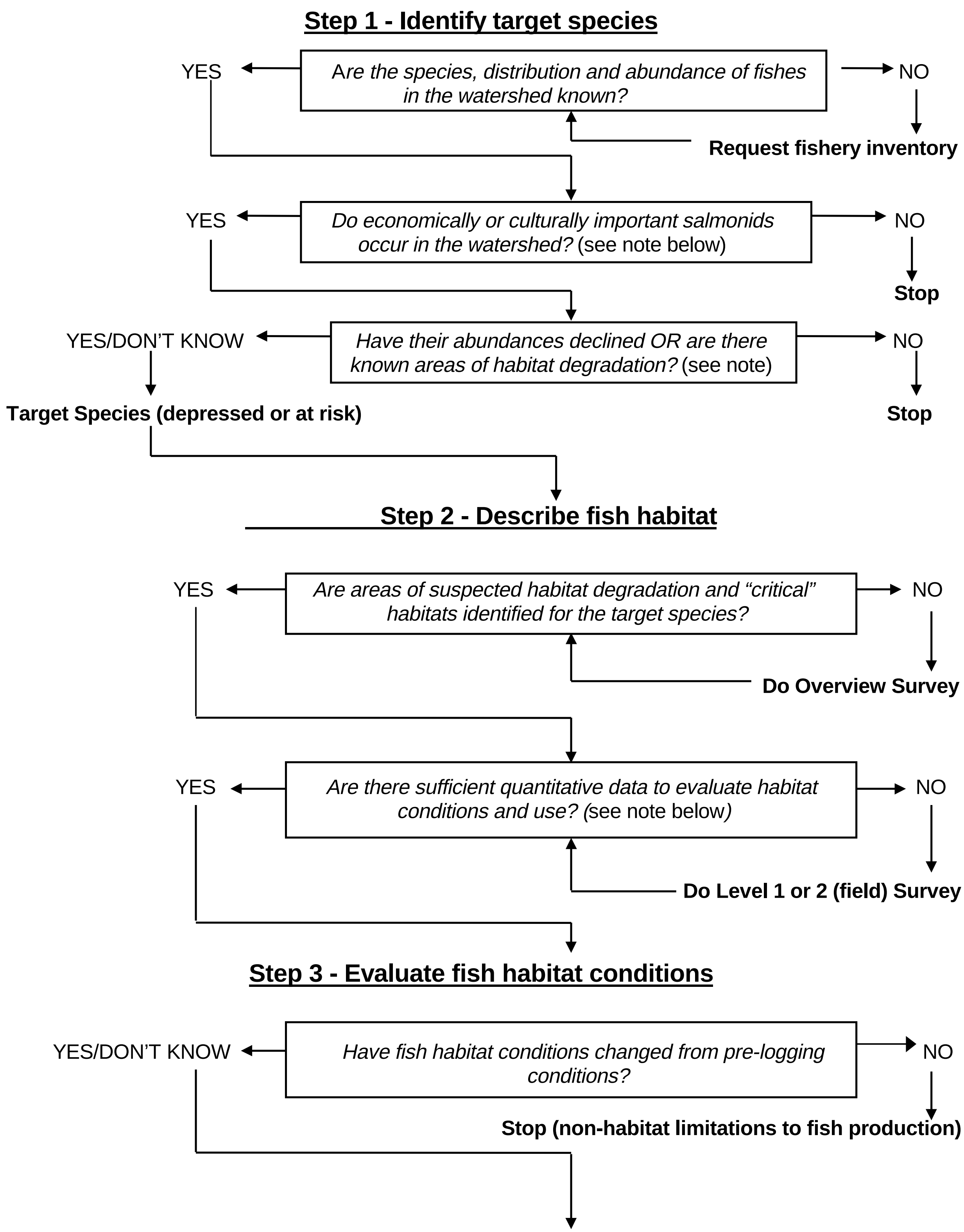
- *to determine what fish species (and life stages) are at risk to the impacts of poor forestry practices in the watershed,*
- *to identify areas of concern that need to be examined in quantitative field surveys of fish habitat,*
- *to identify preliminary restoration strategies (no action, restoration, rehabilitation, mitigation),*
- *where appropriate, to identify preliminary project objectives, scope and priorities.*

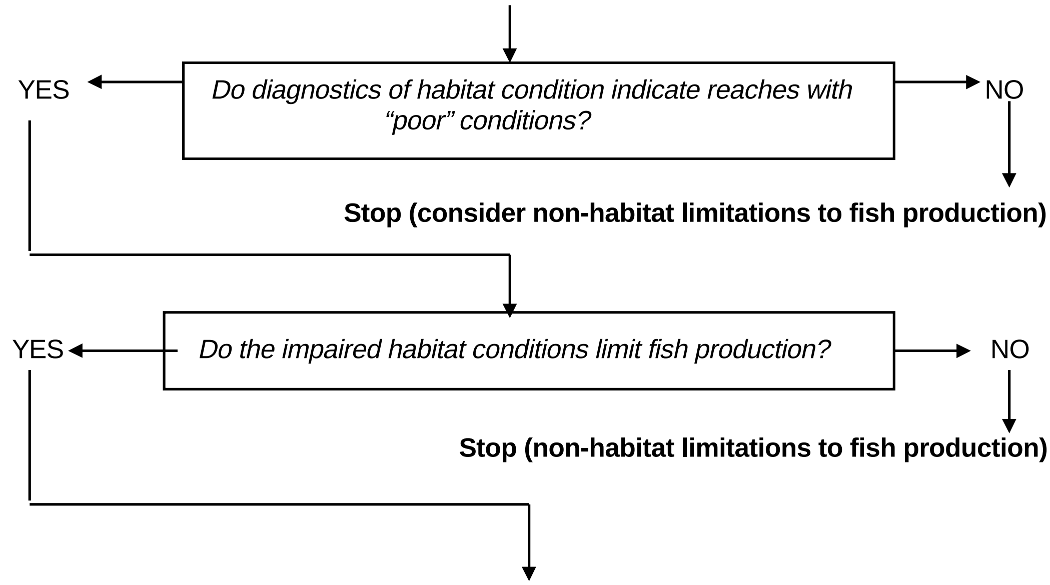
The overview assessment uses existing or easily obtained information to provide a preliminary indication of the factors that limit fish production in the watershed. You iteratively test and modify these initial hypotheses by collecting further information in field surveys and by doing further analyses and interpretations. The results of the overview assessment will direct subsequent field surveys to those areas of the watershed where there is evidence of habitat impairment that may limit fish production, i.e., areas of special concern. The focus of the field survey will vary depending on the target fish species and life stage and on the perceived nature of habitat impairment.

The purpose of the overview assessment is to focus field assessments and preliminary restoration plans on areas where substantial benefits to the fishery resource are likely. If the target species and the areas of special concern are already known, you may be able to proceed directly to field surveys after summarizing the existing data.

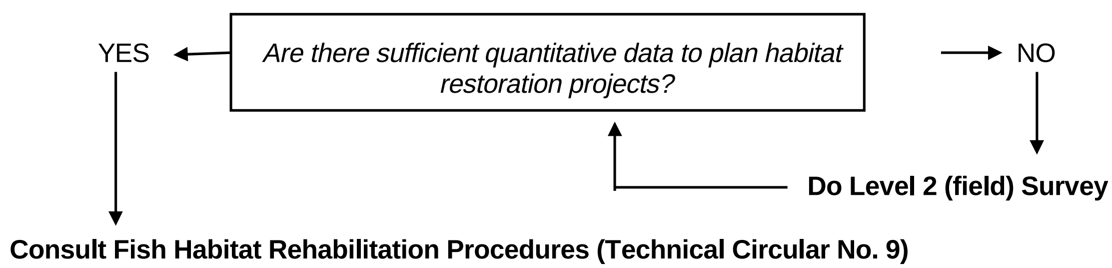
Areas of special concern may include:

Figure 1 - Flowchart of the fish habitat assessment process (see notes below).





Step 4 - Recommend fish habitat restoration methods



Notes:

1. The FHAP follows a watershed assessment (CWAP or IWAP) or a similar review and assessment of the cumulative impacts of forest harvest in the watershed which has suggested land-use impacts on fish or fish habitat. Thus, adverse impacts on fish or their habitat are indicated or suspected before commencing a FHAP.

2. Rare, threatened, or regionally-significant non-salmonids may also be considered as potential target species. Consult regional Fisheries staff.

3. When you examine trends in abundance in Step 1 to identify potentially depressed stocks, look at the abundance of the life stage that uses the habitat that is being considered (e.g., stream-rearing juveniles).

4. Level 2 field surveys are normally restricted to those sites which the level 1 assessment has identified as potentially impaired habitat. You would do a level 2 survey to provide any additional site-specific habitat information that is needed to diagnose the nature of the impairment, as well as to provide the detailed information needed to plan the appropriate habitat rehabilitation project for the site.

- areas of degraded fish habitat,
- other (similar) areas with similar sensitivity to impacts,
- “critical” habitats that are of particular importance to the target species (limiting habitats or heavily used areas).

Note that the results of the watershed assessment procedure (CWAP or IWAP) and the stream channel assessment procedure (Technical Circular No. 7) may help identify areas of special concern in advance of the overview FHAP.

Steps in the Overview Assessment

The **steps** in the overview fish habitat assessment are:

1. delineate and identify the watershed of interest

2. assemble existing information:
   (i) topographical maps
   (ii) aerial photographs
   (iii) fish distribution, abundance and habitat use information

3. establish stream reaches

4. from the existing information,
   (i) identify target fish species
   (ii) summarize trends in fish abundance for the target species
   (iii) map salmonid distributions by life stage
   (iv) identify critical or heavily-used reaches

5. from existing information and/or aerial photographs,
   (i) determine habitat conditions at an overview level
   (ii) evaluate habitat conditions or sensitivity

6. identify areas of special concern

7. suggest preliminary fish habitat rehabilitation strategies,
   (i) restorative measures
   (ii) mitigative measures, if needed.

Identifying the Watershed

Identify the watershed by its gazetteered name and hierarchical watershed code (Anonymous 1988). Refer to the Gazetteer of Canada (Anonymous 1985) for official names. Obtain the watershed code from the MoELP Watershed Dictionary (consult regional WRP staff). Note that sub-basins may have their own codes. If standard watershed codes have not been assigned to the stream, then follow the guidelines in the Forest Practices

Code (FPC) fish-stream classification procedure to assign an interim locational point to the stream mouth.

Determine watershed boundaries, drainage area, stream network pattern and major geological features from 1:50,000 National Topographic Series (NTS) maps and aerial photographs if these are not available from the MoELP Watershed Atlas. Plot a long profile of the mainstem and major tributaries from 1:50,000 NTS maps to identify major reach breaks and average gradients (see Newbury and Gaboury 1993, p. 10, for methods).

Report the following watershed location and tenure information:

- gazetteered name of the watershed, plus any local names
- NTS 1:50,000 or British Columbia Geographic Series (BCGS) 1:20,000 map sheets for the watershed (specify map source)
- hierarchical watershed code
- universal transverse mercator (UTM) coordinates of the stream mouth (use the North American Datum 1983 geo-reference standard)
- stream order at 1:50,000 NTS map scale
- named sub-basins (tributaries) and their watershed codes
- MoF region and district
- nearest community, distance (km) and type of access
- licensee(s) and other significant stakeholders
- forest tenure (TFL, etc.)
- percent private lands.

Existing Information Sources

An early step in a FHAP is to assemble the information that is currently available on the distribution, abundance, habitat requirements, habitat use and habitat conditions for salmonids in the watershed of interest. Information on “critical” habitats and descriptions of known habitat problems are particularly useful.

The overview FHAP examines the following information on forest and aquatic resources:

- FPC fish stream classifications or distribution of salmon and sportfish
- occurrence of rare, threatened, endangered or regionally significant fish
- historic trends in abundance and distribution of salmon or sportfish
- historic trends in fish habitat quantity and quality
- historic trends in water quality and quantity
- amount, locations and trends in the recreational use of aquatic resources

- special public concerns
- non-WRP fishery resource rehabilitation work.

The principal sources for existing information on fish and fish habitat are:

- stream inventory summary system (SISS) database
- fisheries information summary system (FISS) database
- salmon escapement database system (SEDS)
- MoELP aquatic biophysical maps
- MoELP Resource and Analysis Branch (RAB) surveys and maps
- MoELP/MoF/DFO special reports and studies (e.g., the annual steelhead harvest analysis)
- licensee's file information.

The SISS catalogues contain information on fish species distributions, harvest and escapement, life history timing, fish production potential, obstructions to fish migration, and lake, water, and water quality issues. The FISS database, which is gradually replacing SISS, contains similar information in a fully georeferenced format that can be overlain on a 1:50,000 stream network map. RAB files contain standard stream survey information, usually in the form of (unsummarized) reach cards that tabulate habitat characteristics and fish abundance. SSIS, FISS, aquatic biophysical maps and some RAB files are available for viewing at regional offices of the BC Ministry of Environment, Lands and Parks or from the Inventory Section of the BC Fisheries Branch (3rd floor, 1106 Cook Street, Victoria, B.C., V8V 1X4). You can purchase FISS maps from Archetype Print, #335 - 375 Water Street, Vancouver, B.C., V6B 5C6, phone 602-0282. SEDS contains historic salmon escapement estimates for major streams. It is available through DFO divisional offices. Your regional WRP Fisheries Specialist can assist you to obtain information from the above sources.

The database information may be incomplete or out of date. Therefore it is important to interview MoELP and DFO regional fisheries staff to fill in gaps in the information. Special studies such as the MoELP steelhead harvest analysis, annual regional snorkel surveys of juvenile or adult abundance, and visual surveys of spawner numbers may not appear in the databases and must be specifically sought out. Forest tenure holders frequently have fish survey data, as may the various Aboriginal fisheries councils whose jurisdictions include the watershed.

Target Fish Species

The **target species** for fish habitat assessment and restoration are economically or culturally important salmonids whose abundance has declined following past timber harvest or which are known to be sensitive to the effects of logging. These are: anadromous Pacific salmon (coho salmon, chinook salmon, pink salmon, chum salmon, sockeye salmon), non-anadromous salmon (kokanee), resident or anadromous trout (rainbow trout and steelhead, cutthroat trout, brown trout) and char (bull trout, Dolly Varden, brook trout, and lake trout). In some areas target species may also include Arctic grayling, mountain whitefish, and lake whitefish. Exceptionally, the target species may be rare, threatened, endangered, or regionally significant non-salmonids; consult your regional BC Fisheries Branch office or the B.C. Conservation Data Centre for a current listing of such species.

Briefly summarize historic trends in stock abundance (stable, increasing, decreasing) for the dominant species. Catch data and escapement estimates are the most common sources of information on stock abundance. The historic trends in fish abundance may be linked to habitat changes (see below), but they may also indicate stocks that are particularly sensitive to habitat degradation because of low abundance (Anonymous 1993), e.g., stocks of bull trout or summer steelhead.

Where reliable information on stock status exists, you can initially assign priorities to target species either by their relative abundances or by their post-logging declines in abundance. In the absence of reliable abundance data, use anecdotal information from knowledgeable observers to determine dominant species. You will adjust the initial prioritization of target species when more information on the nature and location of logging impacts becomes available. Confirm your initial prioritization with regional Fisheries staff.

Because salmonids differ in their life histories and habitat use, knowing the target salmonid species can greatly increase the efficiency of the FHAP by suggesting likely areas of concern whose conditions need to be evaluated. Consult the references listed above for detailed information on the habitat requirements of salmonids that can be used to suggest possible areas of special concern in the watershed.

If you have no information about salmonid distributions in the watershed but know that fishery values are (or were) significant, request the FRBC-funded fisheries inventory program to establish the species composition and their current distributions by completing the BC Fisheries Branch standard fish inventory in those portions of the stream network where the average reach gradient is less than 20 percent.

Fish Distribution

You will use existing fish distribution (and abundance) information to more clearly identify the portions of the stream network where you must assess fish habitat conditions. These may include **potentially sensitive areas**, such as:

- areas that are (or were) heavily used by fish,

- areas that are (potentially) impacted, such as:
  - (i) areas with marked post-logging changes in fish distribution or abundance, or
  - (ii) areas of the watershed where fish are abnormally absent,
- fish-bearing areas with high connectivity to logging-impaired upslope areas.

You should later confirm the (abnormal) reported absence of fish from portions of the watershed (e.g., above reported barriers).

Organize fish distribution data by stream reach. A **stream reach** is a homogeneous section of stream channel, characterized by uniform discharge, gradient, channel morphology, channel confinement, and streambed and bank materials. There is normally a repetitive pattern of structural features (e.g., pool-riffle sequences) within the reach. Reach boundaries occur at significant changes in:

- gradient (e.g., greater than 2% change, such as at a waterfall),
- confinement (e.g., from a single channel to a braided channel, or from a broad floodplain to a canyon), or
- discharge (e.g., at the confluence of a major tributary, such as one encompassing more than 10% of the watershed area upstream of the confluence).

The channel assessment procedure is the primary source for stream reaches. The FHAP, the channel assessment procedure and the FPC fish-stream identification procedure all organize information by stream reaches, so it is important to define and number reaches consistently. Use recent 1:15,000 or larger scale aerial photographs to define reaches. Appendix C gives sources for maps and aerial photographs. Third order streams (at 1:50,000 scale) typically will have reach lengths on the order of 500 m. Transfer the reach boundaries to 1:20,000 terrain resources information management (TRIM) maps and record their UTM coordinates. Number the reaches sequentially along the mainstem, starting at the stream mouth.

You may wish to subdivide reaches into smaller, more-homogeneous **sections** based on the attributes of the adjacent riparian forest (such as the presence of absence of a riparian buffer strip, or changes in stand characteristics).

If an aquatic biophysical map is available for the watershed, use it to establish the distributions of the target fish species. If an aquatic biophysical map is not available, use the FISS database to map the distributions of target species by life stage and to locate known areas of concern. Check that recent survey information is included. Also use the results of the WAP, road and gully assessments to identify and plot upslope sources of sediment or debris that may impact fish habitat.

Otherwise, summarize existing distribution information, by stream reach, on the **overview fish distribution form** (adapted from LGL Ltd. 1995) for the watershed. Appendix F contains copies of all forms used in the FHAP procedure. Record the following information for each species, life stage and reach:

Reach Number
From the channel assessment procedure.

Section Number
Within the reach (if necessary).

Data Source
Note the source of the information, as:

SISS (stream inventory summary system)
FISS (fisheries information summary system)
ABM (aquatic biophysical maps)
SEDS (spawning escapement data system)
MELP (BC Fisheries Branch reports or studies)
DFO (Canada Department of Fisheries and Oceans reports or special studies)
FOR (forest licensee)
TG (tribal group or aboriginal fisheries council records)
LKNOW (local knowledge).

Survey Methods
Code the methods used to obtain the original juvenile and adult fish distribution information as:

AC = aerial count
AG = angling
AR = angler report
BL = blasting
CR = creel census
DC = dead capture
DN = dip netting
EL = electrofishing
FT = fish traps or fence
GN = gillnetting
MT = minnow traps
PO = poison
SN = seines
SA = stomach analysis
SL = set line
SW = swimming (snorkel count)
UN = unknown
VO = visual observation (i.e., shore count)

Fish Presence
For each salmonid species and life stage (juvenile, adult, spawner), record the presence of the species in the reach and section as:

N = not present
K = presence known
S = suspected presence
H = historically present
U = unknown

Where fish are known to use off-channel habitats such as ephemeral tributaries, side channels, cut-off channels, and other seasonally flooded areas within the floodplain, record their presence as occurring in the adjacent stream reach.

Plot fish distributions by species and life stage on 1:20,000 topographic maps using the TRIM maps as the base map, and summarize the fish distribution information in a georeferenced database, if possible, using Arc/Info formats. Indicate known spawning and rearing areas on the maps. Here and below, if you cannot utilize a geographic information system (GIS) to summarize distribution data, then plot the information on 1:20,000 mylar map overlays and summarize the information in brief tables indexed to map locations. Consult the regional WRP Fisheries Specialist or regional GIS technician for details on GIS formatting.

Habitat Condition

The overview habitat condition assessment attempts:

(1) to further identify *areas of special concern*, such as:

- reaches that contain the only habitat available for a species or life stage,
- reaches with known or suspected habitat degradation,
- reaches that are at risk to logging impacts, particularly altered inputs of sediment and large woody debris, or
- reaches with potential barriers to normal movements among habitats.

(2) to identify *preliminary restoration strategies* and methods.

Where possible, use (existing) recent stream survey data to assess habitat conditions. If recent field survey data are not available, air photo interpretation is an efficient source for overview information on fish habitat condition in medium-sized channels. Photos must be 1:15,000 scale or larger (1:5,000 is highly desirable) and should be recent (taken within the last two years). You can obtain aerial photos from Maps BC (see Appendix B). The licensee may have additional air photos. In some cases, there may be pre-logging air photos from which you can identify post-logging changes in habitat conditions. Air photos taken under bright overcast conditions at times when deciduous trees are not in leaf (early spring or late fall) and flows are low to moderate are best for examining channel and riparian conditions. Note that only certain features such as channel pattern, channel width, large woody debris, and riparian vegetation type may be accurately discerned from aerial photographs.

If suitable recent air photos are not available, options for obtaining equivalent overview information on the stream network include:

- conventional aerial photography (1:5,000 scale),
- aerial videotaping, or
- more extensive level 1 field surveys.

Which option, if any, is best suited to your needs depends on their relative costs in the watershed of interest and on the information about habitat conditions that is available to you. When considering alternative methods of obtaining overview-level information on current habitat conditions, recall that **the intent of the overview assessment is to focus subsequent field assessments and preliminary restoration plans on areas where substantial benefits to the fishery resource are likely**. Consult WRP staff about the need for new aerial photography or aerial videos of the stream.

Maps BC can arrange tenders for aerial photography at the required standard, while commercial companies will take Global Positioning System (GPS)-coordinated aerial videos with a running commentary on habitat conditions by an experienced biologist. Note that standard oblique aerial videos do not normally permit accurate quantitative measurements of stream channel features. Note also that all aerial methods may be largely ineffective for small streams with treed riparian areas.

Aerial image acquisition costs can be quite variable, depending on the operating costs of the aerial platform (balloon, helicopter, fixed-wing aircraft), the remoteness of the site, and the number of photos (which depends upon the scale and desired amount of overlap among photos). Conventional black-and-white air photos at 1:5,000 scale will cost about $70-$100 per km of channel for accessible sites. However, 35 mm colour photos at 1:5,000 scale can cost as little as $20-$50 per km (R.C. Bocking, pers. comm.).

Accurate air photo interpretation is a skill that requires both training and practice. Consult standard texts (e.g., Lillesand and Kiefer 1994) for techniques. Note that at the most commonly-available scale (1:15,000), you are able to determine accurately only large-scale features; 1 mm on the photo represents 15 m on the ground. Use a stereoscopic magnifier (about 2-4 X) to improve resolution, but recognize that your ultimate resolution will likely be ± 5 m. Develop a set of photos that can be used for training and for interpretation checks. Evaluate the accuracy of the air photo interpretations by comparing the results on a test basis against accurate field surveys of the same areas.

Use 1:20,000 TRIM maps as base maps for the air photo analysis of habitat conditions. Some overview information is most-easily obtained from the digital TRIM maps, using standard GIS utilities. Record information from the air photos on the **overview habitat condition form** (Appendix F). This form (modified from LGL Ltd. 1995) facilitates the transfer of georeferenced habitat information to GIS format. Record the gazetteered stream name, watershed code, NTS (1:50,000) map sheets, and UTM coordinates of the stream mouth.

Obtain the appropriate series of stereo air photo pairs from Maps BC. The photos must cover the portion of the stream network known to be used by salmonids or all reaches with gradients of 20% or less if fish distributions are not known. Ensure that the photos cover both the stream channel and the adjacent floodplain. Use the TRIM or NTS topographic maps to ensure that the location and coverage of the air photos are correct. Record the Maps BC flight reference numbers for the air photo series. Number the photographs sequentially beginning at the stream mouth.

Organize the air photo information by stream reach, using the reach breaks and reach numbers from above. Mark reach breaks on the air photos and the digital base map. Begin at the stream mouth and work upstream. Where necessary, divide the reach into more homogeneous sections based on adjacent forest cover (e.g., cut blocks versus forested) or off-channel habitats. Mark section boundaries on the air photos and the digitized base map, and label them alphabetically within the reach, progressing upstream.

Determine photo scale as the ratio of the known (measured) distance between two identifiable points on the ground to the same distance on the photo. Alternatively, calculate the nominal scale of the photo as:

scale = camera focal length / flying height above terrain

where both are in the same units. The flying height is the distance between the aircraft and the object being photographed, so you may need to correct the aircraft elevation information from the Maps BC flight logs by subtracting the average elevation of the land directly below the plane.

For each reach (or section within a reach, if applicable) determine and record the following information:

Reach Number
From the channel assessment procedure or air photo analysis.

Section Code (if applicable)

Reach (or Section) Length in metres (m)
If the reach and section boundaries have been digitized, use GIS utilities to calculate lengths. Otherwise, use a map wheel, following the stream channel. Average measurements taken in both upstream and downstream directions, and multiply by the photo scale. Note that the reach length (and other linear measurements) will vary somewhat depending on the data source (air photo, TRIM map, NTS map) and method of measurement.

Elevation and Channel Gradient (%)
Determine the elevations of the reach and section boundaries. Use the GIS utilities if the section boundaries have been digitized, and use the base map otherwise. Calculate the gradient of each section as the change in elevation over the section divided by the section length, times 100 percent. Where a section boundary does not correspond to an elevation contour line, use the lower adjacent contour at the upstream end and the higher adjacent contour at the downstream end; this will bias the gradient estimate downward. Record the gradient to the nearest 0.1%.

Mean Bankfull Channel Width (W_b) in m
The bankfull channel width is the distance between banks defined by the topographic break from a vertical bank to a flat floodplain and/or by a change from no rooted vegetation to rooted perennial vegetation; consult the stream channel assessment procedure for more precise indicators. Measure W_b directly from the air photo, using a stereo magnifier, and adjust for photo scale and magnification. Take measurements perpendicular to the channel axis at about 100 m intervals along the section and record the average width to the nearest m.

Channel Type and Disturbance Indicators
Channel “type” is a generalized descriptor of the overall morphology of the stream channel. It is used to indicate channel disturbance and to establish the relative value of the channel as salmonid habitat. We use channel type in the FHAP to identify reaches that should be further examined in field surveys, either because they are high-value habitats or because they show obvious disturbance. Post-logging changes to channel features which lower (formerly-high) habitat values are the best indicators of areas of concern, but you may also use indications of disturbance in high- and moderate-value reaches to identify potential areas of concern. You will need to examine a time series of aerial photographs or field surveys to detect changes in channel type. The companion stream channel assessment procedure (WRP Technical Circular No. 7) provides a rigorous evaluation of the nature and extent of channel disturbance that result

from past logging activities; it should be used in conjunction with the FHAP to better identify areas of concern.

The stream channel assessment procedure describes the channel typology. Refer to Figure 2 for schematic examples of the channel types. The channel typology recognizes three basic channel types (step-pool; cascade-pool; riffle-pool, abbreviated as SP, CP and RP, respectively) which are modified by substrate and debris qualifiers: bedrock (r), boulder (b), cobble (c), gravel (g) and wood (w).

Gradient, channel pattern, bar type, LWD characteristics and channel stability then determine the relative value of these channel types as salmonid habitat. Table 1 assigns approximate values to different channel types, but note that these values may vary depending on actual conditions and on the preferences of the target species.

Record the channel type for the reach using the channel codes listed in Table 1. Code the type as U (unknown) if the channel type cannot be discerned from the aerial photographs.

Table 1. Channel type codes and preliminary relative values of different channel types as salmonid habitat under stable, aggrading and degrading channel conditions (see note below).

		Salmonid Habitat Value		
Channel Type	**Channel Code**	***Aggrading Channel***	***Stable Channel***	***Degrading Channel***
Block-Step-Pool	SPr	very low	low	very low
Boulder-Step-Pool	SPb	very low	low-moderate	very low
Debris-Boulder-Step-Pool	SPbw	very low	low-moderate	very low
Boulder-Cascade-Pool	CPb	very low	moderate	very low
Debris-Cobble-Cascade-Pool	CPcw	low	moderate-high	low-moderate
Riffle-Pool	RPcw	low-moderate	very high	moderate
Riffle-Bar-Pool	RPgw	low-moderate	very high	moderate
Pond or small lake	L	moderate-high	moderate-high	moderate-high
Unknown	U	unknown	unknown	unknown

Note: Consult the MoELP regional Fisheries Specialist before applying habitat values.

Use the presence of indicator features (Table 2) to diagnose recent channel disturbances that may lower salmonid habitat values. Record the most evident disturbances, using the codes listed in Table 2. Consult Technical Circular No. 7 for photographed examples and detailed descriptions of the disturbance indicators.

Table 2. Indicators of recent channel disturbance (from Hogan and Bird 1995).

	Indicator Feature	Code
***Bed Characteristics**:*	1. Extensive areas of scour	SC
	2. Extensive areas of (unvegetated) bar	DW
	3. Large, extensive sediment wedges	WG
	4. Elevated mid-channel bars	MB
	5. Extensive riffle zones	LR
	6. Limited pool frequency and extent	FP
Channel pattern:	1. Multiple channels (braiding)	MC
Banks:	1. Eroding banks	EB
	2. Isolated sidechannels or backchannels	BC
LWD:	1. Most LWD parallel to banks	PD
	2. Recently formed LWD jams	JM

Potential Barriers

Note the location and nature of partial or complete blockages to movement by juvenile or adult salmonids and mark them on the base map for field verification. Also check the SSIS files for the locations of known blockages. Distinguish the following types of potential barriers:

a. culverts (CV) *and disused bridges* (BR) - road crossings that constrict the channel can be barriers to fish movement, especially on abandoned roads spanning smaller channels. Consult the results of the road condition assessment to judge the status of culverts and abandoned bridges, or examine them directly.

b. landslides or bank sloughing (LS) - unvegetated actively eroding banks or slopes that produce large fans of sediment or abrupt changes in stream course.

c. log jams (X) - substantial accumulations of logs that completely cover the stream channel.

d. beaver dams (BD) - identified as pools behind a channel-spanning structure of mud and interleaved trees and rocks, usually in low to moderate gradient areas.

e. falls (F) - vertical drops greater than about 2 m.

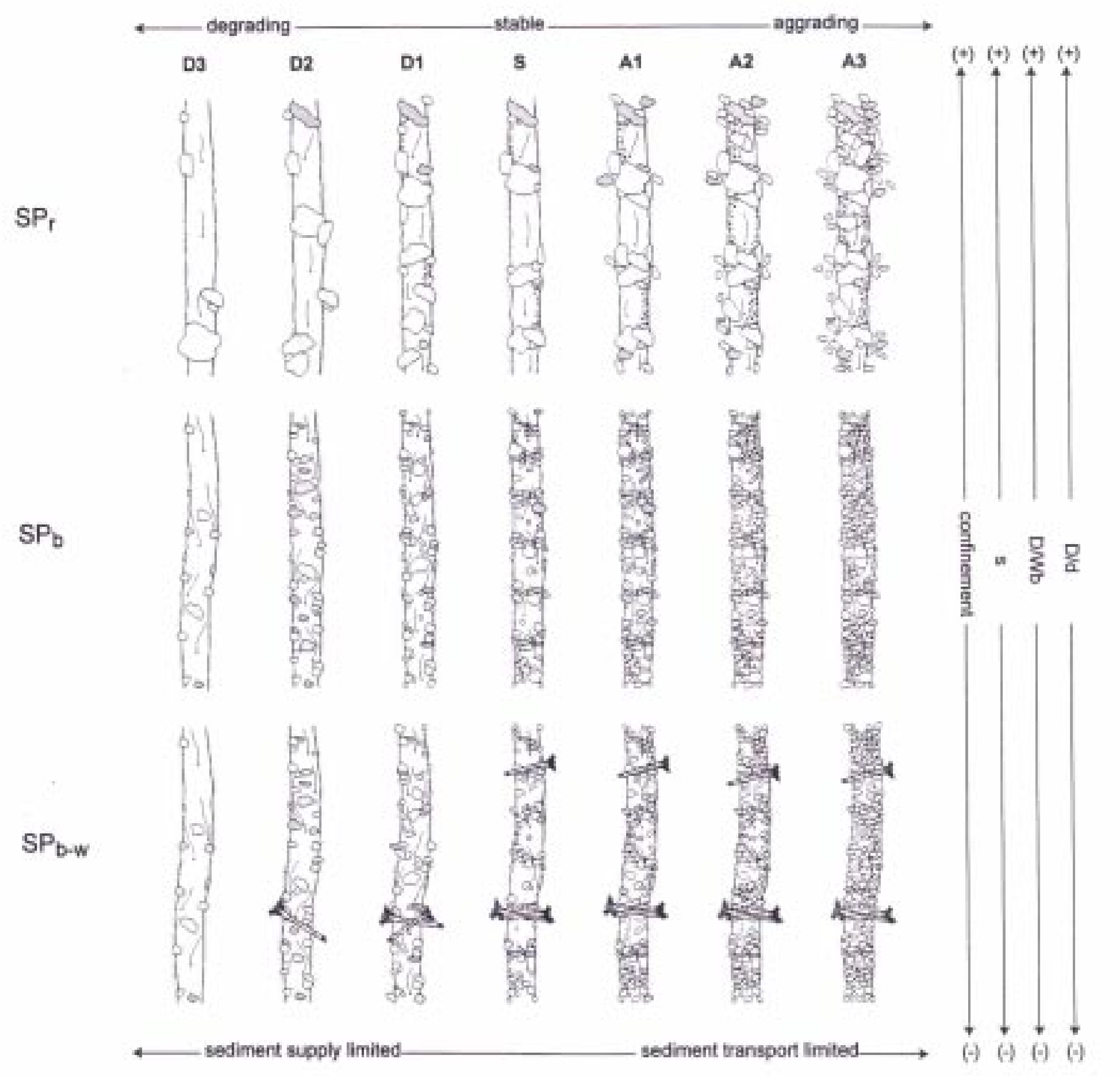
f. cascades or chutes (C) - appear as white water in steep channels.

g. gradient barriers (G) - gradients greater than about 20% are often barriers to fish movement.

h. no barriers (N)

i. unknown (U).

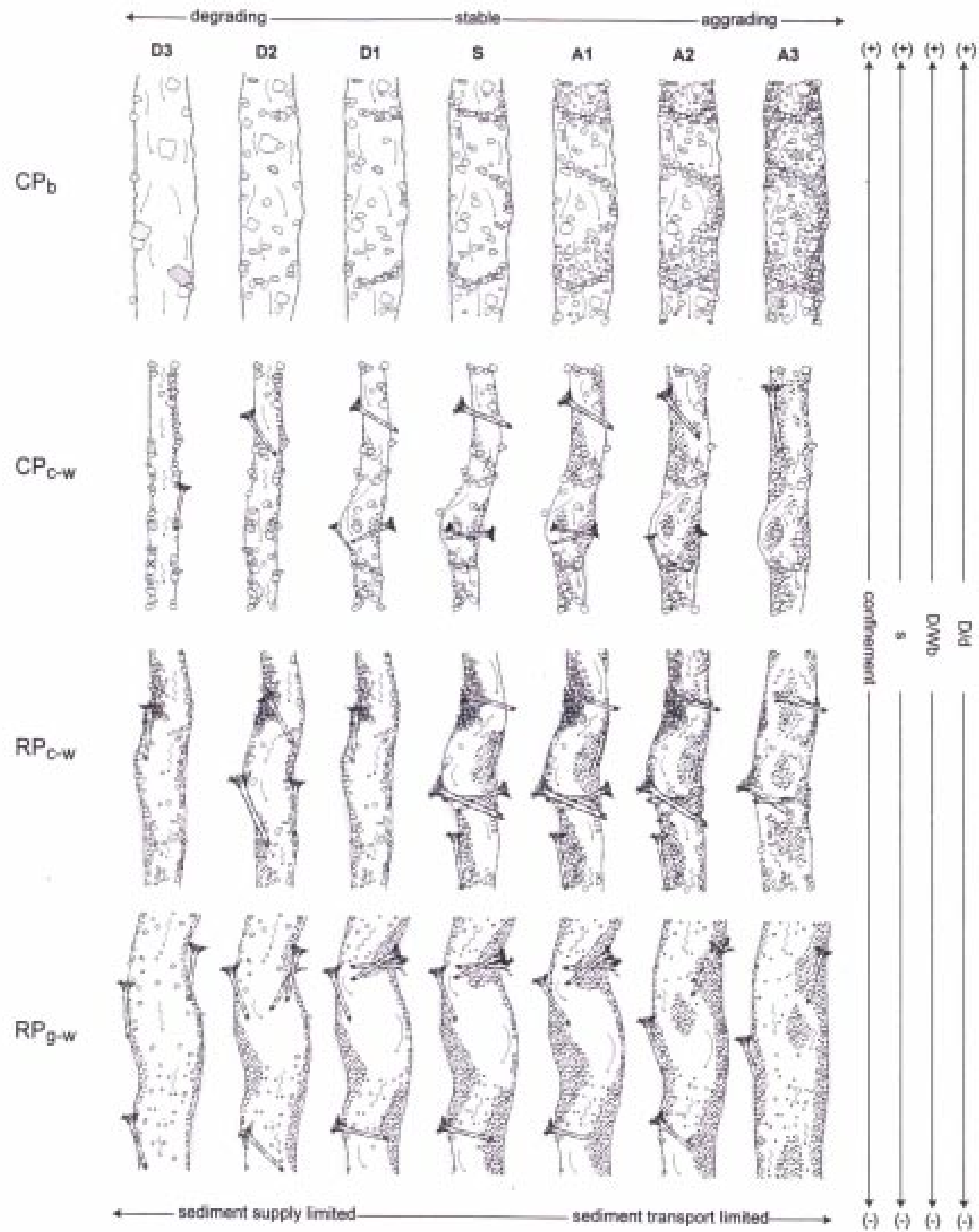
Figure 2. Schematic illustrations of channel types (from Hogan and Bird 1995)



Abbreviations:

D is the size of the largest sediment particle on the channel bed,
d is the bankfull channel depth,
W_b is the bankfull channel width, and
s is the average slope of the channel.

Figure 2. (continued) Channel types



Percent Pools

Estimate to the nearest quartile the proportion of the section area that consists of pools. Note that pool areas vary with flow. Percent pool data are most useful when they refer to low flow conditions. Code the percentage pool as:

0 = no pools in the section
1 = 1-25% pool by area
2 = 26-50% pool by area
3 = 51-75% pool by area
4 = 76-100% pool by area
9 = unable to estimate pool area (e.g., because of canopy closure).

Large Woody Debris (LWD) Amount and Distribution

Logs within the bankfull channel width that can be seen individually on the air photos are LWD. Score the amount of LWD in the section as:

N = no LWD
F = few LWD pieces (fewer than 1 piece per W_b of stream length)
A = abundant LWD
U = unknown.

Categorize the distribution of LWD as:

C = clumped distribution of LWD pieces
E = LWD is evenly-distributed along the channel

Riparian Vegetation Type

Determine the composition of the dominant vegetation type immediately adjacent the stream channel (i.e., in the FPC riparian management area, RMA).

If a riparian assessment is being done, obtain vegetation type and stand structure data from the riparian assessment. Otherwise, use both air photos and forest cover maps (obtainable from the licensee or MoF district offices) to identify the dominant vegetation type. The 1:5,000 forest cover maps provide considerable information on vegetation type and structure beyond that extractable from the air photos. If forest cover maps are available in digital format, merge them with the TRIM base maps to delineate vegetation types within the RMA. Record the dominant riparian vegetation type as:

N = unvegetated. Much bare mineral soil is visible,
G = non-forested grassland or bog (<10% tree cover)
S = shrub/herb. Herbaceous or shrubby vegetation dominate.
C = conifer-dominated riparian forest

D = deciduous-dominated riparian forest
M = mixed conifer-deciduous riparian forest (>25% conifer and deciduous)

Riparian Structural Stage
Record the structural stage of the dominant vegetation in the RMA as:

INIT - the non-vegetated or initial stage following disturbance, with less than 5% cover.
SHR - shrub/herb stage. Less than 10% tree cover.
PS - pole-sapling stage, with trees overtopping the shrub layer, usually less than 15-20 years old.
YF - young forest. Self-thinning is evident and the forest canopy is differentiating into distinct layers. Stand age is 30-80 years.
MF - mature forest with well-developed understory. Conifer-dominated mature forests (MFc) have greater than 50% conifers in the sub-canopy layers while mixed forests (MFm) have greater than 25% component of both coniferous and deciduous trees in all canopy layers.

Canopy Closure (shading)
Categorize the proportion of the surface area of the stream covered by the riparian canopy as (Anonymous 1993):

1 = stream surface and banks visible (0-20% shade)
2 = stream surface and banks visible at times (20-40%)
3 = stream surface visible but banks are not visible (40-70%)
4 = stream surface slightly visible or visible in patches (70-90%)
5 = stream surface not visible (>90% shade)

Off-channel Fish Habitat
Determine the extent of and access to off-channel fish habitat adjacent to the stream section. Include low-energy waters such as pools, sidechannels, oxbows, and other backwaters that are accessible at high discharge, although they may be dry at low flow. Also note backwaters that are isolated from the main stream channel by roads, berms, debris or changes in channel position. Record off-channel fish habitat as:

U = unknown.
P = poor. No off-channel habitat or no access for fish.
F = fair. Little off-channel habitat or poor access for fish.
M = moderate. Some off-channel habitat with good access for fish.
G = good. Abundant off-channel habitat with good access for fish.

Preliminary Habitat Evaluation

The **preliminary assessment** of habitat conditions will be based largely on qualitative comparisons and indicators of habitat disturbance rather than on quantitative measures. You will use the preliminary assessment to identify areas of special concern that must be examined in field surveys.

The values of the habitat variables that were tabulated above provide qualitative information about present habitat conditions (see Table 5, p. 57). Poor conditions or post-logging changes towards poorer conditions may indicate opportunities for fish habitat restoration. Try to interpret the habitat variables as an interconnected set to provide a clearer picture of the causes of harmful changes in habitat conditions. Use the upslope impact potential (see below) to relate observed channel conditions to possible causes as well as to suggest areas of the stream that may be at risk to future impacts.

Channel type, which integrates several habitat variables, provides a broad relative measure of the value of the reach as salmonid habitat (see Table 1). The indicators of recent disturbance to the channel that are listed in Table 2 reduce the value of the channel type as salmonid habitat and suggest the possible causes of habitat impairment.

Other habitat variables also aid in diagnosing habitat quality or indicate causes of habitat degradation. Barriers potentially reduce habitat quality by restricting access to upstream spawning, rearing and overwintering areas. Pools are often excellent rearing and holding habitat. Low pool frequency or extent in otherwise high-value channel types (RPcw and RPgw) greatly reduce habitat values. LWD is important as a cover element and for producing the microhabitat conditions preferred by salmonids as rearing and overwintering habitats. Low amounts of LWD or LWD whose distribution is clumped or parallel to the banks reduce habitat values.

Riparian stand structure and canopy closure greatly influence stream temperature, organic carbon inputs and LWD recruitment to the channel and may influence bank stability. Extensive areas of riparian forest that have been clearcut and are regenerating with shrubs or with young stands of deciduous trees that lack large conifers as structural elements suggest elevated stream temperature, reduced bank stability, and reduced inputs of LWD, all of which generally reduce habitat quality. Young stands of deciduous trees may, however, increase food availability for stream-rearing salmonids by increasing the light reaching the stream to increase instream algal production, and by adding larger quantities of higher-quality leaf litter to stimulate invertebrate production in the stream. The net effect of riparian logging is generally strongly negative, but could be positive in streams where food is the principal limitation to fish production.

Off-channel habitat, especially stable, low-velocity backwaters in RPgw and RPcw channels, are very important overwintering sites and refuge areas during high-flow periods. Loss of access, reductions in extent, decreases in structural complexity, decreases in water quality and reduced cover in off-channel habitats all degrade the quality of salmonid habitat in the reach.

Abnormal turbidity from identifiable, logging-related sources such as mass wasting into the channel, erosion from roads or unvegetated slopes, and bank instability in logged riparian areas may impair salmonid habitat quality. In naturally-turbid glacier-fed streams, however, water quality in off-channel areas and in non-glacial tributaries may be a more important determinant of habitat quality than the effects of turbidity in mainstem reaches.

Use the above indicators and the questions in Appendix E to identify major impacts on salmonid habitat within reaches. Assess the relative severity of impacts from the direction and magnitude of the deviations from expected conditions or from the occurrence of multiple impact indicators, especially in channel types (RPgw, RPcw) with high value as salmonid habitat. Note the nature of the major impacts that occur in the reach or section on the **preliminary habitat evaluation form** (Appendix F). You will use your subjective assessments of habitat value and severity of impacts to delineate areas that must be examined in quantitative field surveys.

Also assess the potential for further impacts from adjacent upslope areas. Use the results of the WAP, road, and gully assessments or aerial photographs to identify adjacent upslope areas with high connectivity to the stream channel where mass wasting, extensive erosion, flow concentration or debris-charged gullies may impact the channel. Record the **upslope impact potential**, by reach, as:

L = low. No obvious upslope impact sources.
M = moderate. Few upslope impact sources *or* low connectivity to the stream channel.
H = high. Many or severe impact sources and high connectivity.
U = unknown upslope impact sources.

Use the georeferenced information on fish distribution, fish use, and habitat quality to delineate and prioritize areas to be examined in level 1 field surveys. Summarize this habitat information as a georeferenced database or as a summary table indexed to location. Using GIS or map overlays, superimpose the distributions of fish and impacted habitats to identify reaches with major habitat impacts or high upslope impact potential that are also heavily used by the target fish species as spawning, rearing or overwintering sites. These reaches are the areas of special concern that are the highest priority to be examined in field surveys. Reaches that are little used by the target species and which appear little impacted are low priorities for field surveys. Reaches where fish use has changed, reaches that are heavily used by fish but which show only moderate impacts to physical habitat, and reaches that are moderately used by fish but which show severe habitat impacts are intermediate priorities.

Delineate areas to be further examined in field surveys on the 1:20,000 base map, identifying reaches by their priority class (high, moderate, low). Attach a brief text summary to each reach, identifying fisheries values and probable habitat impacts within the reach. If possible, suggest restoration opportunities, based on the preliminary observations of nature, cause, and severity of impacts in the reach; record this on the “preliminary habitat assessment” form.

Use the extent and severity of adverse impacts to fish habitat and the risk of further impacts to suggest a likely **restoration strategy** (see Appendix B for definitions), as either:

- restoration,
- rehabilitation,
- mitigation, or
- no action.

In proposing an initial restoration strategy, consider the:

- technical feasibility,
- benefits and costs,
- risk, and
- management implications

of the strategy. The nature of the likely restoration strategy will influence the need for, the extent, and the focus of any level 1 or level 2 field survey.

Output from the Overview Assessment

The **output** from the overview fish habitat assessment will be:

1. a list of salmonid species that are likely targets for restoration activities
2. distribution maps for the target salmonids, showing the locations of critical habitats
3. an initial list of habitat concerns by stream reach
4. a prioritized list of reaches to be further examined in level 1 field surveys
5. a list of possible restoration opportunities, by reach, and
6. an initial restoration strategy, to guide further field surveys and project planning.

Level 1 Field Assessment

Aims of the Level 1 Assessment

The **objectives** of the level 1 assessment are:

- *to confirm or revise our identification of the nature, location, extent and severity of forest harvest impacts on fish habitat*
- *to provide sufficient information to identify and prioritize restoration options, and to identify initial project objectives and scope*
- *to identify the need for any level 2 assessments*
- *to prepare initial budgets and schedules for restoration projects.*

The level 1 assessment tests the initial conjectures that the overview assessment has provided about the factors that limit fish production in the watershed by collecting further quantitative information in field surveys and applying more precise diagnostics to identify habitat impairment. It also provides the quantitative information needed initially to define and plan restoration projects.

Scope of the Level 1 Assessment

The level 1 fish habitat assessment is a purposive field survey of current habitat conditions in selected reaches. If you have completed an overview assessment, a level 1 assessment would examine high priority reaches identified by the overview assessment and would focus on the impacts that were identified as significant in those reaches. If you have not done an overview assessment, you should assemble and review any existing fish distribution and habitat information, similarly to the overview procedure, to define a set of reaches whose habitat condition may influence fish production and which should be examined. If there is no information available on the fish distribution or habitat conditions in the stream, then combine elements of a level 1 habitat survey with a FPC fish-stream identification survey to determine fish species composition, distributions and habitat conditions.

By using existing and overview information, you can usually restrict the level 1 field survey to a relatively small portion of the watershed where habitat information will be useful in defining opportunities for effective restoration projects.

The level 1 assessment uses several features to characterize habitat conditions for the target species. The habitat features of particular importance are:

1. adult holding pools

2. spawning gravel quantity and quality
3. (rearing) pool area and frequency
4. cover in pools and riffles
5. LWD frequency and distribution
6. substrate characteristics of the stream bed
7. off-channel habitat
8. nutrient concentrations during the summer growing season

The field survey collects quantitative information on the above features. Methods to obtain these data are described below. You will also collect qualitative information on other habitat features.

To evaluate habitat conditions, the level 1 assessment compares the values of the above habitat features within the reach to expected values. **If watershed or regional criteria for habitat conditions do not exist, then use the diagnostic criteria of Table 5 to evaluate conditions in the reach**. The evaluation considers conditions in each reach separately, to characterize the quality of the feature within the reach as poor, fair or good.

Survey Design

The level 1 field survey is purposive, in that you normally only survey a specific (non-random) set of stream reaches that have been identified by the overview assessment. Within each reach, you obtain quantitative measurements of habitat characteristics by either:

- complete sampling,
- stratified random subsampling, or
- stratified systematic subsampling (from a random start point)

using naturally-occurring habitat units (e.g., pools, riffles, glides*)* as **strata**. We recommend against the use of an arbitrarily-chosen “representative section” to characterize habitat features within the reach. “Representative” sections are likely to produce biased estimates of reach characteristics and will inflate variance estimates.

Complete sampling within a reach is feasible for some habitat features, but may use resources inefficiently if accurate measurements are costly or time-consuming to obtain (e.g., fish densities).

Complete sampling may be impractical, necessitating some sort of *subsampling*. Because stream reaches are composed of repetitive sequences of naturally-distinguishable habitat units such as pools and riffles, *stratified random subsampling* is often the best method to estimate reach characteristics where you cannot sample all units. Use pools, glides, riffles and cascades as your strata. If the number and location of the sampling units within the various strata are known (e.g., mapped from air photos), then the desired number of habitat units can be randomly chosen from each stratum. Use a random number generator to select the habitat units that are to be sampled in each stratum.

If the distribution of habitat units is not known in advance, use *systematic random sampling* with a separate, random start point for each stratum. It is important that the various strata be sampled independently; each must have a separate random start point. If the planned subsampling fraction for the i-th stratum is 1/K (K is an integer), you would chose an independent start point S between 1 and K. You would start sampling when you encounter the S-th habitat unit in the stratum and sample every K-th unit thereafter. In general you will not know the distribution of habitat units so you will normally use systematic random sampling. If you can sample all habitat units encountered, you need no subsampling, of course.

Estimation or Measurement?

Using an easier (cheaper, faster) but less-accurate method calibrated to an accurate method can greatly increase the efficiency of the survey if the variance among samples is greater than the variance within samples. For example, the linear dimensions of many habitat features can be visually estimated or estimated with a rangefinder with acceptable precision. By calibrating the estimation method to an accurate method (e.g., a surveyor's tape), you can adjust the visual estimates with the calibration ratio. The increase in the number of measurements taken (e.g., complete sampling) may offset the imprecision in the estimation procedure to give a more precise estimate of the habitat feature for a given survey cost.

To calibrate visual or other rapid estimation methods, take both visual and accurate measurements of the habitat feature (say, bankfull channel width W_b) on a systematic subsample of measurements, say 1 in k (k is an integer), beginning from a random, independent start point between 1 and k. You should take at least 10 pairs of measurements spanning a wide range in values. Plot the relationship between the accurate and visual measurements for each calibration to inspect the data for outliers and to ensure that the data pass through the origin. Calculate the **calibration ratio** for the measurement as:

$$\hat{R} = \left(\sum_{i=1}^{M} m_i \Big/ \sum_{i=1}^{M} x_i \right)$$

where m_i is the i-th accurate measurement and x_i is the corresponding visual estimate, i = 1,....,M (10 in this case). Calculate separate calibration ratios for each stratum.

Use the stratum calibration ratio to adjust the rapid (e.g., visual) estimates from habitat units where only the rapid estimates were made:

$$\hat{y} = \hat{R} \cdot x_i$$

where $\hat{y}_i$ is the adjusted i-th estimate, $\hat{R}$ is the calibration ratio for the variable, and x_i is the corresponding rapid estimate.

Hankin and Reeves (1988) and Dolloff et al. (1993) discuss how to combine stratified systematic subsampling with rapid, visual estimation to obtain basinwide estimates of habitat proportions and fish numbers.

Pre-survey Planning

Your pre-survey planning should identify:

- survey locations and scope
- the survey design
- survey methods
- access and transportation constraints
- required permits and operational regulations
- training and safety issues
- the roles and responsibilities of the field crew.

An overview assessment defines the scope of the level 1 field assessment by identifying stream reaches that need to be examined and by suggesting the nature of habitat impairment within these reaches. Mark the reaches to be surveyed on waterproof 1:20,000-scale (or larger) maps that are carried by the survey crew, reference the reach boundaries to known landmarks, and list their approximate UTM coordinates.

Your choice of a survey design and measurement methods depends upon the desired accuracy of the results and upon logistic and budgetary constraints. The absence of detailed information on the distribution of habitat units will often force you to use stratified systematic subsampling as your survey design. Where the overview assessment identifies severe impacts whose nature and extent are unlikely to be mistaken, we suggest a lower sampling fraction and the use of calibrated rapid-estimation methods. Use larger subsampling fractions where more subtle effects must be considered.

Prior to the survey, you should select the classification system that you will use to identify habitat units, determine the habitat characteristics that you will measure, and stratify the survey area into survey units (Dolloff et al. 1993). You should also decide the measurement methods that you will use to characterize habitat units, and review their use with the field crew. We recommend habitat classification systems and measurement methods below, but other methods may be more appropriate in your particular circumstances. If you intend to use non-standard methods, you should obtain the prior approval of the Regional WRP Fisheries Specialist.

Because habitat characteristics may vary with discharge, do the survey under summer base flow conditions. Examine seasonal discharge patterns for the stream or for nearby streams from Water Survey of Canada or BC Water Management Branch discharge records to identify likely base flow conditions. Avoid doing surveys during changes in flow conditions (e.g., after a rainstorm or during snowmelt). Be aware of regional timing windows for instream fisheries work that might affect your survey.

Access to the stream channel may be very limited in remote areas. Logging roads that appear on maps may be unusable. Obtain up-to-date information on stream access and, where possible, verify it before the survey.

Surveys that include fish capture or collection require a fish collection permit from the regional Fisheries section of the BC Ministry of Environment, Lands and Parks (freshwater fishes) and/or from the Canada Department of Fisheries and Oceans (salmon). You can obtain these permits from regional MoELP and DFO offices. There is a small fee for the permit. The field crew must carry the permit and all crew members also require a valid freshwater angling license. Allow up to a month to obtain a fish collection permit. Consult with First Nations fisheries councils regarding any permits needed to work on reserve lands. Inform regional Conservation Officers when and where you will be sampling.

Your survey work must comply with BC Workers Compensation Board regulations. Anonymous (1995, p.98) lists sections of the WCB “Industrial Health and Safety Regulations” that may apply to stream surveys. Identify potential hazards to worker safety through a formal job safety analysis and take steps to minimize risk. Ensure that crew members have appropriate wilderness survival training, first aid training and first aid supplies. Ensure that the survey crew files a field itinerary and that check-in procedures are established and followed. Have contingency plans for removing the survey crew under adverse or emergency conditions.

Ensure that the survey crew is adequately trained and supervised; field work in remote areas costs too much to tolerate erroneous or inaccurate data. Review the work with the crew to ensure that everyone understands why and how activities are carried out. Clearly identify the crew chief, his authority and his responsibilities. The crew chief must ensure that the field work meets the required technical standards. The crew chief should also be responsible for maintaining the field data records.

Habitat Unit Type

The level 1 fish habitat assessment divides each stream reach into strata consisting of distinct, naturally-occurring habitat units. The field crew surveys an independent, random sample of habitat units from each stratum to characterize the average conditions within the reach. We recommend that the level 1 field assessment use a five element habitat unit classification to ensure the consistent identification of geomorphic habitat units.

The hierarchical habitat unit classification system (Hawkins et al. 1993) recommended in the draft MoELP "stream inventory" manual (Anonymous 1995) divides channel geomorphic units into three levels (Table 3). The coarsest division is between fast-flowing and slow-flowing water. The next level divides fast water into turbulent and non-turbulent categories, and roughly corresponds to "riffles" and "glides", broadly defined. Slow water similarly divides into scour pool and dammed pool components. We

Table 3. Classification of geomorphic habitat units (Hawkins et al. 1995).

Level 1	Level 2	Level 3
Fast Water	Turbulent ("riffles")	Fall
		Cascade
		Rapid
		Riffle
		Chute
	Non-turbulent ("glides")	Sheet
		Run
Slow Water ("pools")	Scour Pool	Eddy
		Trench
		Mid-channel
		Convergence
		Lateral
		Plunge
	Dammed Pool	Debris
		Beaver
		Landslide
		Backwater
		Abandoned channel

do not normally use the tertiary units in our level 1 field surveys, but we include them in Table 3 to provide concrete examples of the habitat units that we do use.

The **habitat units** distinguished in a level 1 assessment are:

1. *pools* (both scour pools and dammed pools)
2. non-turbulent fast-flowing water (*glides*, broadly defined),
3. turbulent fast-flowing water (*riffles***,** broadly defined),
4. *cascades* (higher-gradient “riffles”), and
5. *other* (see below).

We employ the familiar names “riffle” and “glide” for fast-flowing waters because most fishery biologists use these names and because true riffle-pool sequences are common in the lower-gradient alluvial areas where surveys will be most common. In steeper gradient reaches, you should further distinguish cascades (steep, coarse-substrate “riffles”).

It is important that you define and name habitat unit types consistently (see below). Train your field crews to a common standard. Consult your Regional WRP Fisheries Specialist for information about WRP training workshops.

Differences in **water velocity**, **morphology**, **local topography** and **substrate size** distinguish habitat unit types. Use the following definitions to delineate habitat units:

Pools are *areas of (relatively) slower, deeper water with a concave bottom profile, finer sediments, and a water surface gradient near 0%.* Scour adjacent to obstructions or the impoundment of water behind obstructions create the pool. Pool-like habitat units must have both the following minimum dimensions (adapted from Schuett-Hames et al. 1994) to be separately identified as pools in our habitat survey:

Bankfull Channel Width (m)	Minimum Area (m^2)	Minimum Residual Depth (m)
0 - 2.5	1.0	0.20
2.5 - 5	2.0	0.40
5 - 10	4.0	0.50
10 - 15	6.0	0.60
15 - 20	8.0	0.70
> 20	10.0	0.80

The **residual depth** is the difference between the maximum pool depth and the depth at the pool outlet, and approximates the pool depth at zero flow (see Figure 3).

Glides here *include all areas of fast-flowing, non-turbulent water*. Glides (and riffles) have relatively flat bottoms in cross-section (cf.

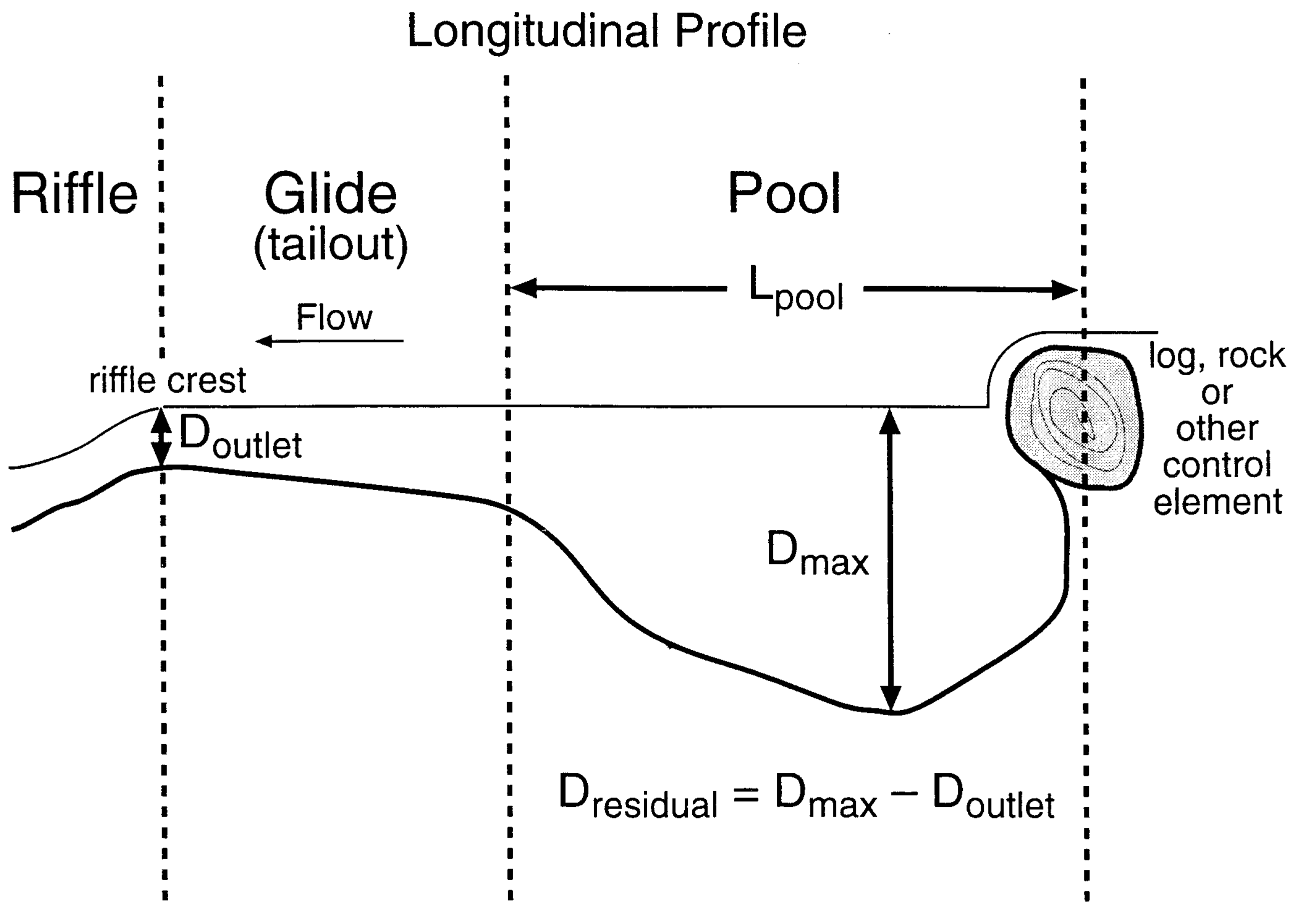


Figure 3. Determining the residual depth of a pool

the concave bottom of pools). Pool tailouts, the elongated transitional zone of moderately-shallow, flat-bottomed water with smooth, laminar flow that occur between pools and riffles in low-gradient channels, are a common form of glide (Figure 3). Water velocity, bottom profile and minimum residual depth criteria help distinguish the tailout glide area from the pool.

Riffles are *areas of turbulent, fast-flowing water*. In alluvial reaches, they are commonly shallow, moderate-gradient areas with gravel or cobble substrates, bed material projecting above the water surface, and with obvious surface turbulence.

Cascades are *steep, stepped "riffles"* of bedrock or emergent cobble or boulders *in channels with gradients greater than about 4%* (Hogan and Bird 1995).

Other. "Other" includes wetland complexes that lack an identifiable primary channel, sloughs, lakes, areas of sub-surface flow, or areas where the channel cannot be observed (e.g., under large log jams).

Macrohabitat units have linear dimensions of the same order as or larger than the wetted width and usually span the wetted channel. However, some habitat units, such as lateral scour pools, may be embedded within larger units. All habitat units must meet minimum size criteria (Table 4) to be distinguished as separate units. Otherwise, combine small units with the adjacent habitat unit that does meet the size criterion.

Table 4. Minimum size criteria for habitat units (adapted from Schuett-Hames et al. 1994).

Bankfull Channel Width (m)	Minimum Area (m^2)
0 - 2.5	1.0
2.5 - 5	2.0
5 - 10	4.0
10 - 15	6.0
15 - 20	8.0
> 20	10.0

Survey Methods

All assessments that are funded by the WRP must use methods that have been approved by the intergovernmental Resource Inventory Committee (RIC). The methods described here are a subset of the approved methods which are discussed in more detail in the MoELP “Lake and stream inventory standards and procedures” manual (Anonymous 1995). You may, however, substitute other appropriate RIC-approved methods for those recommended here.

If a channel assessment procedure is being done, combine the field survey portions of the fish habitat assessment procedure and the channel assessment procedure whenever possible.

Equipment

Level 1 fish habitat surveys require the following equipment:

1. fibreglass surveyor’s tape (50 m length)
2. surveyor’s rod or metre stick (0.01m divisions)
3. clinometer or Abney level
4. hip chain (metre divisions)
5. 1:20,000 (or larger) map
6. handheld Geographic Positioning System (GPS) unit
7. thermometer (or recording thermograph)

8. clip board
9. level 1 habitat survey forms (see Appendix F)
10. waterproof field note book
11. pencils
12. camera and film
13. first aid equipment
14. optical or electronic rangefinder (optional)
15. flow meter (optional).

Calibrate all linear measurement equipment against a designated 50 m standard fibreglass surveyor's tape prior to the start of a survey. Schuett-Hames et al. (1994) provide detailed instructions. Pocket thermometers or thermistors should be calibrated against a calibration thermometer that is traceable to a NBS standard. You should re-calibrate optical or electronic rangefinders several times a day during surveys.

General Information

Fill in the general information required on the **level 1 habitat survey form** (Appendix F). You will have the gazetteered name and watershed code from your Overview Assessment. Note weather conditions and other factors that might affect the survey.

Discharge ($m^3 \cdot s^{-1}$)

Because habitat unit characteristics vary with discharge, survey results are only comparable if they are done under the same flow conditions. Use summer base flow as the standard condition of discharge. Establish a reference site in the lowermost reach that you survey, and measure discharge at the site. The reference site should be in a glide area with smooth, non-turbulent surface flow, be free of obstructions and have stable banks. Use a portable GPS unit to obtain the UTM coordinates of the site, and/or describe its location with respect to a known, re-locatable geographic landmark. If you have access to a flow meter, determine discharge by the "velocity metering" method described in the MoELP "Lake and stream inventory standards and procedures" manual (Anonymous 1995). Otherwise, use the "floating chip" method (Anonymous 1995, p. 158), as follows.

Measure the wetted width (W_w) of the channel at the reference site by stretching your calibrated surveyor's tape across the stream perpendicular to the direction of flow. Measure water depth ($\pm$ 0.01 m) at 5-10 equally-spaced locations across the transect and calculate the mean depth, D. Determine the average water velocity by timing a floating object over a measured distance that is centred on the depth transect location. Establish a release point and a "start timing" point upstream of the depth transect and a "stop timing" site below it. Measure the distance between the start and stop timing transects, and time the object over this distance. A floating orange is an excellent marker because it is semi-buoyant. Determine water velocity at 3-5 locations across the stream width, and calculate an average velocity, V. Calculate discharge as:

$$\text{Discharge } (m^3 \cdot s^{-1}) = R_m \cdot D \cdot V \cdot W_w$$

where D and W_w are in metres, V is in metres per second, and R_m is an adjustment factor to account for bottom roughness, and may vary between 0.75-0.90. Use $R_m \approx 0.75$ for our purposes. Record the discharge on the survey form.

Stream Temperature (°C)

Obtain diel temperature data for streams: (1) that receive high solar insolation, (2) where you anticipate significant diel fluctuations in temperature, (3) where you suspect localized groundwater influences on stream temperature, or (4) where rehabilitation prescriptions may alter stream temperatures.

Take and record stream temperatures (± 0.1 °C) in turbulent water at the head of pools at approximately hourly intervals throughout the day, or place a recording thermograph at such a site for the duration of the survey. Use the comment field to record temperature data.

Subsampling Fractions (1 in k)

If you are subsampling habitat units within the reach, record the *subsampling fractions* (e.g., 1 in 3) for each habitat stratum (pool, glide, riffle, cascade) and record the independent random start point for each habitat stratum. If you are sampling every habitat unit encountered, note this on the form. In both cases, you must distinguish every habitat unit that you encounter; tally the total number of each habitat unit type in the reach.

Calibration of Estimates

Record whether you are *measuring* or *estimating* habitat characteristics. If you are using an estimation method, such as visual estimates, then you must also *calibrate the estimates* against accurate measurements for a subset of the habitat units, as discussed above. You will require separate calibrations for each variable that is estimated and for each habitat type. If more than one observer takes estimates, you must have separate calibrations for each; use a single observer-estimator whenever possible.

Reach and Section Boundaries

Using the 1:20,000 topographic map and aerial photographs, locate and flag the reach break at the downstream end of the reach which you are to survey. You may often need to adjust the position of the reach break determined from the air photos to correspond to ground conditions. Consult with the geomorphologist who is doing the channel assessment to ensure that you both use common reach definitions. Use a portable GPS unit to obtain the UTM coordinates of the reach break, and describe its location with respect to a known, re-locatable geographic landmark. Mark the adjusted reach boundary on your 1:20,000 field map.

Reach and Section Numbers
Record the reach and section numbers from your field map.

Habitat Unit Type
Record the habitat unit type for sampled units as:

P = pool
G = glide
R = riffle
C = cascade, or
O = other. Record the nature of the "other" habitat unit in the comment field.

It is essential that you also tally the *total number of each habitat unit type* in the reach to allow you to expand the substratum estimates.

Habitat Unit Category
You should distinguish habitat units in secondary channels or small habitat units that do not span the main channel from major habitat units in the main channel (Figure 4). Do not neglect secondary channels; they are often important habitats for juvenile fish. Categorize habitat units as (modified from Schuett-Hames et al. 1994):

1 = *primary habitat units*. Primary units are habitat units in the main stream channel which occupy more than 50% of the wetted width.

2 = *secondary habitat units*. Secondary units occur in minor channels that are isolated from the main channel by a vegetated island with perennial plants greater than 1 metre in height. In braided reaches, where many secondary channels occur, record only the habitat units in the dominant channels and note that the channel is braided.

3 = *tertiary habitat units*. Tertiary units are significant, identifiable habitat units within the main stream channel that meet the minimum size criteria (Table 4) but which occupy less than 50% of the wetted width (e.g., they are embedded within a larger habitat unit, or are separated from the primary unit by an obstruction or a gravel bar that lacks perennial vegetation). In a level 1 survey you would normally distinguish only those tertiary units that are *significant as fish habitat* (e.g., deep lateral scour pools); otherwise combine them with the larger adjacent unit that meets the minimum size criterion.

Distance (m)
Determine the location of the *downstream boundary* of the habitat unit from the known survey start point (e.g., the stream mouth or the down-

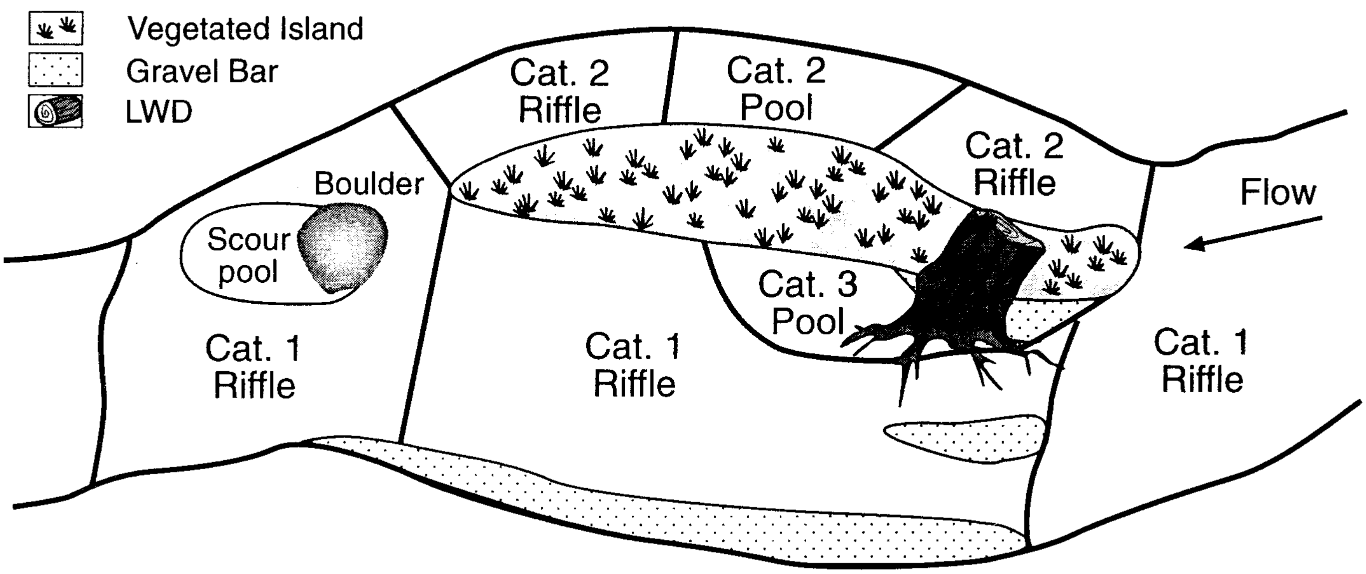


Figure 4. Habitat unit categories (after Schuett-Hames et al. 1994)

stream reach boundary). Measure the distance in metres along the thalweg (the deepest portion of the stream channel), using a calibrated hip chain or surveyor's tape. If you use a hip chain, check that the thread remains out of the stream, and re-establish the start point frequently (by tying off the thread). Be sure also to record the *total length of the reach*.

Length (m)
Measure the length along the thalweg of the habitat unit in metres, using a calibrated surveyor's tape. If the thalweg is not accessible (e.g., because of water depth), take the length measurement at mid-point on the unit's boundary. For sinuous units, take the length as the sum of straight-line lengths along the thalweg.

Your identification of habitat unit boundaries will affect the measured length; be consistent in applying the definitions given above. If the boundary between adjacent habitat types is indistinct, mark the first point in each habitat unit type where you are certain of the type, and establish the boundary half-way between the two points.

Gradient (%)
Use a clinometer or Abney level to measure the gradient (± 0.5%) of the water surface over the habitat unit. Mark the surveyor's rod at the eye level of the measurer. The rod man holds the surveyor's rod vertical at the far

boundary of the habitat unit while the measurer sights the clinometer on this mark to make the gradient measurement.

Mean Water Depth (m)

Determine the mean depth (± 0.05 m) of the habitat unit by averaging 3 depths taken ¼, ½, and ¾ of the distance across a transect perpendicular to the flow at a "representative" site within the habitat unit. Choose this site to portray average conditions within the habitat unit. Although using a "representative" site for depth and width measurements reduces the accuracy of the data, it will identify major habitat problems while greatly speeding the survey. If greater accuracy is required, increase the number of sample points along the transect and/or the number of transects within the habitat unit.

Mean Wetted Width, W_w (m)

Measure the wetted width (± 0.1 m) of the habitat unit as the horizontal distance perpendicular to the channel axis from water's edge on one side to water's edge on the opposite side at the "representative" site used above to determine mean depth. The wetted edge is the point at which sediment particles are no longer surrounded by water. Do not include dry gravel bars in the wetted width. For irregularly-shaped habitat units, determine an average wetted width from 3-5 measurements at equal intervals along the habitat unit. If a tertiary habitat unit is embedded in the primary unit, subtract the width of the embedded unit from the total width to obtain a wetted width for the primary unit.

Mean Bankfull Channel Width, W_b (m)

The FPC "Riparian Management Area Guidebook" defines standards for determining the bankfull channel width of streams. Because W_b is used to adjust for differences in stream size when applying diagnostics, take care to measure it consistently and correctly.

Measure the bankfull channel width (± 0.1 m) at a "representative" site as the horizontal distance perpendicular to the channel axis between the tops of the streambanks on opposite sides of the stream (Figure 5). Identify the top of bank as:

- the elevation of the topographic break from a vertical bank to the floodplain
- the location of changes in vegetation and sediment texture, such as:
    - the presence of undisturbed perennial terrestial vegetation at the bank top, or
    - a change from recently deposited or scoured sediments (clean sands, gravels and cobbles) to undisturbed sediments, frequently with an organic layer (e.g., leaf mould, fine organic litter)

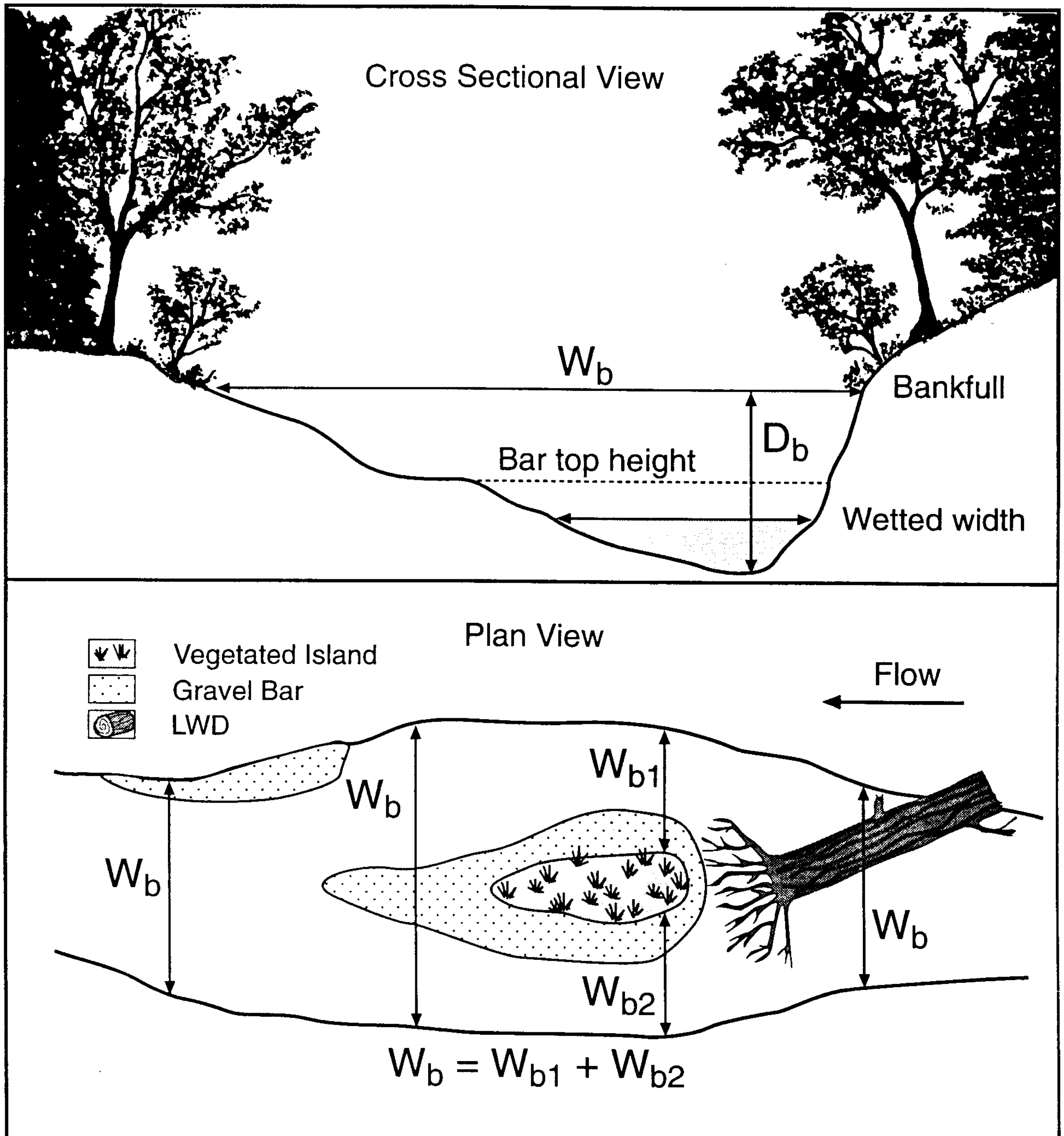


Figure 5. Determining bankfull width, W_b, and bankful depth, D_b

In measuring the bankfull channel width,

- do <u>not</u> include vegetated islands (i.e., islands with perennial terrestial vegetation more than 1 metre in height). If multiple channels are separated by vegetated islands, sum the separate bankfull channel width measurements.

- include unvegetated gravel bars in the bankfull channel width measurement.

Mean Bankfull Depth, D_b (m)
Measure the vertical distance (± 0.05 m) from a horizontal line at the height of the bankfull width to the water surface at the "representative" site at which you measured the bankfull width. For small channels, this can be done by running the surveyors' tape across the channel at the height of the bankfull width and measuring the vertical distance from the tape to the water surface, using the surveyor's rod. The mean bankfull depth is the sum of this distance and the mean water depth. For larger channels, measure the vertical distance from the bank top to the water surface nearest the bank, and add this distance to the mean water depth.

Maximum Pool Depth (m)
For pools, measure (or estimate, if necessary) the maximum water depth (± 0.05 m).

Riffle Crest (Pool Outlet) Depth (m)
For pools, measure the water depth (± 0.05 m) at the pool outlet (see Figure 2).

Residual Depth (m)
Calculate the residual depth (± 0.05 m) of the pool as the difference between the maximum pool depth and the riffle crest depth (or pool outlet depth). Note that pools must meet both minimum surface area and minimum residual depth criteria to be counted.

Pool Type
Record the pool type as:

S = scour pool, formed by scouring around or adjacent to an obstruction such as a log, boulder, or root wad or by flow convergence where two channels join
D = dammed pool, formed by impoundment behind a channel-spanning obstruction such as a beaver dam, log, or log jam
U = unknown (unable to classify).

Dominant and Sub-Dominant Bed Materials
Estimate and record the size-class of the substrate material that covers the largest proportion (dominant) and the second-largest proportion (sub-dominant) of the habitat unit. Categorize substrates as:

S = sands, silts, clays or fine organic material (< 2 mm diameter)
G = gravels (2 - 64 mm)
C = cobbles (64 - 256 mm)
B = boulders (256 - 4000 mm)
R = bedrock (> 4000 mm).

Make the estimate by walking several transects through the habitat unit, where this can be safely done, noting or measuring the length covered by the different particle size-classes. An alternative method is to make subjective estimates of the percentage of the habitat unit covered by each substrate particle size-class. Note, however, that such "quantitative" data are rarely accurate.

Spawning Gravel Amount and Type

Spawning gravels are gravels that are located in areas where water depths greater than 15 cm and water velocities between about 0.3 and 1.0 $m \cdot s^{-1}$ are expected during the spawning season. For anadromous salmon, spawning gravel patches should be 1-2 m^2 in area with a particle size between about 10-150 mm. For (small) resident trout and char, spawning gravel patches should be greater than 0.1 m^2 in area with a particle size between 10-75 mm. Pay particular attention to pool tailouts and riffle crests as potential spawning sites. Record the *presence* of suitable spawning gravels for the target fish species as:

N = no suitable gravel patches in the habitat unit
L = little suitable spawning gravels (e.g., isolated pockets)
H = extensive areas of spawning gravels.

Record the *type* of spawning gravel as:

R = suitable for resident trout and char
A = suitable for anadromous salmon
AR = suitable for both resident trout and anadromous salmon.

Large Woody Debris Tally

Large woody debris (**LWD**) is a piece of dead wood, having a diameter 10 cm or larger over a minimum 2 m length, that intrudes into the bankfull channel. Only a portion of the LWD pieces lying within the bankfull channel (typically less than 40%, Montgomery et al. 1995) are *functional LWD* that influence channel geomorphology by causing scour or impoundment.

The level 1 assessment tallies all LWD within the bankfull channel, because this is how the diagnostic values in Table 5 were derived. Count both LWD that lies (partially) within the low flow and LWD that is partially submerged only at bankfull flow, but do not count LWD on vegetated bar tops above the bankfull channel. Tally debris jams that contain 10 or more LWD pieces as a log jam rather than counting the individual pieces.

We also tally functional LWD by three size classes (10-20 cm diameter, 20-50 cm diameter and > 50 cm diameter) to identify the size of stable LWD in the stream reach. Count as **functional LWD** only those LWD pieces that are the primary cause of the formation or geometry of a pool.

Cover (% by type)
Cover is a structural element in the wetted channel or within 1 metre of the water surface that serves to visually isolate fish and/or to provide suitable microhabitats where fish can hide, rest or feed. Hamilton and Bergersen (1984) discuss the varied meanings associated with "cover".

Estimate the percentage of the total surface area of the habitat unit that is covered by the following *cover types*:

SWD = small woody debris (i.e., smaller than the criteria given above)
LWD = large woody debris, as defined above
B = boulders
C = undercut banks
DP = deep pool (i.e., the portion of a pool with a depth > 1 m)
OV = overhanging vegetation within 1 metre of the water surface
IV = instream vegetation.

Record the percentage of the total surface area of the habitat unit for (up to) the three dominant cover types. Record the amount of cover as:

N = no cover in the habitat unit,
TR = cover element is present but likely comprises less than 2% of the habitat unit area, or
numeric value = the estimated percentage of the total area by cover type.

Off-channel Habitat
Record the presence of off-channel habitat that may be used by fish as refuges or rearing areas at high flows. Pay particular attention to relict channels in the adjacent floodplain which have been isolated by lateral movement of the stream and which could be re-connected to the stream as a restoration project. Note any ground water flows within isolated sidechannels.

Categorize off-channel habitat as:

SC = sidechannels
SL = sloughs (blind-ended channels)
PD = off-channel ponds
WL = seasonally-flooded wetlands

Measure or estimate the length and area of the off-channel habitat unit, and note fish access to the off-channel area as:

N = no access to fish
P = accessible only at high flows
G = accessible at most flows.

Disturbance Indicators

Record the presence of any of the disturbance indicators listed in Table 2. If a channel assessment is being done, then categorize disturbances with the assistance of the geomorphologist wherever possible. If you note eroding banks, comment on the cause, extent, and the likelihood of successful stabilization.

Barriers

Record natural or man-made barriers to fish movement as:

N = no barriers
X = log jams that prevent fish passage
CV = culverts (blocked, perched, velocity barrier)
BR = dis-used bridges (obstruction, velocity barrier)
LS = landslide or bank sloughing that obstructs the channel
BD = beaver dam
F = falls with a vertical drop > 2 m
C = chute or cascade impassable to fish (velocity barrier).

Note that most log jams are readily passable by fish unless a vertical drop is created by bedload and debris storage.

Riparian Vegetation Type

Record the dominant *vegetation type* in the riparian area within 20 m of the stream channel as:

N = largely unvegetated, with much bare mineral soil visible
G = grasslands or bog
SH = shrub/herb, dominated by herbaceous or shrubby vegetation
D = deciduous forest
C = coniferous forest
M = mixed deciduous-coniferous forest.

If a riparian assessment is being done, coordinate your collection of vegetation type and stand structure data with the riparian surveys.

Riparian Structural Stage

Record the *structural stage* of the dominant vegetation in the adjacent riparian area as:

INIT = the non-vegetated or initial colonization stage following disturbance, with less than 5% cover
SHR = shrub/herb stage with less than 10% tree cover
PS = pole-sapling stage, with trees overtopping the shrub layer, usually less than 15-20 years old
YF = young forest. Self-thinning is evident and the forest canopy is differentiating into distinct layers. Stand age is typically 30-80 years.
MF = mature forest with well-developed understory.

Overstream Canopy Closure
Categorize the extent of canopy closure over the stream (i.e., the proportion of the surface area of the stream that is covered by the projecting riparian canopy) as:

0 = none
1 = 1-20% covered
2 = 21-40% covered
3 = 41-70% covered
4 = 71-90% covered
5 = > 90% covered.

Fish Distribution and Relative Abundance
Conduct a low-intensity survey of fish distribution and relative abundance within habitat types to help identify heavily-used habitats that may limit fish production. For a level 1 assessment, we are primarily interested in confirming fish use rather than in obtaining accurate estimates of fish abundance. Therefore we recommend low-intensity, qualitative surveys, although you may use any of the sampling methods discussed in the MoELP “Lake and stream inventory standards and procedures” manual (Anonymous 1995) or the FPC “Fish-stream Identification Guidebook”.

We suggest that you use baited minnow traps (Gee traps) because of their simplicity of use and effectiveness in a wide range of habitat types. They are, however, ineffective for large fish (>20 cm fork length). Swales (1987) discusses their use in different habitat types. Minnow traps are especially useful in spatially-complex habitats (debris jams, offchannel ponds) where other survey methods are largely ineffective.

Standardized electrofishing is an alternative method, but is more complex, much more time-consuming and more dangerous. Snorkelling is an effective survey method in moderate-to-large streams (Slaney and Martin 1987). Refer to Anonymous (1995) for descriptions of other acceptable methods (e.g., shore-based visual estimates, seines, standardized angling, etc.).

Stratify the fish sampling by habitat type. Subsampling habitats may be necessary to keep survey costs reasonable. At the time that the physical habitat sampling is done, clearly mark the habitat units that are to be sampled for fish. Set baited minnow traps at a standard density (say 2 traps per 10 m stream length) for a standard time interval (at least 6h, and ideally 24h). Anchor the traps to shore with a stout line and mark their locations with labelled flagging tape. On retrieval, identify and enumerate the fish. Use McPhail and Carveth (1993) as the standard guide to fish identification, and ensure that the crew can accurately identify the species that are likely to be present. Enumerate fry, parr and smolts separately by species. Record the information on the “Level 1 fish distribution summary form” (Appendix F).

Use large differences in catch per unit effort to identify habitat types that are heavily-used by the target species and life stage, and to delimit fish distributions within the sampled reaches.

Photographs
Take 35 mm photographs of significant habitat features such as LWD characteristics, eroding banks, sediment texture, extensive riffle areas, cover, etc. within the survey reach. Label the picture with its exact location, direction of view (upstream or downstream; left bank or right bank), date and time, and the significant feature that is being noted. Provide a measure of scale in the photograph (e.g., include the surveyor's rod in the picture). Habitat features that are difficult to quantify may be more easily interpreted from a photograph.

Inorganic Nutrients
In areas where nutrient concentrations may limit stream productivity, determine nitrate-nitrogen (NO_3^-N) and soluble reactive phosphorus (SRP) concentrations for the stream at the start of the summer growing season (post-freshet) by collecting a water sample from a riffle area in an alluvial reach near the stream mouth. Follow standard methods of collection (MoELP "Lake and stream inventory standards and procedures" manual, Anonymous 1995) and analysis (APHA 1980).

Data Summary

You must summarize your survey data by reach to provide the reach totals and reach averages for the quantitative variables whose values are used to diagnose habitat impairment (e.g., Table 5). The computations needed to summarize your survey data depend upon the survey design and the measurement methods used to obtain the data. Consult standard texts on survey sampling (e.g., Scheaffer et al. 1979) for detailed information on computations.

In all cases your data will be stratified by habitat unit type (pools, glides, riffles, cascades, other). If you used an accurate measurement method to obtain the data and the strata were sampled independently, then you begin by calculating the mean and variance of the variable for each stratum. You then obtain reach averages and reach totals for the variable as the weighted average of the stratum means or totals:

$$\overline{Y}_{\text{reach mean}} = \frac{1}{N} \sum_{i=1}^{5} N_i \cdot \overline{Y}_i$$

and

$$Y_{\text{reach total}} = \sum_{i=1}^{5} N_i \cdot \overline{Y}_i$$

where:

$\overline{Y}_i$ is the mean value for the i-th stratum (e.g., pools), i = 1,...,5
N is the total number habitat units in the reach, and
N_i is the total number of habitat units in the i-th stratum.

If the variable is estimated with error (e.g., rapid visual estimation calibrated to accurate measurements) rather than being measured with essentially no error and you have used “a two-stage sampling design with equal probability of selection of unequal sized primary sampling units” (Hankin and Reeves 1988, p. 836), then you can determine stratum totals using adjusted estimates, as discussed above:

$$\hat{y} = \hat{R} \cdot x_i$$

where $\hat{y}_i$ is the adjusted i-th estimate, x_i is the corresponding rapid estimate, and $\hat{R}$ is the calibration ratio for the variable. The stratum total is then:

$$\hat{Y}_{stratum} = \frac{N_i}{n_i} \sum_{i=1}^{n} \hat{y}_i$$

where n_i is the number of habitat units in which rapid estimates were made and N_i is the total number of habitat units in the stratum ($n \approx N_i / k$ for a 1 in k subsample). If accurate measurements and visual estimates were taken on M units in the stratum to develop the calibration ratio, then use the accurate measurements rather than the adjusted visual estimates for those M units of the n when estimating the stratum total. Because these strata totals are independent (strata were independently sampled), you obtain the reach total by adding the strata totals. See Dolloff et al. (1993) for a clear example of the use of two-stage sampling to determine fish abundance and habitat type areas.

Some of the diagnostics in Table 5 are counts per bankfull channel width. To calculate these, first determine the number of bankfull channel widths in the reach by dividing the total reach length by the mean bankfull channel width. Then obtain, say, the number of large LWD pieces per bankfull channel width, by dividing the total number of large LWD pieces in the reach by the number of mean bankfull channel widths in the reach,

LWD per W_b = LWD tally / (reach length / W_b).

Summarize this habitat information as a georeferenced database or as a summary table indexed to locations.

Habitat Evaluation

Identify potential physical habitat limitations to salmonid production by comparing the amounts and characteristics of physical habitats against standards for similar, undisturbed streams to detect habitats that are degraded or at risk, and which may be improved by fish habitat restoration projects. Pay special attention to habitats that are (or were) heavily used by salmonids, and to habitats whose availability is limited.

There are several ways **to identify degraded areas** from the overview and level 1 habitat assessment data:

1. compare pre- and post-logging habitat conditions within specific reaches, to identify deleterious changes.

2. compare present habitat conditions within reaches against "standards" for similar, undisturbed reaches to detect differences that suggest habitat impairment. The standards can be:

    (i) average habitat conditions in similar, undisturbed reaches within the watershed of interest,
    (ii) average habitat conditions within similar reaches in similar, undisturbed watersheds in the ecoregion, or
    (iii) expected habitat conditions from published summaries of habitat use by the target species.

3. observe indicators of habitat damage within the reach.

A direct demonstration of (harmful) habitat changes by comparing pre- and post-logging conditions within the same stream reach is the most convincing indication of habitat impairment. You will need pre-logging habitat data, either from field surveys or from the analysis of aerial photographs, to establish that changes have occurred. To interpret the observed changes as deleterious, consider the known habitat needs and preferences of the target species. You should also consider the likely role of natural disturbance in causing the observed changes.

In many cases pre-logging data are unavailable, and you will infer damage by comparing present habitat conditions against expected conditions. If similar, undisturbed channel types can be found within the watershed, determine the average conditions in the undisturbed reaches and use deviations from these average conditions to indicate habitat change in logged reaches. If you cannot obtain data for similar unperturbed reaches in the watershed, use average habitat conditions for the same channel types in similar watersheds in the ecoregion where these data exist or can be easily obtained from other inventory or pre-harvest planning programs. Consult WRP staff regarding the availability and use of regional standards. Lastly, use "generic" descriptors of habitat quality (Table 5) to identify damaged or poor habitat conditions if more precise measures are not available.

Table 5. Diagnostics of salmonid habitat condition at the reach level (from Anonymous 1993); see notes below.

Habitat Parameter	Gradient or W_b Class	Use	Quality		
			Poor	**Fair**	**Good**
Percent pool (by area)	<2 %, < 15 m wide	Summer/winter rearing habitat	< 40 %	40 - 55%	> 55 %
Percent pool (by area)	2-5 % , < 15 m wide	Summer/winter rearing habitat	< 30 %	30 - 40 %	> 40 %
Percent pool (by area)	>5 % , < 15 m wide	Summer/winter rearing habitat	< 20 %	20 - 30 %	> 30 %
Pool frequency (mean pool spacing)	<2 %, < 15 m wide	Summer/winter rearing habitat	> 4 channel widths per pool	2 - 4 channel widths per pool	< 2 channel widths per pool
Pool frequency (mean pool spacing)	2-5 % , < 15 m wide	Summer/winter rearing habitat	> 4 channel widths per pool	2 - 4 channel widths per pool	< 2 channel widths per pool
Pool frequency (mean pool spacing)	>5 % , < 15 m wide	Summer/winter rearing habitat	> 4 channel widths per pool	2 - 4 channel widths per pool	< 2 channel widths per pool
LWD pieces per bankfull channel width	all	Summer/winter rearing habitat	< 1	1 - 2	> 2
% wood cover in pools	< 5 %, < 15 m wide	Summer/winter rearing habitat	most pools in low category 0 - 5 %	most pools in moderate category 6 - 20 %	most pools in high category > 20 %
Boulder cover in gravel-cobble riffles	all	Summer/winter rearing habitat	< 10 %	10 - 30 %	> 30 %
Overhead cover	all	Summer/winter rearing habitat	< 10 %	10 - 20 %	> 20 %
Substrate	all	Winter rearing habitat	interstices filled: sand or small gravel subdominant in cobble or boulder dominant	interstices reduced: sand subdominant in some units with cobble or boulder dominant	interstices clear: sand or small gravel rarely subdominant in any habitat unit

Table 5. (continued). Diagnostics of salmonid habitat condition (from Anonymous 1993).

Habitat Parameter	Gradient or W_b Class	Use	Quality: Poor	Quality: Fair	Quality: Good
Off-channel habitat	< 3 % , all widths	Winter rearing habitat	few or no backwaters, no off-channel ponds	some backwaters	backwaters with cover and pond, oxbows and other low energy off-channel areas
Holding pools	all	Adult migration	few pools/km > 1 m deep with good cover, cool		adequate pools/km, > 1 m deep with good cover, cool
Access to spawning areas	all	Adult migration	access blocked by low water, culvert, falls, temperature		no blockages
Gravel quantity	all	Spawning and incubation	absent or little		Frequent spawning areas
Gravel quality	all	Spawning and incubation	sand is dominant substrate at some sites	sand is subdominant substrate at some sites	sand is never dominant or subdominant substrate
Redd scour	all	Spawning and incubation	evidence of extensive redd scour	some scour or potential for scour	stable with low potential for scour
Inorganic nutrients	all	Summer rearing habitat	spawner numbers depressed and NO_3-N < 20 $\mu g \cdot L^{-1}$ and / or SRP < 1 $\mu g \cdot L^{-1}$	spawner numbers normal; NO_3-N from 20-40 $\mu g \cdot L^{-1}$ and SRP from 1-2 $\mu g \cdot L^{-1}$	NO_3-N > 60 $\mu g \cdot L^{-1}$ and SRP >3 $\mu g \cdot L^{-1}$

Notes:

1. Use this table when regional standards are not available.
2. We currently lack standards for channels with W_b > 15 m. Be cautious in the application of the above diagnostics to such channels.

If you use differences between observed and expected conditions to infer habitat change in a disturbed reach, ensure that you are, in fact, comparing similar channel types. The undisturbed reaches used to establish expected conditions must match the disturbed reach with respect to channel type, gradient, confinement, discharge, and natural vegetation in order to attribute observed differences to the disturbance.

The principal aim of your habitat evaluation is to identify habitat conditions in the surveyed reaches that may limit salmonid fish production and to suggest restoration projects to rectify these limitations. Use the new field data to review the results from your preliminary (i.e., overview) habitat evaluation. Apply additional diagnoses (e.g., Table 5) to better indicate habitat impairment where the new field data permit this to be done. Apply the methods discussed above for the preliminary habitat evaluation to the new survey data.

Sequentially consider whether the habitat requirements of the various life stages of the target fishes are met by current conditions within the watershed. Use the major questions from Appendix E to help identify potential limitations. Where limitations are evident, note the locations, extent and severity of the habitat conditions that indicate the limitations. Be as specific as possible about the impacts and probable causes of habitat impairment.

Pay special attention to associations between fish abundance and particular habitat conditions which might suggest the functional processes through which the limitation occurs. Use your knowledge of the life history and habitat requirements of the target species to guide your interpretation of habitat conditions. Continually ask yourself whether the observed conditions are likely to be a significant limitation to fish production in the watershed. Comparisons between your data and conditions in analogous reaches in similar, unimpacted watersheds are especially informative in assessing the severity of observed impacts.

Try to identify the underlying physical or biological process that causes the observed limitation. Will you be able to restore the process to its pre-logging condition? Be aware that some logging-induced changes to the physical processes that influence ambient factors in the stream may continue to degrade habitat conditions for long periods into the future. Consider what in-stream restoration work will reduce the impacts of the process on fish until the process has been returned to normal.

Using both the overview and level 1 field data, **summarize indicators of fish habitat impairment for each reach**. Use the georeferenced information on fish distribution, fish use, and habitat quality to identify the reaches with major habitat impacts that are also heavily used by the target fish species as spawning, rearing or overwintering sites. Attach a brief text summary to each reach, identifying fisheries values and probable habitat impacts within the reach.

Review this habitat condition data to identify opportunities for effective rehabilitation projects; consult WRP Technical Circular No. 9 for detailed information on rehabilitation methods. You should also examine the results of the channel assessment procedure for indications of altered geomorphic processes that might influence fish habitat conditions and/or your choice of restoration methods. Also review the upslope impact indicators from the overview assessment of the reach.

Initial Planning for Fish Habitat Restoration Projects

It is essential that you state clearly the objectives and scope of proposed fish habitat restoration projects and that these objectives address the probable limitations to fish production that the field assessments have suggested. Develop your fish habitat restoration projects as an integrated set that treats the major habitat limitations to fish production that arise from the assessment.

A statement of **project objectives** should identify:

- the concerns that initiated the project
- the specific goals of the project, and
- its relationship to the overall goals of the restoration plan for the entire watershed.

Project scope includes:

- the topics and activities to be considered (or excluded) in the project
- the spatial bounds of the project
- the time frame for the project, and
- its links to other program components.

For example, you may observe a lack of functional LWD and associated scour pools with complex cover in low gradient reaches that are used by coho juveniles as summer rearing habitat. The low abundance of coho in a watershed with adequate adult escapements and spawning areas and with large amounts of off-channel winter rearing habitat suggests that summer habitat is a potential limitation to coho production in the watershed. The physical process that generates the preferred summer habitat of juvenile coho is scour around stable LWD to produce pool habitat with both overhead and instream cover. Technical Circular No. 9 identifies LWD placements as an effective restoration method in channels where increased sediment storage is not occurring. The channel assessment procedure did not reveal channel aggradation or other disturbance indicators associated with increased sediment inputs. Comparison of observed LWD abundance (0.2 pieces per bankfull channel width) with those in similar channels in nearby, unlogged watersheds (2.2 pieces per channel width) suggests that about an additional 100 pieces would be needed in the 750 m reach whose bankfull width is 15 m. Natural LWD occurs primarily as evenly-spaced single pieces greater than 30 cm diameter in similar unlogged reaches. Thus, a possible restoration objective might “to increase the abundance of small pools with complex cover to produce summer rearing habitat for coho fry by constructing 100 log placements with logs > 30 cm in diameter and with the placements distributed evenly over the 750 m reach”.

Where several rehabilitation projects are possible, employ the criteria discussed in the preliminary habitat assessment to prioritize them. Refer to WRP Technical Circular No. 1 (Guidelines for Planning Watershed Restoration Projects) for additional information on establishing priorities.

Reporting

The level 1 fish habitat assessment report should provide the outlines of an integrated fish habitat restoration plan for the watershed. It should verify the nature, locations and severity of impacts to fishery resources; recommend restoration strategies; identify project objectives and project scope; and give initial priorities for restoration work. The focus of the report is not only to identify the type and locations of impacts but also to provide an accurate evaluation of the opportunities for habitat restoration activities.

The text of the report should describe the methods used in the field assessments, the areas examined, and the results of the assessments. Map overlays are particularly useful in identifying areas of the watershed where impacts are evident. The level 1 report should suggest restoration strategies and should provide a classification of impacts as low, medium or high priorities for restoration (using the criteria of WRP Technical Circular No. 1). Tabulate significant problems, identify project objectives and preferred restoration strategies, and provide work sequence priorities by area (e.g., by sub-basin). Try to provide preliminary estimates of time and costs, based on the restoration strategies and priorities that you have identified. Make specific recommendations for necessary level 2 assessments. Provide the data (field notes, data forms, maps) and analyses to support your interpretations as appendices to the report.

The level 1 assessment report develops initial statements of project scope and objectives for the components of the integrated watershed-level restoration plan. The major elements of the plan and likely approaches to restoration derive from the level 1 assessment results. In some cases, level 2 assessment results will be needed to flesh out the initial plan into specific prescriptions and implementation schedules, but the level 1 assessments define the problem. In some cases, a level 1 assessment may provide sufficient information to proceed with restoration prescriptions.

Level 2 Field Assessment

Aims of the Level 2 Assessment

You will conduct level 2 field assessments where you require additional site-specific information to diagnose the nature of the habitat impairment, to identify or plan effective restoration or mitigation prescriptions, or to confirm or revise the initial statements of project scope, objectives and priorities.

The objectives of level 2 assessments are:

- *to identify appropriate restoration options and priorities, and*
- *to provide detailed site information needed to prepare rehabilitation prescriptions*.

Scope of the Level 2 Assessment

Level 2 field assessments are (usually) limited in scope to specific sites that the level 1 assessment has identified as potentially impaired and where you require additional information to identify or to plan appropriate rehabilitation activities. A level 2 assessment consists normally of detailed measurements or inspections at particular sites to provide the specific information needed to develop appropriate habitat rehabilitation plans. Any surveys that are required as part of level 2 assessments should provide precise, quantitative data to address specific uncertainties in the design of the fish habitat rehabilitation program. For example, you may need an accurate estimate of the size of a remnant fish population to assess the likely benefits of a costly habitat rehabilitation program; a basin-wide survey of fish abundance might then be appropriate. Or, for example, you may need to survey a detailed channel profile to design a groundwater-channel rearing project. Use the results of the level 2 assessment to clarify the objectives and scope of restoration activities at specific locations, and to provide necessary detailed site information.

Assessment Methods

You will usually design a level 2 assessment to provide the specific information needed to select, plan and implement a habitat rehabilitation project that a level 1 assessment has suggested. The exact nature of the assessment depends upon your information needs. Consult WRP Technical Circular No. 9, which specifies the information requirements of common rehabilitation techniques. Manuals such as Newbury and Gaboury (1993) also describe in detail the information needed to plan certain types of restoration projects.

In general, you will require more precise, site-specific information on stream channel morphology and fish use than that provided by the level 1 assessment. Detailed plans of rehabilitation sites or analogous undisturbed reference sites will be a common requirement; refer to Newbury and Gaboury (1993) for sketch plan and plane table survey methods. Use the quantitative methods specified in the MoELP "Lake and stream inventory standards and procedures" manual to acquire any additional information. We recommend Hankin and Reeves' (1988) two-stage sampling design for quantitative estimates of fish abundance, where these are needed for restoration planning (note that other management needs for detailed fish abundance or habitat condition information should be addressed through the FRBC fisheries inventory program). Dolloff et al. (1993) give a clear description and a worked example of the method. Note that you can substitute other rapid quantitative estimation methods for the visual estimates used by Hankin and Reeves. Have your regional WRP Fisheries Specialist review and approve the methods that you propose to use in a level 2 assessment before embarking on the work.

To increase the utility of level 2 field assessments, you should review initial statements of project objectives and scope from the level 1 assessment to **direct the level 2 field assessments to high priority sites**. Ensure that those doing the assessments have the training, experience and a sufficient understanding of the project scope and objectives to accurately document and correctly interpret present conditions and to recommend suitable prescriptions for restoration.

Restoration Prescriptions

The prescriptive phase of project planning involves identifying and evaluating habitat problems, and determining a "best" course of action to address them. Use the results of the level 2 assessments to clarify the objectives and scope of restoration activities at specific locations. The recommended prescriptions must be consistent with the higher level objectives of the integrated watershed restoration plan and with regional management plans for the area. Make sure that your prescriptions conform to current standards for the activities (e.g., with Forest Practices Code regulations).

The set of proven, effective methods for fish habitat rehabilitation is limited. Typical prescriptions will entail one or more of:

- restoring fish access and spawning sites
- streambank rehabilitation
- off-channel habitat rehabilitation
- restoration of LWD
- accelerating the recovery of log jam habitat
- boulder clusters to restore rearing habitat
- deflectors and weirs to rehabilitate mainstem rearing habitat

- re-constructing channelized habitat
- inorganic nutrient additions to restore productivity, or
- minimum flow augmentation.

You should discuss novel restoration methods with district WRP staff and with appropriate regional WRP technical experts before prescribing them.

Establishing suitable restoration prescriptions involves both formal analyses and professional judgement, and is often best done on-site. Try to write clear and detailed prescriptions that can be used as technical specifications for the on-site work. Clear, detailed prescriptions also facilitate accurate budget estimates. Photographs, sketches and drawings are useful aids to formulating clear prescriptions. Try to avoid costly engineering drawings unless they are essential.

Describe the purpose of any proposed restoration and the specific concerns to be dealt with at each site. Using Technical Circular No. 9, identify effective restoration prescriptions to attain the desired site objectives. Where several corrective actions are possible, provide a rationale for the recommended prescription. Predict the likely resource benefits of the work, using published biostandards (Adams and Whyte 1990; also see WRP Technical Circular No. 9) and identify any constraints that may influence the effectiveness of the work.

Refer to Technical Circular No. 9 (Fish Habitat Rehabilitation Procedures) for appropriate formats to prepare and present restoration prescriptions. Summarize the necessary restoration work on a site-by-site basis in a concise overview table that indicates:

- the exact location of the site
- the boundaries of the work site
- the nature of the problem
- the precise objectives of the work
- the recommended prescription(s)
- the work sequence priority of the site works
- special concerns (safety, environmental protection, timing)
- labour and materials requirements
- estimated costs
- the expected benefits of the work

It is important to locate work sites accurately. If possible, use Global Positioning Systems to obtain UTM coordinates for the site. Record the distance to the site from some well defined location (e.g., along a road) and accurately indicate the site on large scale maps (e.g., 1:5,000 or 1:20,000 as appropriate). You may want to lay out the work site with flagging tape, painted marks, or boundary stakes at the same time that you develop the prescription. Having an accurate location will be important for postimplementation monitoring when the problem that initiated the restoration work may no longer be visible to mark the site.

Acknowledgements

We thank Bob Bocking, Tony Cheong, Marc Gaboury, Doug Johnston, Wendell Koning, Ross Neuman, Gerry Oliver, Daiva Zaldokas and the participants in the FHAP training workshops for suggesting changes to the assessment procedure. We are grateful to the authors of the "Fish Habitat" module of the Washington State watershed assessment procedure for providing the basic form of the analysis. The overview assessment procedure was adapted from that developed by LGL Ltd. Comments by Blair Holtby, Gerry Oliver and Craig Wightman improved the original interim procedure.

References

Adams, M.A. and I.W. Whyte. 1990. Fish habitat enhancement: a manual for freshwater, estuarine, and marine habitats. Canada Department of Fisheries and Oceans, Vancouver.

American Public Health Association. 1980. Standard methods for the examination of water and wastewater. 15th edition. American Public Health Association, Washington.

Anonymous. 1980. Stream enhancement guide. British Columbia Ministry of Environment and Canada Department of Fisheries and Oceans, Vancouver.

Anonymous. 1985. Gazetteer of Canada. Canadian Permanent Committee on Geographical Names. Canada Department of Energy, Mines and Resources, Ottawa.

Anonymous. 1988. A guide to the hierarchical watershed coding system for British Columbia. BC Ministry of Environment, Water Management Branch, Victoria.

Anonymous. 1993. Fish habitat. pp. F1-F36. *In* Standard methodology for conducting watershed analysis. Version 2.0. Washington Forest Practices Board, Washington State Department of Natural Resources, Olympia

Anonymous. 1995. Lake and stream inventory standards and procedures, BC Ministry of Environment, Lands and Parks, Fisheries Branch, Victoria.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. pp. 83-138. *In* W.R. Meehan [ed.] Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, Bethesda, Maryland.

Dolloff, C.A., D.G. Hankin and G.H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. United States Department of Agriculture, Forest Service, General Technical Report SE-83, Asheville, North Carolina.

Fausch, K.D., C.L. Hawkes, and M.G. Parsons. 1988. Models that predict standing crop of stream fish from habitat variables: 1950-1985. United States Department of Agriculture, Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-213, Portland, Oregon.

Groot, C. and L. Margolis. 1991. Pacific salmon life histories. UBC Press, Vancouver.

Hamilton, K. and E.P. Bergersen. 1984. Methods to estimate aquatic habitat variables. Colorado Cooperative Fishery Research Unit, Colorado State University, Fort Collins, Colorado.

Hankin, D.G. and G.H. Reeves. 1988. Estimating total fish abundance and habitat area in small streams based visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences 45: 834-844.

Hartman, G.F. and J.C. Scrivener. 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Canadian Bulletin of Fisheries and Aquatic Sciences 223, Ottawa, Ontario.

Hawkins, C.P., J.L. Kershner, P.A. Bisson, M.D. Bryant, L.M. Decker, S.V. Gregory, D.A. McCullough, C.K. Overton, G.H. Reeves, R.J. Steedman, and M.K. Young. 1993. A hierarchical approach to classifying stream habitat features. Fisheries 18: 3-12.

Hogan, D.L. and S.A. Bird. 1995. Channel assessment procedure. British Columbia Ministry of Environment, Lands and Parks and British Columbia Ministry of Forests, Watershed Restoration Program, Technical Circular No. 7, Victoria.

Koski, K.V. 1992. Restoring stream habitats affected by logging activities. pp. 343-403 *In* G.W. Thayer [ed.] Restoring the nation's marine environment. Maryland Sea Grant College, University of Maryland, College Park.

Lillesand, T.M. and R.W. Kiefer. 1994. Remote sensing and image interpretation. third edition. John Wiley and Sons, New York.

LGL Limited. 1995. Deena Creek watershed rehabilitation. Council of the Haida Nation, Skidegate, Haida Gwaii.

McPhail, J.D. and Carveth, R. 1993. Field key to the freshwater fishes of British Columbia. Department of Zoology, University of British Columbia, Vancouver.

Meehan, W.R. 1991. [ed.] Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, Bethesda, Maryland.

Montgomery, D.R., J.M. Buffington, R.D. Smith, K.M. Schmidt, and G. Pess. 1995. Pool spacing in forested streams. Water Resources Research 31: 1097-1105.

Newbury, R.W. and M.N. Gaboury. 1993. Stream analysis and fish habitat design. Manitoba Department of Natural Resources, Winnipeg.

Reeves, G.H., F.H. Everest, and T.E. Nickelson. 1989. Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. United States Department of Agriculture, Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-245, Portland, Oregon.

Scheaffer, R.L., W. Mendenhall and L. Ott. 1979. Elementary survey sampling. Duxbury Press, Boston, Massachusetts.

Schuett-Hames, D., A. Pleuss, L. Bullchild, and S. Hall. 1994. Ambient monitoring program manual, Timber-Fish-Wildlife, Northwest Indian Fisheries Commission, Olympia, Washington.

Scrivener, J.C. and T.G. Brown. 1993. Impacts and complexity of forest practices on streams and their salmonid fishes in British Columbia. *In* G. Shooner and S. Asselin [eds.] Le développement du Saumon atlantique au Québec: connaître les règles du jeu pour réussir. Colloque international de la Fédération québecoise pour le saumon atlantique, Québec, décembre 1992. Collection *Salmo salar* n^{o} 1: 201 pp.

Slaney, P.A. and A.D. Martin. 1987. Accuracy of underwater census of trout populations in a large stream in British Columbia. North American Journal of Fisheries Management 7: 117-122.

Slaney, P.A. 1995. The Watershed Restoration Program of British Columbia: an opportunity and a challenge. pp. 117-133 *In* W.T. Dushenko, H.E. Poll and K. Johnston [eds.] Environmental Impact Assessment and Remediation: Towards 2000. Canadian Society of Environmental Biologists, Toronto.

Slaney, P.A. [ed.] 1996. Fish habitat rehabilitation procedures. British Columbia Ministry of Environment, Lands and Parks and British Columbia Ministry of Forests, Watershed Restoration Program, Technical Circular No. 9 (available April 1996).

Swales, S. 1987. The use of small wire-mesh traps in sampling juvenile salmonids. Aquaculture and Fisheries Management 18: 187-195.

Appendix A. WRP Technical Circulars.

This series of circulars provides a standard set of techniques to assess opportunities for restoration activities and to plan appropriate restoration prescriptions. The first two circulars provide: (1) an overview of the planning process, and (2) an assessment process for determining the cumulative effects of forest harvest on forest resources in the watershed. The remaining circulars describe procedures for assessing specific watershed components in more detail, and specify activities and standards to assist the rehabilitation of watersheds.

The titles in the series are:

1. Guidelines for Planning Watershed Restoration Projects
2. Watershed Assessment Procedure (Interim Methods) *out of print*
3. Forest Road Rehabilitation Handbook (Interim Methods)
4. Forest Site Rehabilitation for Coastal British Columbia (Interim Methods) *out of print*
5. Gully Assessment Procedure for British Columbia Forests (Interim Methods) *out of print*
6. Riparian Assessment Procedures (Interim Methods)
7. Channel Assessment Procedure (Interim Methods)
8. Fish Habitat Assessment Procedure
9. Fish Habitat Rehabilitation Procedures *available May 1996*

Many WRP (interim) assessment procedures overlap with procedures that will be required as part of the new Forest Practices Code (FPC). When the Forest Practice Code guidebooks are published, beginning in 1995, they will supersede WRP circulars. In particular, WRP Technical Circular No. 2 - Watershed Assessment Procedure (Interim Methods) has been replaced by two FPC guidebooks:

Coastal Watershed Assessment Procedure Guidebook
Interior Watershed Assessment Procedure Guidebook

and WRP Technical Circular No. 5 - Gully Assessment Procedure (Interim Methods) has been replaced by the FPC guidebook:

Gully Assessment Procedure Guidebook.

In planning restoration activities, it is important to recognize the linkages among the various physical and biological subcomponents of watersheds and to integrate activities to ensure their successful implementation. Although the circulars treat particular aspects of watershed restoration separately, you should use them together to develop an integrated program that considers activities for the entire watershed.

Copies of the WRP Technical Circulars are available from the WRP coordinators in your regional MoELP and MoF offices, or from:

Forest Renewal Coordination Office
Ministry of Environment, Lands and Parks
Suite 300, 1005 Broad Street
Victoria, B.C., V8W 2A1.

Appendix B. Definitions

There are several frequently-used terms in this manual whose meaning needs definition:

condition assessment - an objective procedure to characterize the present state of a natural resource in a watershed and to diagnose resource impairment that can be remedied by restoration activities.

fisheries sensitive zones - side and back channels, ponds, swamps, seasonally flooded depressions, lake littoral zones and estuaries that are seasonally occupied by over-wintering anadromous fishes (refer to the Forest Practices Code)

floodplain - the low-lying, topographically flat area adjacent to a stream channel which is regularly flooded by stream water on a periodic basis and which shows evidence of the action of flowing water, such as active or inactive flood channels, recent fluvial soils, rafted debris, or tree scarring.

forest resources - the new Forest Practices Code of British Columbia Act defines forest resources as “resources and values associated with forests and range including, without limitation, timber, water, wildlife, fisheries, recreation, botanical forest products, forage, and biological diversity”.

gully - a long, linear depression incised into steep hillslopes, where the overall gradient is at least 25%, with a channel confined in a V-notch ravine with banks higher than 3 m, sideslopes steeper than 40 percent and an overall length greater than 100 metres.

mass wasting - landslide processes, including debris falls, debris slides, debris avalanches, debris flows, debris torrents, rockfalls, rockslides, slumps and earthflows, and the small scale slumping, collapse and ravelling of road cuts and fills.

mitigation - activities undertaken to compensate for the impairment of natural resources where restoration or rehabilitation is not feasible. Mitigation may not replace like-with-like and need not occur in the damaged watershed.

rehabilitation - returning to a state of health and useful activity. In this manual, rehabilitation means producing conditions more favourable to particular groups of organisms, especially the economically-valuable or aesthetically-desired components of the native flora and fauna, without necessarily returning the system to its undisturbed condition.

restoration - bringing back to a former or original condition (e.g., the pre-logging state). In this manual the term “restoration” is meant to include rehabilitation.

riparian area - the land adjacent to the normal high water line in a stream or lake whose soils and vegetation are influenced by the presence of the ponded or channelized water. Riparian management areas are administratively-defined strips of land adjacent to certain stream channels; consult the Forest Practices Code and regulations for their definition.

stakeholders - local groups that have a legitimate interest in the management of a watershed and its forest resources, especially those groups with a legally-recognized interest.

stream - a watercourse formed when water flows between continuous, definable banks. The flow in the channel may be perennial or intermittent.

stream order - stream order is a scale-dependent property of drainage networks that describes the position and approximate size of a stream segment in the network. First order streams are headwater streams that have no tributaries. A second order stream is formed where two first order streams join, a third order stream is formed where two second order streams join, etc. Note that the confluence of a second order stream with a first order stream remains a second order stream.

stream reach - a homogeneous segment of a drainage network, characterized by uniform channel pattern, gradient, substrate, and channel confinement.

watershed - an area of land (the catchment or drainage basin), bounded peripherally by a topographic height of land, that delivers water along a stream channel to a common outlet. Watersheds are the natural landscape units from which hierarchical drainage networks are formed.

Appendix C. Sources of Overview Information

You can obtain NTS (1:50,000) and BCGS (1:20,000) topographic maps and digital format TRIM maps (1:20,000) from:

> Maps BC
> Map and Airphoto Sales
> 3rd floor, 1802 Douglas Street
> Victoria, B.C., V8V 1X4

Note that TRIM digital maps are georeferenced to North American Datum 1983 UTM standards (NAD83) whereas many NTS maps are referenced to NAD27.

You can obtain an index of soil maps from Maps BC, at the above address.

You may be able to obtain terrain stability maps, forest cover maps, and access management plan maps from the district MoF office or from the forest tenure holder (licensee).

Maps BC may have historic and current aerial photographs of the watershed. Some forest tenure holders may have additional aerial photographs. Note that flight lines are usually not arranged by watershed; consult Maps BC about how to identify the photo series that you need to cover the watershed.

You can access information on fish distribution, species composition, and fish habitat characteristics from the Stream Information Summary System (SISS) through your regional BC Fisheries Branch office or through:

> Inventory and Data Systems Section
> BC Fisheries Branch
> Ministry of Environment, Lands and Parks
> 1106 Cook Street, 3rd floor
> Victoria, B.C., V8V 1X4.

Available FISS maps can be purchased from:

> Archetype Print
> #335 - 375 Water Street
> Vancouver, B.C., V6B 5C6
> phone (604) 602-0282.

Appendix D. Standard Fish Species Codes

CODE	COMMON NAMES	LATIN NAMES
	Fish (General)	
AF	All Species	
SP	Species Present, not identified	
NF	No Fish	
	Salmonids (Salmon, Trout, Char)	
SA	Salmon (General)	*Oncorhynchus* spp., *Salmo salar*
AO	All Salmon	*Oncorhynchus* spp., *Salmo salar*
AS	Atlantic Salmon	*Salmo salar*
GB	Brown Trout, German Brown Trout	*Salmo trutta*
AGB	Anadromous Brown Trout, Anadromous German Brown Trout	*Salmo trutta*
CM	Chum Salmon, Dog Salmon	*Oncorhynchus keta*
CH	Chinook Salmon, Spring Salmon, King Salmon, Tyee	*O. tshawytscha*
PK	Pink Salmon, Humpback Salmon	*O. gorbuscha*
CO	Coho Salmon	*O. kisutch*
SK	Sockeye Salmon	*O. nerka*
KO	Kokanee	*O. nerka*
CT	Cutthroat Trout (General)	*O. clarki* (formerly *Salmo clarki*)
ACT	Anadromous Cutthroat Trout	*O. clarki* (formerly *Salmo clarki*)
CCT	Coastal Cutthroat Trout	*O. clarki clarki* (formerly *Salmo clarki clarki*)
WCT	Westslope Cutthroat Trout (preferred) Yellowstone Cutthroat Trout	*O. clarki lewisi* (formerly *Salmo clarki lewisi*)
RB	Rainbow Trout, Kamloops Trout	*O. mykiss* (formerly *Salmo gairdneri*)
ST	Steelhead	*O. mykiss* (formerly *Salmo gairdneri*)
AC	Arctic Char	*Salvelinus alpinus*
BT	Bull Trout	*S. confluentus*
DV	Dolly Varden, Dolly Varden Char	*S. malma*
ADV	Anadromous Dolly Varden, Anadromous Dolly Varden Char	*S. malma*
EB	Brook Trout, Eastern Brook Trout	*S. fontinalis*
AEB	Anadromous Eastern Brook Trout	*S. fontinalis*
SPK	Splake	*Salvelinus fontinalis x namaycush*

CODE	COMMON NAMES	LATIN NAMES
LT	Lake Trout, Lake Char	*S. namaycush*
	Sturgeon	
SG	Sturgeons (General)	*Acipenser* spp.
GSG	Green Sturgeon	*A. medirostris*
WSG	White Sturgeon	*A. transmontanus*
	Cod	
BB	Burbot, Freshwater Ling Cod, Ling, Loche, Lawyer	*Lota lota*
	Whitefish	
WG	Whitefish (General)	*Prosopium* spp., *Coregonus* spp., *Stenodus* sp.
PW	Pygmy Whitefish, Coulter's Whitefish	*Prosopium coulteri*
GPW	Giant Pygmy Whitefish	*P.* sp., poss. subspecies of *Prosopium coulteri*
MW	Mountain Whitefish, Rocky Mountain Whitefish	*P. williamsoni*
RW	Round Whitefish	*P. cylindraceum*
LW	Lake Whitefish, Common Whitefish, Humpback Whitefish	*Coregonus clupeaformis*
HW	Humpbacked Whitefish	*C. pidschian*
BW	Broad Whitefish, Round-nosed Whitefish, Sheep-nose Whitefish	*C. nasus*
SQ	Squanga	*C.* sp.
CS	Least Cisco	*C. sardinella*
CA	Arctic Cisco	*C. autumnalis*
CL	Lake Cisco	*C. artedii*
IN	Inconnu, Sheefish, "Conny"	*Stenodus leucichthys*
	Lampreys	
L	Lampreys (General)	*Lampetra* spp.
AL	Arctic Lamprey	*L. ?*
PL	Pacific Lamprey, Sea Lamprey	*L. tridentata*
BL	Western Brook Lamprey	*L. richardsoni*
RL	River Lamprey, Western Lamprey	*L. ayresi*
MCL	Morrison Creek Lamprey	*L. richardsoni marifaga*
LL	Lake Lamprey, Cowichan Lamprey	*L. macrostoma*
	Grayling	
GR	Arctic Grayling	*Thymallus arcticus*
	Goldeyes	
GE	Goldeye	*Hiodon alosoides*

CODE	COMMON NAMES	LATIN NAMES
	Herrings	
SH	American Shad	*Alosa sapidissima*
	Minnows	
C	Minnows (General)	many, all cyprinids
CP	Carp	*Cyprinus carpio*
GC	Goldfish	*Carassius auratus*
TC	Tench	*Tinca tinca*
RSC	Redside Shiner	*Richardsonius balteatus*
STC	Spottail Shiner	*Notropis hudsonius*
ESC	Emerald Shiner	*N. atherinoides*
CBC	Chub, General	
FHC	Flathead Chub	*Platygobio gracilis*
LKC	Lake Chub	*Couesius plumbeus*
PCC	Peamouth Chub, Peamouth	*Mylocheilus caurinus*
NSC	Northern Squawfish	*Ptychocheilus oregonensis*
CMC	Chiselmouth	*Acrocheilus alutaceus*
BMC	Brassy Minnow	*Hybognathus hankinsoni*
DC	Dace, General	*Rhinichthys* spp., *Phoxinus* spp.
LNC	Longnose Dace	*Rhinichthys cataractae*
NDC	Nooksack Dace	*Rhinichthys* sp.
SDC	Speckled Dace	*R. osculus*
LDC	Leopard Dace	*R. falcatus*
UDC	Umatilla Dace	*R. umatilla*
FDC	Finescale Dace	*Phoxinus neogaeus* (formerly *Pfrille neogaea* and *Chrosomus neogaeus*)
RDC	Northern Redbelly Dace	*P. eos* (formerly *Chrosomus eos*)
PDC	Pearl Dace, Northern Pearl Dace	*Margariscus margarita* (formerly *Semotilus margarita*)
FM	Fathead Minnow	*Pimephales promelas*
	Suckers	
SU	Suckers, General	*Catostomus* sp.
CSU	Largescale Sucker, Coarsescale Sucker	*Catostomus macrocheilus*
WSU	White Sucker	*C. commersoni*
BSU	Bridgelip Sucker, Columbia Small-scaled Sucker	*C. columbianus*
LSU	Longnose Sucker, Fine-scaled Sucker, Northern Sucker	*C. catostomus*

CODE	COMMON NAMES	LATIN NAMES
SSU	Salish Sucker	*C.* sp.
MSU	Mountain Sucker, Northern/Plains Mountain Sucker	*C. platyrhynchus* (formerly *Pantosteus jordani*)
Catfish		
BH	Catfish, General (pref.), Bullheads	
BNH	Brown Bullhead, Brown Catfish	*Ameiurus nebulosus* (formerly *Ictalurus nebulosus*)
BKH	Black Bullhead, Black Catfish	*A. melas* (formerly *Ictalurus melas*)
Pike		
NP	Northern Pike, Jackfish, Jack	*Esox lucius*
Smelts		
SM	Smelts, General	
RSM	Rainbow Smelt	*Osmerus dentex*
EU	Eulachon, Candlefish	*Thaleichthys pacificus*
LSM	Longfin Smelt	*Spirinchus thaleichthys*
PLS	Pygmy Longfin Smelt	*Spirinchus* spp.
SSM	Surf Smelt	*Hypomesus pretiosus*
Sticklebacks		
SB	Sticklebacks, General	
TSB	Threespine Stickleback	*Gasterosteus aculeatus*
CSB	Charlotte Unarmoured Stickleback, Unarmoured Stickleback	*G.* sp.
LSB	Lake Sticklebacks (Enos, Paxton, Priest, Balkwill, Emily, Hadley)	*G.* sp.
GSB	Giant Stickleback, Giant Black	*G.* sp.
BSB	Brook Stickleback	*Culaea inconstans*
NSB	Ninespine Stickleback	*Pungitius pungitius*
Sculpins		
CC	Sculpins, General (pref.), Bullheads- (do not use)	Primarily *Cottus* spp.
CCA	Sharpnose Sculpin	*Clinocottus acuticeps*
COM	Tidepool Sculpin	*Oligocottus maculosus*
CLA	Pacific Staghorn Sculpin, Staghorn Sculpin	*Leptocottus armatus*
CMT	Deepwater Sculpin	*Myoxocephalus thompsoni (quadricornis ?)*
CAS	Prickly Sculpin	*Cottus asper*
CAL	Coastrange Sculpin, Aleutian Sculpin	*C. aleuticus*
CRI	Spoonhead Sculpin, Spoonhead Muddler	*C. ricei*

CODE	COMMON NAMES	LATIN NAMES
CRH	Torrent Sculpin	*C. rhotheus*
CCG	Slimy Sculpin	*C. cognatus*
CCN	Shorthead Sculpin	*C. confusus*
CBA	Mottled Sculpin	*C. bairdi*
CCL	Cultus Lake Sculpin	*C.* sp.
	Sunfish/Bass	
BS	Bass/Sunfish, General	*Micropterus* spp., *Lepomis* sp., *Pomoxis* sp.
PMB	Pumpkinseed, Sunfish, Pumpkinseed Sunfish	*Lepomis gibbosus*
BCB	Black Crappie, Calico Bass	*Pomoxis nigromaculatus*
SMB	Smallmouth Bass, Smallmouth Black Bass	*Micropterus dolomieui*
LMB	Largemouth Bass, Largemouth Black Bass	*M. salmoides*
	Perches	
P	Perch, General	*Perca* sp., *Stizostedion* sp.
YP	Yellow Perch, american Yellow Perch, many others	*Perca flavescens*
WP	Walleye, Pike-perch, Pickerel, Dore, many others	*Stizostedion vitreum*
	Flounders	
SFL	Starry Flounder	*Platichthys stellatus*
	Troutperch	
TP	Troutperch	*Percopis omiscomaycus*
	Mosquitofish	
GAM	Mosquitofish, Gambusia	*Gambusia* sp.

Appendix E. Questions for Habitat Evaluation

Use the following questions (modified from Anonymous 1993) to help evaluate salmonid habitat information at the stream reach scale and to identify data needs. The questions are organized into groups corresponding to salmonid life stages in streams. Use the major questions in bold italics as **a check-list to identify potentially degraded or limiting habitats**. Use the series of yes/no questions to help you answer the major (bold italicized) questions. If you lack the information to answer a series of yes/no questions, try to answer the major question from the available information, note possible needs for further information, and proceed to the next question. Pay particular attention to evaluating summer and winter rearing habitats.

Adult upstream migration

1. Are there obstructions to upstream migration?

1. Are there reaches within the watershed with an average stream gradient less than 10 % where there are no anadromous salmonids?

....	yes	Obstructions may be present; go to 2
....	no	There are no significant barriers to upstream migration.
....	don't know	Determine the limits to fish distribution in the basin (FPC fish stream classification).

2. Are present upstream limits of salmonid distribution less than the historical limits?

....	yes	Obstructions may be present; go to 3
....	no	Any blockage is likely to be part of the natural landscape. Locate and categorize the blockage as high gradient (chutes, waterfalls), dams (log jam, landslides, beaver dam), low surface flow (aggraded channel, low discharge).
....	don't know	Go to 3

3. Are there sites with large vertical drops during the upstream migration period (greater than about 2-2.5 m for salmon or steelhead and 0.8 m for resident trout)?

....	yes	Potentially impassable obstruction; go to 4
....	no	Go to 4
....	don't know	An overview or level 1 habitat survey is required

to locate potential obstructions to spawner migration.

4. Are there sites with high water velocities over the upstream migration period (velocities greater than about 2.5 $m{\cdot}s^{-1}$ for salmon or 1.2 $m{\cdot}s^{-1}$ for *resident trout)?*

.... yes — Potentially impassable obstruction; go to 5
.... no — Go to 5

5. Do large areas have maximum water depths less than 0.1 m during the upstream migration period?

.... yes — Potentially impassable obstruction; go to 6
.... no — Go to 6

6. Does the site have maximum water temperatures above 20°C for lengthy periods during the upstream migration period?

.... yes — Potentially impassable obstruction; go to 7
.... no — Go to 7

7. Can you identify the cause of the obstruction?

.... yes — Categorize the obstruction; go to 8
.... no — An overview or level 1 habitat survey is required; go to 8

8. Does the vertical drop originate from one of these sources:

a. debris jam?
b. landslide?
c. failed or poorly maintained culvert?
d. poorly designed culvert or other road crossing?
e. man-made dam or irrigation diversion?
f. beaver dam?

.... yes — Consider rehabilitation prescriptions; go to 9
.... no — Natural obstruction; go to 9

9. Does the high water-velocity barrier originate from one of these sources:

a. poorly designed culvert?
b. failed or poorly maintained culvert?
c. debris jam?
d. channel constriction from man-made structure?
e. channel constriction from landslide?

.... yes — Consider rehabilitation prescriptions; go to 10
.... no — Natural obstruction; go to 10

10. Does the shallow water depth originate from one of these sources:

a. poorly designed culvert?
b. failed or poorly maintained culvert?
c. channel widening from bank erosion?
d. channel aggradation?
e. channel diversion?

.... yes — Consider rehabilitation prescriptions; go to 11
.... no — Natural obstruction; go to 11

11. Does the high water temperature originate from one of these sources:

a. extensively logged riparian zone?
b. heat discharge from industrial facility?

.... yes — Consider rehabilitation prescriptions.
.... no — Natural obstruction.

2. Is there reduced or inadequate quantity / quality of adult holding habitat?

1. Are there important summer steelhead, summer chinook, summer coho or other stocks in the watershed that use holding pools for lengthy periods?

.... yes — Go to 2
.... no/don't know — Go to 4

2. Can you identify the locations of adult holding pools in the watershed?

.... yes — Go to 3
.... no — A level 1 fish habitat survey is required to locate pools with depths greater than 1 m at low flow and with adequate overhead cover; go to 3

3. Has pool infilling, increased water temperature during the period of adult use, or reduced cover from large woody debris, large boulders, turbulence, depths greater than 1 m, and cutbanks reduced the number or quality of known adult holding pools?

.... yes — Consider rehabilitation prescriptions; go to 4
.... no/don't know — Go to 4

4. Are there fewer than 1 pool·km^{-1} with more than 20 % surface cover and with residual depths greater than 1 m during the period of adult migration?

.... yes — Consider prescriptions for rehabilitation if the average bankfull channel width is greater than 10 m.
.... no — Adequate adult holding areas.
.... don't know — Do a level 1 fish habitat survey.

Spawning and incubation conditions

1. Are suitable spawning gravels available in the watershed?

Suitable spawning sites for salmonids are areas such as pool tail-outs where the dominant substrate sizes are approximately 1 to 10 cm diameter, fines (particle size less than about 2 mm, e.g., silts, sands) comprise less than 30 % of the substrate, minimum water depths exceed 15 to 30 cm, and water velocities are between about 10 and 100 cm·s^{-1}. Generally, individual patches of gravel must be 1-2 m^2 to be considered likely spawning habitats. Bjornn and Reiser (1991) list substrate size, minimum patch size, water depth, and water velocity criteria for spawning areas by salmonid species.

1. Are the historical locations of spawning sites known?

.... yes — Go to 3
.... no — Go to 2

2. Are there areas of potential spawning gravels, as defined above?

.... yes — Go to 3
.... no — Consider rehabilitation prescriptions.
.... don't know — A level 1 fish habitat survey is required.

3. Is more than 30 % of the surface area of historical spawning gravels covered or replaced by sands or other fine sediments?

.... yes — Possible degradation of spawning habitat. Determine source of fines; go to 5
.... no — Go to 4
.... don't know — A level 1 fish habitat survey is required; go to 4

4. Have historical spawning gravels been scoured leaving a substrate of cobble, boulder or bedrock?

.... yes — Develop rehabilitation prescription; go to 5
.... no — Go to 5
.... don't know — A level 1 fish habitat survey is required; go to 5

5. Is the estimated area of potential spawning gravel in the basin less than 25 % of that needed? Estimate the area of spawning gravel that is needed by multiplying one-half the escapement target or average historical escapement for the basin by the area per redd for the species of interest: chinook salmon 10 m^2; chum salmon 2 m^2; coho salmon 3 m^2; pink salmon 0.5-1 m^2; sockeye salmon 2 m^2; steelhead trout 4-5 m^2; resident trout and char 0.2 m^2 (Bjorrn and Reiser 1991).

.... yes — Consider rehabilitation prescriptions; go to 6
.... no — Adequate quantity of spawning gravels; go to 6
.... don't know — Go to 6

6. Is sand the dominant substrate at some potential spawning sites?

.... yes — Possible poor spawning habitat; determine source of fines.
.... no — Adequate spawning gravel quality.
.... don't know — A level 1 fish habitat survey is required.

2. Has the stability of spawning areas decreased?

1. Is there evidence of frequent redd scour to the egg pocket depth (15-30 cm)?

.... yes — Possible degradation of spawning habitat; go to 2
.... no/don't know — Go to 2

2. Is there evidence of frequent redd dewatering or freezing?

.... yes	Possible degradation of spawning habitat.
.... no	Spawning gravels are stable.
.... don't know	Unable to assess the stability of spawning gravels.

Summer rearing

1. Has pool area, pool depth or pool abundance decreased?

Evaluate changes in pool abundance and total pool area. If you are using a time series of aerial photographs, ensure that they were taken at similar discharge stages.

1. Is the mean bankfull width in the reach less than 15 m?

.... yes	"Small" stream. Go to 2
.... no	"Large" stream. Go to 8
.... don't know	An overview or level 1 fish habitat survey is required.

2. Is the average stream gradient less than 2 % in this reach?

.... yes	Go to 3
.... no	Go to 4
.... don't know	Calculate reach gradient from topographic map contours.

3. Do pools comprise less than 40 % of the total reach area?

.... yes	Summer rearing habitat may be degraded or limiting for pool-dependent species such as coho. Consider rehabilitation prescriptions. Go to 8
.... no	Adequate pools. Go to 8
.... don't know	An overview or level 1 fish habitat survey is required.

4. Is the average stream gradient between 2 % and 5 % in this reach?

.... yes	Go to 5
.... no	Go to 6

5. Do pools comprise less than 30 % of the total reach area?

.... yes	Summer rearing habitat may be degraded or limiting for pool-dependent species such as coho. Consider rehabilitation prescriptions.
.... no	Adequate pools. Go to 8
.... don't know	An overview or level 1 fish habitat survey is required.

6. Is the average stream gradient greater than 5 % in this reach?

.... yes	Go to 7

.... no Go to 8

7. Do pools comprise less than 20 % of the total reach area?

.... yes Summer rearing habitat may be degraded or limiting for pool-dependent species such as coho. Consider rehabilitation prescriptions. Go to 8

.... no Adequate pools. Go to 8

.... don't know An overview or level 1 fish habitat survey is required.

8. Is the mean spacing between pools greater than 4 bankfull widths?

.... yes Summer rearing habitat may be degraded or limiting for pool-dependent species such as coho. Consider rehabilitation prescriptions. Go to 9

.... no Adequate pools. Go to 9

.... don't know An overview or level 1 fish habitat survey is required.

9. Are there fewer than 1 pool·km^{-1} with residual depths greater than 1 m during the summer low flows?

.... yes Summer rearing habitat may be degraded or limiting for pool-dependent species such as coho. Consider rehabilitation prescriptions.

.... no Adequate pools.

.... don't know An overview or level 1 fish habitat survey is required.

2. Has in-channel cover or habitat complexity decreased in summer rearing habitat? Consider both pools and riffles for the relevant species.

1. Is there fewer than one large woody debris (LWD) piece per bankfull channel width in CPcw, RPcw or RPgw channels?

.... yes Summer rearing habitat may be degraded or limiting. Consider rehabilitation prescriptions. Go to 2

.... no Adequate LWD. Go to 2

.... don't know An overview or level 1 fish habitat survey is required.

2. Is overhead cover less than 10 % of the wetted channel area? Overhead cover includes LWD, large boulders, cutbanks, or overhanging vegetation within 1 m of the water surface.

.... yes Summer rearing habitat may be degraded or limiting. Consider rehabilitation prescriptions. Go to 3

.... no Adequate overhead cover. Go to 3

.... don't know	An overview or level 1 fish habitat survey is required.

3. Is boulder cover in cobble-boulder riffles less than 10 % of the wetted riffle area?

.... yes	Summer rearing habitat may be degraded or limiting for species that use riffles (e.g., steelhead parr). Consider rehabilitation prescriptions. Go to 4
.... no	Adequate boulder cover. Go to 4
.... don't know	An overview or level 1 fish habitat survey is required.

4. Is average wood cover (SWD and LWD) in pools less than 5 % of the pool area?

.... yes	Summer rearing habitat may be degraded or limiting for pool-rearing species. Consider rehabilitation methods.
.... no	Adequate cover.
.... don't know	An overview or level 1 fish habitat survey is required.

3. Do unsuitably high water temperatures or low dissolved oxygen conditions occur during summer low flows?

1. Do maximum water temperatures exceed 20°C for lengthy periods during the summer low flow period?

.... yes	Summer rearing habitat may be degraded or limiting. Consider rehabilitation prescriptions. Go to 2
.... no	Adequate summer temperatures. Go to 2
.... don't know	Go to 2

2. Do dissolved oxygen levels less than 5 $mg \cdot L^{-1}$ occur during the summer low flow period?

.... yes	Summer rearing habitat may be degraded or limiting. Consider rehabilitation prescriptions.
.... no	Adequate oxygen concentrations.

4. Does channel dewatering (e.g., subsurface flow or a series of isolated pools), or marked reduction in surface flow from upstream to downstream along a reach, occur during summer low flow?

.... yes	Summer rearing habitat may be degraded or limiting. Determine the source of aggrading channel sediments.
.... no	Summer flows normal

5. Do prolonged periods of high turbidity occur?

.... yes	Summer rearing habitat may be degraded. Determine source of turbidity.
.... no	Go to next question

6. Has food abundance has decreased?

1. Are riparian areas logged to the stream bank and not reforested?

.... yes	Inputs of riparian SOD (terrestial insects and detritus) may be reduced. Consider riparian rehabilitation.
.... no	Normal terrestial inputs of insects and detritus.

2. Are mayfly and stonefly nymphs and caddisfly larvae scarce in suitable habitats?

.... yes	Low or reduced food availability. Consider rehabilitation prescriptions such as stream fertilization if the physical habitat is unimpacted.
.... no	Normal food availability.

Winter rearing

1. Has overwinter cover been diminished? Consider:

- ***have large, deep pools with abundant LWD or boulder cover decreased in size or abundance?***
- ***has the availability or quality of off-channel habitat been reduced? Note especially the connections between off-channel habitats and the main channels.***
- ***has infilling reduced the amount of winter hiding habitat in coarse substrate (rubble and boulders) in riffles and pools?***
- ***have peak flows increased in frequency or magnitude?***

1. Are there fewer than 1 pool·km^{-1} with depths greater than 1 m during the winter?

.... yes	Consider prescriptions for rehabilitation if average bankfull channel width is greater than 10 m. Go to 2
.... no	Adequate deep pools. Go to 2
.... don’t know	An overview or level 1 fish habitat survey is required.

2. Do cover elements such as LWD comprise less than 10 % of the area of deep pools?

.... yes	Possible degradation of overwintering habitat. Consider rehabilitation prescriptions. Go to 3
.... no	adequate cover in deep pools. Go to 3
.... don't know	An overview or level 1 fish habitat survey is required.

3. Do cover elements such as boulders comprise less than 10 % of the area of cobble riffles?

.... yes	Possible degradation of overwintering habitat. Consider rehabilitation prescriptions. Go to 4
.... no	Adequate boulder cover. Go to 4
.... don't know	An overview or level 1 fish habitat survey is required.

4. Have backwaters or off-channel ponds been isolated from the main channel?

.... yes	Possible loss of overwintering habitat. Consider rehabilitation prescriptions. Go to 5
.... no	Adequate access to offchannel habitat. Go to 5
.... don't know	An overview or level 1 fish habitat survey is required.

5. Are backwaters or off-channel ponds with cover connected to the main stream channel during winter flows?

.... yes	Adequate access. Go to 6
.... no	Possible loss of overwintering habitat. Consider rehabilitation prescriptions. Go to 6
.... don't know	An overview or level 1 fish habitat survey is required.

6. Are sand or very small gravel the subdominant substrates in cobble- or boulder-dominant substrates?

.... yes	Possible infilling of overwintering habitat Determine source of fines. Go to 7
.... no	Adequate interstitial refuges. Go to 7
.... don't know	An overview or level 1 fish habitat survey is required.

7. Have peak winter flows increased?

.... yes	Possible degradation of overwintering habitat.
.... no	Overwintering habitat not impacted by increased flows.

Juvenile migration

1. Are there obstructions to migration among habitats? Consider the following potential obstructions:

- ***reduced connections with tributaries and off-channel or seasonal habitats?***
- ***impassable reaches from low or subsurface flow? At what time of year are these conditions present?***
- ***impassable culverts?***
- ***impassable debris jams? natural dams? falls or chutes?***
- ***artificial obstructions such as dams or irrigation diversions?***
- ***areas where migration is impeded by water quality factors such as high temperatures?***

Appendix F. Forms for the FHAP

The forms that are required for the FHAP follow:

Form 1. Overview assessment - Fish distribution summary form

Form 2. Overview assessment - Habitat condition summary form

Form 3. Overview assessment - Preliminary habitat assessment form

Form 4. Level 1 field assessment - Habitat survey data form

Form 5. Level 1 field assessment - Fish distribution data form

Form 6. Level 1 assessment - Habitat diagnosis summary form

Overview Assessment - Fish Distribution Summary Form

Watershed Name: ____ NTS maps: _______________________________

Watershed Code: ____ Forest District: ____________________________

Reach No.	Section No.	Data Source	Survey Method		SK			CH			CO			PK			ST			RB			CT			DV			BT	
			juv	ad	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad

Overview Assessment - Habitat Condition Summary Form

Watershed Name: ____ Sub-basin: _________________________

Watershed Code: ____ NTS maps: _________________________

Air Photo Series: ____________________ Photo Numbers: _______________ Photo scale: _________________________

Reach Number	Section Code	Length (m)	Elevation (m)		Gradient (%)	W_b (m)	Channel Type	Disturbance Types			Barriers	Pools Code	LWD Codes		Riparian Type	Stand Structure	Canopy Closure	Offchannel Habitats
			Upper	Lower														

Overview Assessment - Preliminary Habitat Assessment Form

Watershed Name: ________________________________ UTM Coordinates: ________________________________

Watershed Code: ________________________________ NTS maps: ____________________

Reach	Section	Habitat Value	Upslope Impact Potential	Major Impacts	Priority	Restoration Opportunities

Level 1 - Habitat Survey Data Form

Forest District: ______________________ Watershed: ______________________________ Sub-Basin: ___________________

NTS map sheet: ______________________ Weather: _______________________________ Discharge ($m^3 \cdot s^{-1}$): _____________

Survey Date: _______/_______/_______ Survey Crew: _________________ Subsampling Fractions: ____/____/____/____/____

(d / m / y) (**R** / **P** / **G** / **C** / **O**)

	Reach Number	Distance (m)	Habitat Unit		Length (m)	Gradient (%)	Mean Depth				Mean Width		Pools Only				Bed Material Type			
			Type	Cat			Bankfull (m)	Water (m)			Bankfull (m)	Wetted (m)	Max. Depth (m)	Crest (m)	Residual (m)	Pool Type	Dom.	Sub-Dom.	Spawning Gravel?	
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				

	Total LWD Tally	Functional LWD Tally			Cover				Offchannel Habitat			Disturbance Indicators			Riparian Vegetation			Barriers	Comments
		10 - 20 cm	20 - 50 cm	> 50 cm	Cover Type	%	Cover Type	%	Type	Access	Length (m)				Type	Structure	Canopy Closure		
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			

			Habitat Unit				Mean Depth				Mean Width		Pools Only				Bed Material Type			
	Reach Number	Distance (m)	Type	Cat	Length (m)	Gradient (%)	Bankfull (m)	Water (m)			Bankfull (m)	Wetted (m)	Max. Depth (m)	Crest (m)	Residual (m)	Pool Type	Dom.	Sub-Dom.	Spawning Gravel?	
11																				
12																				
13																				
14																				
15																				
16																				
17																				
18																				
19																				
20																				
21																				
22																				
23																				
24																				

	Total LWD Tally	Functional LWD Tally			Cover				Offchannel Habitat			Disturbance Indicators			Riparian Vegetation			Barriers	Comments
		10 - 20 cm	20 - 50 cm	> 50 cm	Cover Type	%	Cover Type	%	Type	Access	Length (m)				Type	Structure	Canopy Closure		
11																			
12																			
13																			
14																			
15																			
16																			
17																			
18																			
19																			
20																			
21																			
22																			
23																			
24																			

Level 1 habitat survey data form (adapted from Anonymous 1993).

DISCHARGE: Estimate DISCHARGE ($m^3 \cdot s^{-1}$) at the origin of the survey as:

0.75 x VELOCITY x MEAN DEPTH x WETTED WIDTH

where VELOCITY is the average velocity ($m \cdot s^{-1}$) of a floating object over a measured length centred on the survey point, MEAN DEPTH (m) is the average of 5-10 measurements at equal intervals along a transect perpendicular to the direction of flow, and WETTED WIDTH (m) is the measured distance along the transect across the flow.

SUBSAMPLING FRACTIONS: If habitat units are subsampled, record the independent subsampling fractions for Riffles, Pools, Glides, Cascades or Other units (e.g., 1 in 5 / 1 in 2 / 1 in 5 / 1 in 5 / 1 in 3).

DISTANCE: Measure the DISTANCE in metres from the survey origin (normally the stream mouth) to the downstream boundary of the habitat unit, using a hip chain. Measure the LENGTH (m) of the habitat unit similarly.

HABITAT UNITS: Distinguish among POOLS (P), GLIDES (G), RIFFLES (R), CASCADES (C) and OTHER (O) habitat unit types and PRIMARY (1), SECONDARY (2), or TERTIARY (3) categories. Primary habitat units occupy more than 50% of the wetted width of the main channel. Secondary units are occupy secondary channels. Tertiary units are embedded within primary units but meet the minimum size criteria. Pools must equal or exceed the following minimum areas and minimum residual depths to be separately counted as pools:

Bankfull Channel Width (m)	Minimum Area (m^2)	Minimum Residual Depth (m)
0 - 2.5	1.0	0.20
2.5 - 5	2.0	0.40
5 - 10	4.0	0.50
10 - 15	6.0	0.60
15 - 20	8.0	0.70
> 20	10.0	0.80

DEPTH and WIDTH MEASUREMENTS:

MEAN BANKFULL CHANNEL WIDTH is the average width (±0.1m) across transects perpendicular to the channel axis between banks defined by the presence of permanent rooted vegetation (usually trees or shrubs). For habitat units with a relatively uniform width, measure the mean bankfull channel width at a “representative” point. For irregularly shaped habitat units, take 1-5 measured widths at equal intervals to determine a mean value. MEAN WETTED WIDTH is the average width (m) of the water surface across transects perpendicular to the channel axis. MEAN DEPTH is average depth (±0.05 m) at 3 (or more) equally-spaced points along a transect perpendicular to the channel axis. MEAN BANKFULL DEPTH is the depth from the height of the bankfull channel to the channel bottom.

POOL MEASUREMENTS:

MAXIMUM DEPTH in m (± 0.05 m) at the deepest point. RIFFLE CREST DEPTH in m is the water depth measured at the riffle crest (i.e., at the pool overflow or pool control element) of the pool. RESIDUAL DEPTH in m is the difference between the maximum pool depth and the riffle crest depth. It is (approximately) the depth of water that would be retained in the pool at zero flow. POOL TYPE is the structural feature that causes the pool to form, either a SCOUR pool, or a DAMMED pool or UNKNOWN.

BED MATERIAL: The DOMINANT AND SUBDOMINANT SUBSTRATES are the bed material types that cover the largest and second largest percentage of the area of the habitat unit. Categorize substrates as:

- S - sands, silts, clays, or fine organic material (<2 mm diameter)
- G - gravels (2 - 64 mm)
- C - cobbles (64 - 256 mm)
- B - boulder (> 256 mm)
- R - bedrock (> 4000 mm)

SPAWNING GRAVELS are gravels located in areas where water depths greater than 15 cm and water velocities in the range 0.3 - 1.0 $m \cdot s^{-1}$ are expected during the spawning season. Categorize SPAWNING GRAVEL TYPE as:

- A - an area of gravel suitable for anadromous salmon (10-150 mm, at least 1.5 m^2).
- R - an area of gravel suitable for resident trout and charr (10-75 mm, at least 0.1 m^2)
- AR - both salmon and resident trout spawning habitat is present.

Categorize the AMOUNT OF SPAWNING GRAVEL as: N = none; L = isolated pockets only; or H = extensive amounts.

LARGE WOODY DEBRIS: is defined as wood within the bankfull channel with a diameter equal to or greater than 10 cm over a length greater than 2 m. FUNCTIONAL LWD are those pieces that influence channel geomorphology (by causing scour or impoundment). Count all LWD pieces for the TOTAL LWD TALLY and separately tally FUNCTIONAL LWD pieces by diameter class.

COVER: % cover is the percent of the wetted surface area that is covered by WOODY DEBRIS (LWD or SWD), BOULDERS (B), CUTBANKS (C), DEEP POOLS (DP), OVERHANGING VEGETATION within 1 m of the water surface (OV) or INSTREAM VEGETATION (IV). Record the percentage cover as TR if it is less than 2% of the habitat unit area.

OFFCHANNEL HABITAT: Note the presence of offchannel habitats such as: SIDECHANNELS (SC), SLOUGHS (SL), PONDS (PD), and seasonally flooded WETLANDS (WL) that could be used as refuge areas during high flows. Note the access to the offchannel habitat as: NO ACCESS to fish (N), ACCESSIBLE AT HIGH FLOWS only (P), or ACCESSIBLE AT MOST FLOWS (G). Determine the LENGTH (m) of the offchannel habitat.

DISTURBANCE INDICATORS: Record the presence of the following disturbance indicators:

	Indicator Feature	Code
Bed Characteristics:	1. Extensive areas of scour	SC
	2. Extensive areas of (unvegetated) bar	DW
	3. Large, extensive sediment wedges	WG
	4. Elevated mid-channel bars	MB
	5. Extensive riffle zones	LR
	6. Limited pool frequency and extent	FP
Channel pattern:	1. Multiple channels (braiding)	MC
Banks:	1. Eroding banks	EB
	2. Isolated sidechannels or backchannels	BC
LWD:	1. Most LWD parallel to banks	PD
	2. Recently formed LWD jams	JM

RIPARIAN VEGETATION: Record the dominant riparian VEGETATION TYPE as:

N - UNVEGETATED. Much bare mineral soil is visible.
S - SHRUB/HERB. Herbaceous or shrubby vegetation dominate.
C - CONIFEROUS forest
D - DECIDUOUS forest
M - MIXED CONIFER-DECIDUOUS forest

Record the STRUCTURAL STAGE of the dominant vegetation in the RMA as:

INIT - the non-vegetated or initial stage following disturbance, with less than 5% cover.
SHR - shrub/herb stage. Less than 10% tree cover.
PS - pole-sapling stage, with trees overtopping the shrub layer, usually less than 15-20 years old.
YF - young forest. Self-thinning is evident and the forest canopy is differentiating into distinct layers. Stand age is 30-80 years.
MF - mature forest with well-developed understory.

Categorize the CANOPY CLOSURE (i.e., proportion of the surface area of the stream covered by the projecting riparian canopy) as:

1 - 0-20% covered
2 - 20-40% covered
3 - 40-70% covered
4 - 70-90% covered
5 - >90% covered

BARRIERS: Record natural and man-made barriers to fish movement as:

no barriers (N)
log jams (X)
culverts (CV) and disused bridges (BR)
beaver dams (BD)
falls (F) - vertical drops greater than 2 m.
landslides or bank sloughing (LS)
cascades or chutes (C)

Level 1 - Fish Distribution Data Form

Watershed Name: ______________________________ UTM Code: ______________________

Watershed Code: ______________________________ Forest District: ______________________

Survey Crew: ______________________________ Date: ______________________

Reach	Section	Habitat	Survey Method		SK	SK	SK	CH	CH	CH	CM	CM	CM	CO	CO	CO	PK	PK	PK	ST	ST	ST	RB	RB	RB	CT	CT	CT	DV	DV	DV	BT	BT	BT
Number		Type	Adults	Juveniles	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp	juv	ad	sp

Level 1 - Habitat Diagnosis Summary Form (from Anonymous 1993)

Calculate mean values of habitat conditions over each reach and use the values from Table 5 to rate habitat conditions within reaches as poor, fair or good.

Watershed Name: ________________________________ UTM Code: ________________________

Watershed Code: ________________________________ Forest District: ____________________

Reach Number	% Pools		Pool Frequency		LWD Pieces per Channel Width		% Wood Cover		Dominant Substrates		Off-Channel Habitat		Gravel Quantity		Holding Pools	
	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating