Guidelines for the collection and analysis of fish and fish habitat data for the purpose of assessing impacts from small hydropower projects in British Columbia

Prepared by: Todd Hatfield
Solander Ecological Research Ltd.
Victoria BC

Adam Lewis
EcoFish Research Ltd.
Courtenay BC

Scott Babakaiff
BC Ministry of Environment
Surrey BC

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Cover photos by Scott Barrett.

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INTRODUCTION

These guidelines identify methodologies recommended by the Environmental Stewardship Division, Ministry of Environment (MOE) for collection and analysis of fish-related data for assessment of biological impacts in small, steep streams. The guidelines are aimed at proponents of small water power projects. The focus is on fish and flow related impact assessment and permitting because these are directly related to the mandate and regulatory responsibilities of MOE in granting a water licence and managing the province's fish and wildlife resources. There is some mention of other regulatory issues, but readers should not construe these guidelines as providing direction on behalf of all agencies. Proponents are therefore encouraged to discuss regulatory approvals and permitting with Fisheries and Oceans Canada (DFO), and other agencies.

Every project assessment will have its own specific challenges, such as scant existing data, difficult access to study sites, or difficult sampling conditions. As a result, it is not easy to assign a single set of methods as best for all conditions. A prescriptive approach is thus avoided in these guidelines, and the focus is on deliverables for decision making. To achieve these deliverables, recommended best practices are indicated, and references are provided to existing standards for data collection and analysis. Ultimately, study design and analysis is at the discretion of professionals undertaking the studies and successful impact assessment rests heavily on the professionals involved.

The expectation is that studies will be undertaken as laid out in the various assessment methods, unless scientifically-defensible reasons are presented by a certified professional with sufficient experience in instream flow assessment and fish habitat analysis. Reasons for varying from these methods must be documented with a convincing, factual argument for the adoption of alternative methods, with references to supporting literature.

These guidelines present fisheries information requirements for a project review and methods used to collect, analyze and present the information. These guidelines are not a review of existing empirical assessment methods, nor or they a review of available models for predicting fish presence, fish abundance or flow recommendations. The methods selected have been widely-used and are deemed acceptable for this application.

Most water power projects will require detailed studies, particularly if they are located on fish-bearing streams. Some projects may have less intensive water use requirements or be located on non-fish bearing watercourses. Proponents have the option of using existing MOE/DFO flow threshold guidelines (Hatfield et al. 2003) if they wish to avoid undertaking detailed studies. Proponents who wish to use more water than is specified in the flow thresholds will need to fulfill all components presented in these guidelines.

1.1 Professional Requirements

Environmental impact assessment is a specialized field, requiring the collection, analysis, and reporting of specific physical and biological information—requirements that must be fulfilled before review of a proposed water use can proceed. These data will be used to examine water licence applications for risk to fish and fish habitat. Inventory and assessment standards have

been developed for numerous types of data and analyses, and are reviewed in this document. Where empirical data are collected specifically for a project, and submitted as part of a water license application, they should meet or exceed existing standards, and be signed off by a certified professional with appropriate experience (e.g., R.P. Bio.). Likewise, the design and execution of a monitoring program should be signed off by a certified professional with appropriate experience (e.g., R.P. Bio.).

PRELIMINARY PROJECT DESCRIPTION

Proponents should provide a reliable and sufficiently detailed Preliminary Project Description to allow MOE staff to screen and prioritize review of the water licence application. The project description should include information that is readily available **without completing field work**, and be accompanied by mapping at an appropriate detail.

The methods and deliverables for a Preliminary Project Description are as follows. The locations of all proposed project infrastructure should be properly geo-referenced and mapped on TRIM base (1:20 000). All maps related to fisheries resources should adhere to mapping standards identified in Standards for Fish and Fish Habitat Maps Version 3.0 (RIC 2001). Proponents should adhere to related standards, where they exist, when presenting information on other resources and infrastructure.

The first deliverable is project overview information:

1. Location map (1:50 000 to 1:250 000)
2. Watershed overview: drainage area at intake and powerhouse, general description of surface materials, hypsometry, stream order (from 1:20 000 map), glacial and lake coverage.
3. Topographic maps (on 1:20 000 TRIM base) showing: all streams and tributaries affected, all points of diversion, watershed boundaries, existing roads and trails, all physical infrastructure required for project construction, operation and maintenance: dam, diversion weir, penstock, powerhouse, transmission corridor, access roads (e.g., approximate new road length, approximate length of reconstruction of old road). Also describe the proposed construction timing and duration of work.
4. Describe dam structure (type and height), diversion weir, proposed operating regime, construction schedule, impact area, project lifespan

The second deliverable of the preliminary project description is biological and ecological information:

1. Compile and map (1:20 000 to 1:50 000) known information on resident and anadromous fish (utilization, species presence and distribution)
2. Compile and map (1:5 000 to 1:20 000) known information on red and blue listed animals, plants and plant communities, COSEWIC and SARA listed species and regionally significant species as per MOE guidelines (Step 1 in "Working Draft Guidelines for Dealing with Development Effects on Species and Ecosystems at Risk")
3. Compile and map (1:5 000 to 1:20 000) known information on Wildlife Habitat Areas (WHAs), Ungulate Winter Ranges (UWRs) and other habitats required under the Wildlife Act. The IWMS website for WHAs: http://www.env.gov.bc.ca/wld/frpa/iwms/index.html . For information on UWRs

contact Regional MOE staff or check http://www.env.gov.bc.ca/wld/frpa/uwr/index.html .

4. Status of fish stocks and ecotypes in project area (e.g., are current populations healthy and capable of supporting sport fisheries? Are trout or char migratory and utilizing areas downstream of project?)
5. Baseflow water chemistry data with emphasis on low-level macro-nutrient parameters (N, P), alkalinity (mg L^{-1} $CaCO_3$) and electrical conductivity (µS cm^{-1}).

Existing biological information should be collated for the project impact area using existing web-based tools that link to the provincial fisheries database and the 1:50 000 watershed atlas. The provincial "Habitat Wizard" (http://www.env.gov.bc.ca/habwiz/) should be used to create stream and lake reports for all waterbodies in the project impact area. This information can be organized to indicate the known distribution of fish species, watershed codes, stocking history and the availability of existing information such as bathymetric maps and data reports. Many existing reports are available through various search tools and cataloguing systems, such as the Fisheries Project Registry (http://www.canbcdw.pac.dfo-mpo.gc.ca/fpr/Qf_Welcome.asp), Ecological Reports Catalogue (http://srmapps.gov.bc.ca/apps/acat/), FISS Data Reports query (http://srmapps.gov.bc.ca/apps/fidq/), MOE Biodiversity & Wildlife Publications (http://wlapwww.gov.bc.ca/wld/pub/pub.htm), the Ministry of Forests and Range library (http://www.for.gov.bc.ca/hfd/LIBRARY/index.htm). Relevant hard copy reports and stock assessment data are available in regional MOE files or at MOE Headquarters in Victoria. These may be accessed through MOE Fisheries Section staff and visits to regional offices.

The 1:20 000 TRIM-based map should indicate boundaries of the project influence (as per Lewis et al., 2004), known or map-determined reach breaks, known fish-bearing waterbodies, and waterbody names and identifier codes. The map should indicate project features, such as point of diversion, point of discharge, and upstream and downstream impact limit. All data sources should be identified or referenced. One of the objectives in presenting existing biological information is to understand the suite of fish species that exist in the general area, even if specific information is lacking for all waterbodies within the project impact area. It is therefore important to indicate known fish presence in areas outside the project boundaries if there are no confirmed fish-bearing streams within the project area. Maps should adhere to existing mapping standards from the Standards for Fish and Fish Habitat Maps Version 3.0 (RIC 2001).

The third deliverable of the preliminary project description is hydrology information required to support a description of project operations. Details on hydrology requirements can be found in Land and Water BC (2004); information should be presented graphically and in tables using appropriate summary statistics:

1. Preliminary regional analysis to estimate mean annual discharge (MAD), mean monthly discharges (MMD), 7-day average low flow (mean annual, 5, 20 and 50 years), and 200-year instantaneous peak flow. Provide flow exceedence curves for each month and determine 80% exceedence flow in m sec^{-1} and %MAD. Include a map of all long-term WSC stations in the area of interest showing stations selected for regional analysis.
2. Maximum quantity of water to be diverted
3. Elevations and relative catchments of intake and powerhouse

4. Channel confinement, geology and stream type. One may use large scale air photos or maps to determine the likelihood of the diversion reach containing off-channel habitats, fish barriers (partial or complete), or narrow canyonized sections.
5. Ecosection, ecoregion and ecoprovince of diversion reach: support for proposed unit runoff, seasonal flow regime and fish productivity.

The fourth deliverable of the preliminary project description is geomorphology information:

1. Length of erodible channel in diversion reach as a proportion of total diversion reach.
2. Gradient of diversion reach, and presence of features that may affect sediment transport such as valley constrictions and major gradient breaks (e.g., lakes, waterfalls, etc.).

DEVELOPMENT PLAN

The Development Plan will be the primary document submitted to MOE prior to water licensing, and will supplement information provided in the Preliminary Project Description with the collection and analysis of **field-based data**.

Fish-related information to be provided in the Development Plan includes fish-bearing status (Section 1.2), fish abundance and distribution in the diversion reach (Section 0), and fish habitat classification in the diversion reach (Section 1.4). Additional biological information to be provided includes basic water chemistry data (Section 1.5), macro-invertebrate data (Section 1.9), wildlife and species-at-risk (SAR), and assessment of project impacts on these species (Section 1.10).

Hydrologic information to be provided in the Development Plan is a description of on-site hydrometric data, a regional analysis, and a series of estimates integrating the regional analysis and onsite data (Section 1.6). The primary geomorphic information to be provided in the Development Plan is an assessment of the likelihood of future channel changes associated with dam operation and flow diversion, as well as a terrain stability assessment in relation to all project infrastructure (Section 1.7).

The instream flow assessment (Section 1.8) to be provided in the Development Plan makes use of information summarized in Sections 1.2 to 1.7, and may require additional data, depending on the assessment method used.

1.2 Fish-bearing Status

Conditions of a water licence will hinge on the ecological values of fish and fish habitat. All stream reaches within the study area should be assumed fish-bearing unless site-specific fish sampling information indicates otherwise. Non-fish bearing status of any stream reach must be proved with data collected at the site of interest over a minimum of two field seasons. Proponents must demonstrate due diligence with respect to study design, sampling methods, and level of sampling effort. For example, sampling must occur during the season in which fish are most likely to be present, using suitable sampling methods. Barriers that determine fish bearing status should be thoroughly documented.

Fish-bearing status is often determined as part of an overview-level survey, as described in Reconnaissance (1:20 000) Fish and Fish Habitat Inventory: Standards and Procedures (RISC 2001). Overview surveys can be used to determine whether stream reaches have a very high probability or very low probability of fish presence, or something in between. Where streams are likely to be fish-bearing, proponents may wish to use fish-bearing status surveys, as described in the Fish Stream Identification Guidebook (FPC 1998) which include more detailed studies of fish abundance and distribution — there is no need to duplicate sampling effort to provide separate deliverables for fish-bearing status and information on abundance and distribution of fish species and life stages.

Recommended methods to determine fish-bearing status are as follows:

1. Lewis et al. (2004) provide methods for defining the study area for fish sampling, and the justification for repeat samples and use of preferred methods.
2. The Fish-Stream Identification Guidebook (Forest Practices Code of British Columbia 1998) provides an excellent discussion of relevant sampling methods, their relative merits, and the level of effort required to determine non-fish bearing status.
3. Fish Collection Methods and Standards (Province of British Columbia 1997) discusses sampling permit requirements, gear selection, and fish handling and sample processing techniques.
4. Reconnaissance (1:20 000) Fish and Fish Habitat Inventory: Standards and Procedures – Version 2.0, (RISC 2001) its errata, and other referenced documents present requirements for fish and fish habitat data collection, reporting, quality assurance, and submission to the provincial fisheries program.

The primary deliverables are as follows:

1. The key deliverable of a fish presence-absence survey is a 1:20 000 TRIM-based map showing sampling locations, methods used, and fish sampling results. Requirements for mapping of fish presence-absence are presented in Standards for Fish and Fish Habitat Maps (RIC 2001) and Reconnaissance (1:20 000) Fish and Fish Habitat Inventory: Standards and Procedures - Version 2.0, Errata No. 2 (RISC 2006).
2. In addition to a map-based results summary it will be necessary to provide a description of the methods used, the level of effort expended, the conditions encountered in the field, and photo documentation. These data are typically required as a condition of a fish collection permit.
3. Data collection and submission requirements are outlined in the Reconnaissance (1:20 000) Fish and Fish Habitat Inventory: Standards and Procedures -Version 2.0 (RISC 2001) and Errata No. 2 (RISC 2006).

Where streams are determined to be non-fish bearing, the requirements for impact assessment and approval will be less since fish-related studies are not required. For example, deliverables associated with Sections 0, 1.4 and 1.8 will not be required. Many of the other deliverables noted in these guidelines will still be required in full, although some study requirements may be reduced. Proponents seeking water licences on non-fish bearing streams should clarify information requirements with MOE staff.

More extensive and intensive sampling will be required in streams that support species of elevated importance, such as:

- red- or blue-listed species as designated by the Province's Conservation Data Center (e.g., coastal cutthroat trout, Dolly Varden, bull trout).
- identified wildlife management species as defined in the Province's Identified Wildlife Management Strategy (e.g., coastal cutthroat trout).
- species with complex and varied life histories (e.g., adfluvial, fluvial, and isolated fluvial life strategies) in combination with complex geomorphic characteristics such as headwater lakes, low gradient mainstem channels, and offchannel habitats.

1.3 Fish Abundance and Distribution

Information on fish abundance and distribution should be gathered for the entire project area to identify the potential presence of productive fish habitats that could be impacted by the proposed project. Headwater lakes, tributary streams and off-channel habitats that may support fish in the impacted reaches should be sampled to determine seasonal use for spawning, rearing and refuge habitat by potentially affected populations.

This information should include:

1. fish species and life stages present,
2. indicators of fish abundance,
3. fish distribution (in space and time),
4. life history timing, and
5. source and reliability of information.

Data collected to support a water licence application should meet or exceed existing inventory standards (e.g., RISC 2001 and other documents available at http://ilmbwww.gov.bc.ca/risc/pubs/aquatic/index.htm), and other specific references noted below. Permits will be required for sampling or collection of fish in all waters. Fish data collected under these permits must be submitted to the Province, following Fish Data Submission process (www.env.gov.bc.ca/fish_data_sub/index.html).

Recommended methods are as follows:

1. Lewis et al. (2004) provide methods for defining the study area, and the use of preferred methods for fish sampling. Briefly, methods to determine the species and life stages present in a stream and their relative abundances are the same as those used to establish fish-bearing status: electrofishing, snorkelling, minnow trapping, angling, and seining. Sampling techniques may require adaptation to prevailing conditions. For example, electrofishing is not effective for measuring densities of fish in high flow or in steep streams. Systematic and intense sampling is generally required to compare abundance between reaches and make inferences regarding habitat quality. Streams with exceptional fish values may require intensive techniques, such as mark-recapture and radio-tagging.
2. Selection of "control" and "impact" sites should occur in anticipation of monitoring needs (see Appendix A). Control sites will generally be chosen upstream of the POD, and impact sites will be within the diversion reach. A minimum of five control and five impact sites should be established. These sites should be sampled using methods appropriate for local conditions and the species of interest, however, multiple pass electrofishing with removal is preferred (Seber and Le Cren 1967; De Leeuw 1981;

Murphy and Willis 1996). Sampling sites of a minimum 100 m^2 should be enclosed with fine-meshed stop nets. Note that this requires considerably more effort than fish presence-absence surveys. We encourage use of two sampling methods at each site (e.g., electrofishing and minnow trapping, or electrofishing and snorkelling) to ensure adequate sampling of deepwater habitats, which may be not sampled effectively by electrofishing.

3. Abundance indicators should be expressed as the number and biomass of fish caught per unit effort and area. This should be done on a species and life stage basis. More detailed stock assessments may be warranted in streams with highly productive or diverse fish habitats: regulatory agencies may identify these high value fish habitats.
4. Detailed biological information should be collected from captured fish including species, life stage, length and weight, maturity, and age (through analysis of scales, otoliths, or fin rays). All fish captured should be identified by species and age class, and measured for fork length (± 1 mm) and weight (± 0.1 g). A subsample of five fish per site of each species/life history phase (as inferred from size distribution in the field) should be retained for aging.
5. Species and life histories should be defined using appropriate reference materials.
    a. Fish species can be identified using a number of different sources. Scott and Crossman (1973) provide keys for a broad number of species; however, this reference is dated and does not include recent species classifications (e.g., bull trout). McPhail and Carveth (1993) provide more recent information organized by region within BC. Pollard et al. (1997) provide a key to the difficult-to-classify juvenile life stages.
    b. Age classes can be designated through a combination of size-class and structure aging analysis (Schreck and Moyle 1990; Murphy and Willis 1996).
    c. Life history timing should be determined with site-specific information and/or information from nearby watershed. This would include information on the timing of migration and spawning. Egg incubation and fry emergence timing can be inferred from site-specific timing of spawning and water temperature, combined with relationships of egg incubation vs. temperature, available in the scientific literature.
6. Data collection forms and instructions are available to facilitate collection of fish and habitat information (http://ilmbwww.gov.bc.ca/risc/pubs/aquatic/).

In terms of deliverables, all data should be provided in complete reports, with individual data appended. Mapping should be provided at 1:20 000 scale or finer. The information should be sufficiently detailed to allow a reviewer to reconstruct the analysis from the raw data. All calculations methods should be provided, including model equations. Reports should follow a standard reporting format: the Council of Science Editors (2006) provides an effective standard. Lewis et al. (2004) provide methods for defining the study area for fish sampling, and the justification for repeat samples and use of preferred methods. All data collected should meet the Minimum Data Submission Standards.

1.4 Fish Habitat Classification

Fish habitat assessments are required to describe the quality, abundance and distribution of fish habitats in the project area. In particular, the assessment will focus on the estimation of changes

in physical habitat associated with flow diversions and impoundments, and altered flow regimes. This information should be collected in a sufficiently broad and detailed manner to allow an assessment of impacts from the proposed land and water uses. The overview-level inventory undertaken when determining fish-bearing status (Section 1.2) provides a framework for developing a sampling plan for the detailed assessments. A sampling plan must be submitted to the regulatory authorities for approval prior to undertaking the sampling program.

Fish habitats can be organized at different spatial scales to facilitate analysis. Three scales of analysis are identified: macrohabitat (reach scale), mesohabitat (hydraulic unit scale), and microhabitat (site-specific scale). For the purposes of habitat classification, recommended methods are provided for macrohabitat and mesohabitat; microhabitat information is discussed as a component of the instream flow assessment (Section 1.8).

Macrohabitats are large homogenous sections of fish habitat, equivalent to stream reaches as defined in the Fish Habitat Assessment Procedures Manual (Johnstone and Slaney 1996): "a homogeneous section of stream channel, characterized by uniform discharge, gradient, channel morphology, channel confinement, and streambed and bank materials." Reach boundaries are identified at significant changes in gradient, confinement, and/or discharge. Johnstone and Slaney (1996) provide the following guidance for establishing reach breaks: "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)." Strict adherence to these criteria is not required, provided that anticipated impacts from water use are similar within the defined reach. Obvious locations for reach breaks are the proposed project POD and powerhouse, as these locations will be the points of substantial flow change. Analyses of habitat should be summarized by reach.

Mesohabitats are medium-sized stream features defined by stream hydraulic characteristics. Reaches are stratified into mesohabitats (pools, glides, runs, riffles, cascades, etc.) so that the composition of each reach can be defined and expressed in linear distance (m) of channel occupied by each mesohabitat type. This facilitates expansion of microhabitat data to an areal expression of habitat quantity and quality, which may be utilized in the instream flow assessment (Section 1.8) and/or proposed mitigation and compensation (Section 1.13). Mesohabitat definitions can be found in Johnston and Slaney (1996).

Microhabitats are point-specific physical habitat conditions. These conditions are typically quantified using measures of depth, velocity, substrate, and cover, although other variables may be included. These variables are highly sensitive to flow change, and are collected across the stream in a linear transect. A detailed description of the methodology required to design and collect these data is presented in Appendix A of Lewis et al. (2004). Microhabitat analysis and deliverables are discussed in Section 1.8.

The deliverables for fish habitat classification focus on macro- and mesohabitats, are defined in Lewis et al. (2004) and include:

1. 1:20 000 scale (or less) detailed maps delineating reach breaks (i.e., macrohabitats) and mesohabitat units.

2. Tables showing reach information, including watershed area, reach locations, reach gradients, and reach lengths.
3. Tables showing breakdown of mesohabitat units by reach, quantified by linear length (m) and surface area (m^2) of each unit.
4. Tables showing barrier locations, height and width.
5. Photos of potential barriers to migration.
6. Photos of representative macro- and mesohabitats at baseflow and higher flows (see Lewis et al. 2004 for further instructions).
7. An appendix with all habitat data sheets (transcribed field data sheets).

1.5 Water Quality

Water use can affect water quality indirectly by altering volume of water in a channel or directly by returning water of altered quality to the river channel. To properly assess water use projects, a description is required for historic (i.e., natural) water quality, present conditions, and predicted conditions with the proposed project. A set of parameters has been identified for monitoring at water use projects (see Table 3 in Lewis et al. 2004). At a minimum, information provided must include an emphasis on temperature, low-level macro-nutrient parameters (N, P), total alkalinity and electrical conductivity ($\mu S\ cm^{-1}$). Additional parameters may be required by the regulatory agencies where there are site-specific issues.

Recommended methods are as follows:

1. If water quality is monitored using discrete grab samples, the procedures presented in the Ambient Fresh Water and Effluent Sampling Manual (RISC 1997b) are to be followed. The frequency of sampling, number of replicates, unit of measurement, and specific comments are provided in Lewis et al. (2004). For discrete grab sampling all parameters require three replicates per site. The minimum detectable concentration (MDC) must be specified for each parameter.
2. There are critical periods for measurement of some parameters. These will vary among streams and must be identified by a qualified professional in consultation with regulatory agency personnel.
3. For temperature assessment, continuous (automated) recording thermographs should be installed and set to collect water temperature every two hours or less. Two replicates are specified to reduce the chance of data loss or corruption.
4. Continuous (automated) monitoring of pH, conductivity, temperature, turbidity, dissolved oxygen, total dissolved solids, chlorophyll, nitrate, ammonia, chloride, depth and flow is now readily done with available technology. When planning detailed assessments, proponents should consider the greater sample size that can be achieved with continuous data recording. If automated monitoring is conducted, the proponent is directed to follow the provincial methods standard (BC Ministry of Environment 2006).
5. Non-consumptive water uses such as hydroelectric projects will require a minimum of three water quality monitoring sites: one upstream of the project, one in the diversion section, and another downstream of the powerhouse. The location of sites within each stream section may vary depending on site-specific conditions and the water quality parameter(s) being measured. Further discussion of site selection considerations is provided in Lewis et al. (2004).

6. Several RISC manuals provide guidelines for designing and implementing a water quality monitoring program (see http://ilmbwww.gov.bc.ca/risc/pubs/aquatic/index.htm).
7. Proponents should ensure that water quality data collection follows the procedures in the methods standards for quality control and assurance.
8. Information submitted by water licence applicants should meet or exceed the standards published by the Resources Inventory Standards Committee (see http://ilmbwww.gov.bc.ca/risc/ .

Deliverables for water quality information should be presented in a manner that communicates a project's effects at all times of the year. The RISC manual "Guidelines for interpreting water quality data" (RISC 1998b) provides detailed direction for screening, editing, compiling, presenting, analyzing, and interpreting water quality data. Water quality data are to be sent to the provincial databases: EMS for discrete sample data and WIDM for automated (continuous) data.

The following minimum data requirements are expected:

1. 1:20 000 scale (or less) detailed maps identifying water quality sampling sites. All sites are to be georeferenced and given an EMS Identification number.
2. Tables showing water quality by site and sampling period for each parameter. MDL and QA/QC information should also be presented.
3. Summary table showing average and variance in water quality for each reach and stream section for each parameter.
4. Graphs of each water quality variable by sampling period with relevant water quality guideline shown on the graph.
5. Photographs of each water quality station (during any one sampling).
6. An appendix with laboratory results and water quality field notes.

1.6 Hydrologic Information

The LWBC Hydrometric Guidelines (2004) provide extensive detail of the information required for water licensing, but is summarized for the Development Plan as follows:

1. At least one year of on-site hydrometric data, including:
    a. a description of the monitoring site and equipment used
    b. a minimum of ten discharge measurements, well-distributed through the range of flows experienced in a typical year (e.g., 10% to 200% MAD)
    c. photos of the site at high and low flow limits of the discharge and stage measurements
    d. chronological record of site visits with copies of original gauging notes and level check notes
    e. chronological summary of gauge level checks indicating all applicable gauge corrections
    f. a fully documented methodology for generation of rating curve and flow estimates
    g. rating curve and regression ANOVA using statistical software (e.g., JMP, SPSS); details are specified in LWBC (2004)
    h. quantitative estimates of error and bias, along with associated discussion.

2. Regional analysis, including:
    a. map of long-term WSC stations in the area of interest showing stations selected for regional analysis
    b. a regional station table summarizing key basin characteristics and flow statistics for regional WSC stations
    c. description of the criteria employed to select candidate stations for regional analysis
    d. description of the methodology used in regional analysis
    e. discussion of error analysis.
3. Stream flow estimates, integrating onsite data and regional analysis:
    a. plot of collected on-site daily data superimposed on concurrent daily discharge from WSC station(s) used in regional analysis
    b. regression analysis quantitatively defines relation between on-site data and WSC station(s) used in regional analysis
    c. stream flow estimates: MAD, MMD, 7-day average low flow (estimated over four return periods: mean annual, 5, 10 and 20 year), and peak flows (estimated over five return periods: mean annual, 5, 10, 20 and 200 year).
    d. formal comparison of the various unit runoff values derived
    e. flow duration curves: mean annual and monthly flow duration curves (both natural and diverted plant flow should be identified) with an explanation of any correction factors
    f. summary table and plot of mean monthly flows for 5-, 10- and 20-year dry and wet Return periods
    g. discussion and quantitative estimates of error and bias.
4. If local inflow to the diversion section exceeds 10% of MAD at the intake, an additional time series of baseline and post-project flow conditions should be calculated at the powerhouse.

1.7 Geomorphic Information

Ecological and geomorphological processes can be altered by water use, so potential changes in these processes and potential impacts to aquatic and riparian fish habitat must be addressed. Guidelines for assessments of these processes are described in Lewis et al. (2004); however, the level of detail provided is more general than for other assessments, such as fish habitat. The value of ecological processes to fish and aquatic habitat are not well-understood, however, five discrete functions have been identified:

1. Flushing flow – removing sediment and organic debris from gravel substrates,
2. Channel maintenance – recruiting gravel and large organic debris to stream channel through erosion, transport and sorting of substrate,
3. Flood pulse – alternately wetting terrestrial habitats, providing access for fish and fertilizing floodplains with dissolved nutrients, and drying them, allowing for rapid terrestrial growth that in turn supports aquatic life during periods of wetting,
4. Connectivity – linking stream channel habitats with off-channel and riparian habitats, and
5. Source of behavioural cues – initiating critical behavioural changes in fish, such as inducing migration in response to flow change.

These functions may not be relevant to all stream reaches. Thus, each issue should be addressed by presenting appropriate physical (hydrology, geomorphology) and/or biological (habitat or behaviour) data to demonstrate the importance (or lack thereof) of the issue as it relates to the proposed project. To address ecological considerations, proponents should answer the questions and provide information on the five points above as directed in Table 5 of Lewis et al. (2004). Specific methods are not identified to address these functions because of the general absence of consistent, formally-defined methods. Proponents should rely on the guidance of qualified professionals.

The purpose of a geomorphology assessment is to assess whether project-induced changes in stream flows will alter the relationship between flow, sediment, and channel form, with concomitant impacts to fish habitats. An assessment is required to describe natural channel conditions, whether previous land and water uses have altered channel conditions, and to what extent the proposed project will alter present channel conditions via water diversion and changes in throughput of sediment and/or large woody debris. Channel geomorphology may influence the nature of project impacts to fish and should be evaluated at an overview level by an experienced certified professional (P.Eng. or P.Geo.) with experience in geomorphology, geology, geotechnical engineering, or a similar field. Detailed geomorphology assessments will be required where changes in flows could alter fish habitat via alteration of sediment transport and large woody debris. The decision to pursue a detailed geomorphology study must be made by an experienced professional as described above, and a convincing explanation for not pursuing such detailed studies must be provided, along with references to similar projects where impacts to sediment transport and channel condition were negligible.

The deliverables for a geomorphic assessment are as follows:

1. Overview-level geomorphological analysis is usually completed with aerial photograph interpretation. The availability of TRIM data and orthophotos allows use of GIS-based tools for analysis of watershed features. Maps at 1:50 000 and 1:20 000 scales are required to present information on watershed characteristics, channel conditions, and sediment sources.
2. Locations of off-channel habitats, wetlands, and areas of seasonal flooding should be identified on 1:20 000 maps.
3. Table 3 of Lewis et al. (2004) will be completed and supported by data including physical measurement, photographs, and detailed mapping, where appropriate.
4. A detailed study will describe, for the project watershed, the watershed physical characteristics, the physical channel condition, influences of water and land use on channel processes, and potential impacts of the proposed water use on present and future conditions. Detailed geomorphologic data are typically collected by field-based surveys and investigations. The type, measures, and methods of data collection are varied, and guidance can be found in the published literature and government publications. Additional requirements for a detailed study can be found in Lewis et al. (2004), along with references to publications that provide guidance on study methods.
5. In addition to instream geomorphic issues, there is a requirement to conduct a terrain stability assessment in relation to all project infrastructure.

1.8 Impact Assessment for Fish

Lewis et al. (2004) provide a conceptual framework for the impact assessment. When designing the impact assessment, site-specific information, the scientific literature, and professional judgment should be used to identify key environmental variables, time periods, and study locations. Impact assessment can be simplified if critical life history periods or production bottlenecks can be identified. For example, low flow conditions during the growing season are considered to often result in habitat limitations for juvenile salmonids and create habitat bottlenecks that limit productive capacity. In such cases instream flow studies should focus on defining habitat conditions during the low flow period for those species and life stages of interest.

Based on an expanded version of the steps from Section 4.1.1.10 of Lewis et al. (2004):

a) Identify the species of concern. Note that there may be more than one.
b) Identify all limiting life stage(s) for the species of concern.
c) Identify habitat parameters that are most important to the species of concern.
d) Identify the habitat and flow needs by month for each species and life stage of concern.
e) Identify critical time period(s) for the species and life history(s) of interest.
f) Calculate habitat quantity for the life stage/species of concern within the reaches/mesohabitats of importance during the critical period. There may be multiple critical periods as there are for "habitat bottlenecks."
g) Calculate and graph flow exceedence curves by month for two flow states (natural baseline and post-project).
h) Calculate the duration and magnitude of low flows by season under baseline and post-project conditions.
i) Calculate physical habitat as a function of daily flow for each day in the critical period, using the historic flow record under baseline and post-project conditions. Also consider over-wintering habitat requirements compared to summer habitat defence periods.
j) Compare baseline to post-Project conditions (tables, graphs)
k) Use site-specific information, scientific literature, and professional judgment to interpret the biological significance of the estimated changes in habitat.

Implicit in these steps (a to k) are the following requirements:

1. Establishment of no less than five surveyed cross-sections at locations within the diversion reach deemed by a Professional Biologist to be limiting for maintenance of fish populations at the proposed instream flow regime. Post-project audit will confirm whether the habitat-flow analysis is correct or subject to further refinement.
2. Photographs at several locations within the diversion reach (including the five cross-sections) at a known discharge, preferably near the lowest instream flow proposed by the proponent. In place of onsite inspection by agencies, this allows a quick perception check.
3. Analysis of changes in hydraulic properties at the cross-sections as a function of stream flow. Methods of analysis may be simple (e.g., Riffle Analysis using approved H.S.I. curves, At-a-station hydraulic geometry) or detailed (PHabSim) but must follow standard protocol. A detailed description of the methodology required to design and collect these data is presented in Appendix A of Lewis et al. (2004).
4. Proposed instream flows tabulated on a monthly basis (or bi-weekly, if appropriate), expressed in three flow metrics: flow (L s^{-1} or m^3 sec^{-1}), as a percentage of mean annual

discharge (i.e., % MAD) and as the return period of an equivalent 7-day low flow. Proposed instream flows must also be shown graphically, overlaying fish periodicity and residual flows, completed for average, drought and wet years. The analysis must be done for an average year, a drought year (e.g., year has a 7-day low flow with a return period >10 years), and a wet year (e.g., year includes a flood discharge with a return period > 10 years), using specific time benchmarks (e.g., 1976 as a wet year). The instream flows must clearly indicate all periods and water year types during which no diversions will occur.

5. Discussion and professional assessment of how proposed instream flows will impact fish periodicity, abundance and distribution via mechanisms associated with changes in water quality (as per Sections 1.5 and 1.8). Note that for items 5 to 9 the channel response in the diversion section will be affected in part by sediment and LWD inputs, past the dam (Section 1.15).
6. Discussion and professional assessment of how proposed instream flows may affect fish access to habitats within the affected reaches, as well as tributaries and off-channel habitats.
7. Discussion and professional assessment of how proposed instream flows will affect ecological function via Flushing Flows and channel maintenance, Flood Pulse, Connectivity, Source of fish behavioural cues, Passage and spawning flows (as per Sections 1.7 and 1.8).
8. Discussion and professional assessment of how proposed instream flows will alter stream lateral and vertical channel stability (as per Sections 1.7 and 1.8).
9. Discussion and professional assessment of how proposed instream flows will alter quantity and quality of mesohabitats for fish (as per Sections 1.4, 1.7 and 1.8).
10. Discussion and professional assessment of how proposed instream flows will impact other species within the Project Area (as per Sections 1.9 and 1.10).

Deliverables for the instream flow assessment:

1. The impact assessment is the point at which all project-related information is brought together to assess the effects of flow alterations on instream and riparian values. Reports should describe methods and results for all information needs noted in Section 0 of this document, that are relevant to determining the effects of flow alterations on fish and fish habitat. The report should be prepared following formats suggested in Council of Science Editors (2006). Example documents may be available from agency staff.
2. Presentation and analysis of microhabitat data including:
    a. Tables of transect-specific data such as georeferenced transect location, channel width (m), wetted width (m), mean depth (m), mean velocity (m sec^{-1}), and useable weighted width (m). It is appropriate to provide some discussion of how transect sites were selected, and how representative these habitats are of areas in the diversion reach.
    b. Plots of wetted width, mean depth, mean velocity, and useable weighted width as a function of flow for each transect.
3. Lewis et al. (2004) provide an example of how to apply these ten steps in an impact assessment and show examples of the tables and graphics required to present the data.
4. Statistical confidence must be presented for each component of the analysis, including the empirical relationship between habitat and flow. The assessment should include a comparison of impact magnitude and statistical confidence intervals.

5. The assessment should include a discussion of the biological significance of changes in comparison to the results of similar studies in the grey or scientific literature.

1.9 Impact Assessment for Macroinvertebrates

Macroinvertebrates and their habitats are often considered in instream flow assessments in an effort to preserve food sources for fish, because many fish species, including all stream-rearing salmonids, depend on drift of invertebrates from upstream areas. There are no existing provincial guidelines for sampling and analysing invertebrate drift, although efforts are underway to produce such guidelines. Invertebrate sampling methods and deliverables are presented in detail in Appendix A, and are summarized below.

Abundance and distribution of macroinvertebrates in the drift should be characterized through the use of drift samplers. Methods for selecting study sites, deploying drift nets, and a variety of study-related issues are presented and discussed in Appendix A. The primary science literature on this subject is large and should be used as an additional guide. All project assessments will require at least one year of data on macroinvertebrate drift. Additional pre- and post-project sampling may be required as part of a monitoring program (see Section 1.14).

Drift sample data should be tabulated and graphed for presentation to show seasonal and locational patterns in diversity, abundance and biomass. Taxonomic data should be used to characterize the taxonomic makeup of the drift. Analyses of invertebrate abundance and biomass will examine within- and, where possible, among-year trends. It is expected that the primary measure of invertebrate abundance will be biomass and quantity rather than diversity. Variance in seasonal and locational abundance must be estimated and discussed.

In terms of deliverables, it is expected that an assessment of invertebrate production will be primarily descriptive and provide a reference point for biological productivity in a stream. Invertebrate sampling will also create a baseline for post-project monitoring and comparison. In some cases, regulators may require impact assessment procedures based on invertebrate habitat suitability methods.

1.10 Impact Assessment for Wildlife and Species-at-risk

A Development Plan must include an impact assessment of wildlife and protected species (e.g., species at risk, regionally-significant species, etc.). The assessment should follow the most up-to-date guidelines available from MOE (see http://www.env.gov.bc.ca/wld/serisk.htm); as of November 2006, it is recommended that proponents use the "Draft Guidelines for Dealing with Development Effects on Species and Ecosystems at Risk" (see http://www.bieapfremp.org/Toolbox%20pdfs/SAR%202006.pdf). Irrespective of the guidelines used, the assessment should include:

1. Presence/absence assessment on red and blue listed animals, plants and plant communities, COSEWIC and SARA listed species and regionally significant species as identified in the Preliminary Project Description. (Also a requirement of the preliminary project description.)

2. An assessment and summary of project construction and operation effects on identified red and blue listed species and ecosystems, SARA-listed species and regionally significant species.
3. Consideration of how project construction and operation will affect Wildlife Habitat Areas (WHA), Ungulate Winter Ranges (UWR) and other habitats requiring assessment or protection under the Wildlife Act. Field verification of information provided in the Preliminary Project Description (i.e., based on the IWMS website for WHAs, http://www.env.gov.bc.ca/wld/frpa/iwms/index.html) may be required, based on input from an experienced wildlife biologist.
4. Consideration of cumulative impacts to wildlife and habitat (see Section 1.12).

OTHER IMPACTS, MONITORING AND OPERATIONAL PLANS

1.11 Construction and Footprint Impacts

Construction-related impacts are those incurred during the construction phase of a project, and may be associated with activities such as land clearing, grading, and instream construction. Impacts are generally short-term and may include effects such as increases in suspended sediments, or other temporary disturbances to aquatic habitat. Where construction activities may cause HADD, proponents are requested to discuss permitting requirements with DFO. Proponents should also be aware that Water Stewardship Division maintains a regulatory interest in "work in and about a stream" through the BC Water Act, and may provide input to mitigation plans and measures. A number of best management practices (e.g., instream work windows) are provided on MOE regional websites (http://wlapwww.gov.bc.ca/regops/index.html).

Footprint impacts are generally long-term effects from the construction of a water use project. Displacement of aquatic habitat at the site of a dam, headpond or powerhouse is an example of a footprint impact. Such impacts may require a Fisheries Act authorization from DFO and habitat compensation. Proponents are requested to discuss this topic directly with DFO.

1.12 Cumulative Impacts

The term "cumulative effects" has been used in different ways. It refers here specifically to the combined effects on the environment from separate activities, including other hydroelectric projects within the region, and activities that are not associated with the proposed project. The emphasis of a cumulative effects assessment (CEA) is the interaction of multiple activities to produce an environmental impact. CEA has been promoted as a necessary part of impact assessments because the effects of unrelated activities (say for example, fishing and forestry) when assessed individually may be considered insignificant, but the incremental effects when measured together may be considered significant. Assessment of cumulative effects is now required by federal legislation when a project is subject to a federal environmental assessment under the *Canadian Environmental Assessment Act*.

Potential cumulative impacts may occur to the natural and the human environment. The biophysical, social, and economic parameters considered by a CEA may include, but are not necessarily limited to: Aesthetics, Economy, First Nations Interests, Fish and Fish Habitat,

Flooding, Navigation, Water Quality, Wildlife and Wildlife Habitat, Fishing, Hunting, Mining, and Recreation.

Cumulative effects assessments are a federal responsibility, and project proponents are encouraged to discuss requirements with federal regulators. Some information on this subject is available on the Environment Canada website (http://www.ec.gc.ca/ea-ee/eaprocesses/cumulative_effects_e.asp) including a "Cumulative Effects Assessment Practitioners Guide" (Hegmann et al. 1999). Project proponents should be aware that CEAs usually require input from a qualified professional.

1.13 Mitigation and Compensation

Mitigation refers to measures taken to avoid or reduce the likelihood of negative impacts of construction and operation of an intake or diversion. Compensation on the other hand, refers to intentional activities undertaken to offset inevitable impacts once they occur. Compensation offsets negative impacts by providing benefits elsewhere in the system. Thus, the purpose of mitigation is to avoid impacts, whereas the use of compensation implies acceptance of impacts. The requirement for mitigation and compensation are outlined in DFO's "no net loss" principle (DFO 1986, 1995), which states that "the Department will strive to balance unavoidable habitat losses with habitat replacement on a project-by-project basis so that further reductions to Canada's fisheries resources due to habitat loss or damage may be prevented" (DFO 1986).

Mitigation is a superior option to compensation, and proponents are expected to develop mitigation measures to ensure the fish resource is protected during construction and operation of the proposed project. Where habitat alteration, disruption or destruction (HADD) is unavoidable and a Fisheries Act authorization is required, proponents are instructed to develop and submit compensation plans to compensate for habitat impacts and ensure that compensation is effective. Whether habitat compensation is required, and the exact nature of the compensation, is outside the scope of this document. Proponents are encouraged to discuss compensation requirements with DFO staff.

1.14 Monitoring Program

Monitoring is the cornerstone of effective resource management, providing the feedback that allows post-implementation assessment of management decisions and programs. At present, there are no existing provincial guidelines for monitoring of small hydropower projects. Suggested methods and deliverables are presented in Appendix A, and are summarized below. The underlying logic for monitoring and many of the considerations of an effective monitoring program are discussed in detail in Hatfield et al. (2003).

The suggested monitoring methods for small hydropower projects rely on data collected for the project impact assessment and similar data that would typically be collected following project approval and implementation. Data requirements differ depending on the presence or absence of fish in the project area. Project streams with fish present should monitor a minimum of fish abundance and invertebrate drift during base flow conditions. Where specific concerns arise during the project assessment (e.g., water quality) at least one additional variable may need to be monitored. In project streams with no fish present, proponents should monitor a minimum

of invertebrate drift during base flow conditions. Where specific concerns arise during the project assessment (e.g., water quality) at least one additional variable may need to be monitored. Thus, a minimum of two or three variables will be monitored in fish-bearing streams, and one or two variables will be monitored in non-fish bearing streams. The number of variables required for monitoring will be determined in consultation with regulatory agencies. Where high value anadromous fisheries are present, required monitoring effort may increase.

The most appropriate design for a biotic response monitoring program is a Before-After, Control-Impact (BACI) design, in which "control" sites (i.e., streams or reaches without water withdrawal) are monitored simultaneously with "impact" sites for a predetermined period both before and after project implementation. Appendix A discusses selection of study sites for monitoring, and considerations in the overall monitoring study design, including selection and measurement of primary and secondary monitoring variables.

Based on minimum statistical considerations, monitoring should be conducted for several years, and include pre- and post-project data. Appropriate experimental designs can be developed using the web-based tool at: http://www.stat.sfu.ca/~cschwarz/Consulting/Babakaiff/, and regulatory staff can provide examples of good monitoring programs. Sampling should be carried out in a standardised manner and follow a specified schedule to ensure consistency among years in data quality and collection procedures. A data report that discusses inferences and presents conclusions should be prepared annually, and summarizes the year's findings and data collected to date. All raw data should be included in appendices and submitted to the regulatory agencies in pdf format for archiving. A final report should be prepared at the end of the monitoring program that summarizes results of the entire program, discusses inferences pertaining to project impacts, and presents conclusions concerning the management questions posed. Additional considerations in providing these deliverables are discussed in Appendix A.

The Monitoring Program must be suitable to determine the nature of impacts of the project on fish and wildlife. This could include:

a) monitoring of flows to ensure sufficient water to maintain fish passage and populations, especially during periods of low flow,
b) compliance and effectiveness monitoring of compensation activities,
c) monitoring to ensure that screening of water intakes is effective in preventing entrainment of fish into the penstock, and
d) monitoring to ensure that post-construction sediment and erosion control measures are effective.

The operational monitoring program must include collection and analysis of no less than one year of pre-diversion fish abundance, and/or baseline data (e.g., macro invertebrate drift estimates) for species deemed to be impacted by the proposed project. These may include terrestrial species impacted during migration or from seasonal use of an area (e.g., grizzly bears, ungulates).

Compliance monitoring will require installation of a pressure transducer in diversion reach, and development of rating curve to convert measurements to stream flow. Flows are to be monitored continuously by the proponent so that any deficiencies in the instream flow are

identified, acknowledged and resolved. Flow data are to be submitted to Water Stewardship Division and Environmental Stewardship Division annually.

1.15 Operational Plans

Operational Plans describe the parameters and criteria by which a project will be operated. Operational plans are the purview of MOE where resident fish are present and DFO where anadromous species are present. At a minimum, the operational plans must include presentation and assessment of:

1. fish screening
2. flow ramping rates (see Cathcart 2005 for guidance), and
3. sediment and LWD management in the diversion reach (i.e., how will these be allowed to pass the diversion dam).

DATA SUBMISSION

Fish and Fish Habitat — As a condition of fish collection permits in British Columbia, fish and fish habitat data must be submitted to MOE. Collection permits are obtained through the Permit and Authorization Service Bureau (http://www.env.gov.bc.ca/pasb/). Data are to be submitted electronically through the Fish Data Submission process using Minimum Data Submission Standards and the required data Reporting Formats. To submit data, proponents must meet the minimum Data Submission Standards, however, if additional habitat and sampling information was collected, the process will allow inclusion of these data in the provincial databases. The Reconnaissance (1:20 000) Fish and Fish habitat Inventory: Standards and Procedures –Version 2.0, (RISC 2001) its errata, and other referenced documents present requirements for data collection, quality assurance, and submission to the provincial fisheries program.

Detailed fish habitat studies and impact assessments should be submitted to Regional MOE offices in hardcopy as part of the water license application. Electronic copies should be submitted to the Regional Environmental Stewardship Division (ESD) referrals coordinator in pdf form for electronic archiving.

Invertebrate, Wildlife and SAR Sampling — Baseline sampling data should be submitted to Regional MOE-ESD in hardcopy as part of the water license application. Electronic copies should be submitted in pdf form for electronic archiving.

Water Quality — Water quality data should be submitted to MOE into the appropriate Ministry databases, WQDMS, and Environmental Monitoring System (EMS) to provide wide access to the information.

Monitoring Data — All monitoring reports should be submitted to Regional MOE in hardcopy as part of the conditions of water license approvals. Electronic copies should be submitted in pdf form for electronic archiving.

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APPENDIX A

DETAILED METHODS FOR INVERTEBRATES AND MONITORING

INVERTEBRATE SAMPLING

Salmonid growth and abundance has been shown to be directly linked to the abundance of drifting invertebrate prey. Maintenance of food sources for fish is the primary motivation for studies of macroinvertebrates. Numerous studies have shown changes in invertebrate abundance and distribution in response to flow regulation, although the magnitude of biological response varies among locations and with characteristics of the regulated flow. Taxonomic shifts are common following large changes in flow regime. The concentration of invertebrate prey in the drift in a given stream, and how it changes as a consequence of water use, is a measure of both the productive capacity of the stream and how it responds to water use.

Recommended Methods

This section was written with significant input from J. Rosenfeld, Fisheries Section, Ministry of Environment.

Abundance and distribution of macroinvertebrates in the drift should be characterized through the use of drift samplers, which are vertically fixed nets that collect invertebrates suspended in the water column. Samplers are held in place with vertical stakes pounded into the substrate (e.g., quarter-inch diameter steel rod for removable sets, rebar, T-bar, or angle iron for permanent stakes that are left in the stream). Unlike Surber samplers, which can be used to gather benthic samples quickly and efficiently at any time of day, drift samplers must be set in the current and left to "fish" for an extended period. They should be placed in a location with an intermediate velocity so the net will collect a representative quantity of invertebrates without clogging. Drift sampling equipment may be conventional, fixed plankton-type drift nets (with a plastic or metal collar) or Mundie-style drift samplers (Mundie 1964; Field-Dodgson 1985; Figure 1). The drift samplers should use a 250 µm mesh to retain invertebrates of most importance to fish. General sampling procedures are discussed in Cavanagh et al. (1997). To ensure standardization within and across sampling programs, we recommend the following additional protocols. The design is based on monitoring information requirements and a power analysis assuming the following: coefficient of variation in drift samples = 50%, alpha = 0.05, power = 0.8, effect size = 50%. Some adjustments to the sampling protocols may be required depending on local conditions.

Invertebrate drift usually varies during the day, peaking at dusk and dawn and with generally higher rates at night than during the day. Drift-feeding fishes typically do not feed at night and often have peak feeding activity at dawn and dusk. It is best to sample drift in daytime to reflect prey abundances available to fish, but proponents should avoid sampling in mid-day in low productivity streams. To minimize variance associated with sampling time, equipment should be deployed for approximately four to six hours. In some cases (e.g., high drift abundance or high concentration of suspended solids that could clog the net) it may be necessary to undertake

multiple sets to achieve this duration, but it is preferable to set equipment in a location where multiple sets are not required. Sampling should begin at least one hour after dawn, with all sampling completed at least one hour before dusk. Proponents should indicate the time of day of sampling.

Considerable effort should be expended to ensure that sampling conditions are as similar as possible among years because results will vary with differences in flow, time of day, light levels, temperature, habitat types, trap placement, etc. Comparisons among sampling dates will be more meaningful if conditions are similar.

The number of sampling sites required is dependent on the length of the proposed diversion reach, but a minimum of three locations in the project stream should be sampled, with a goal of adequate representation of the affected stream reach. At least one of the sites should be within the proposed diversion reach, with at least one other upstream of the diversion, with the aim of assessing drift into and out of the diversions reach. The site in the diversion reach should be in a high productivity riffle (i.e., good invertebrate habitat) and upstream of significant local inflow (i.e., ~ 5% of total inflow in the reach).

All sample sites should be georeferenced, and in representative habitat in the downstream half of a riffle section. Small steep streams are often dominated by cascades and pools, so judgement by an experienced professional will be required to select appropriate sampling habitats. Habitats should be avoided where clogging of the net is likely over short durations. Clogging may occur from suspended solids, floating debris and high invertebrate drift. Clogging is most likely in high velocity areas where the net filters a high volume of water. As the drift net clogs, water is filtered at a much lower rate, ultimately making the sample unusable. Site selection is critical; ideally, nets should be set in areas with water velocities of 20 to 40 cm sec^{-1}. These areas tend not to have actively foraging fish (which could skew drift estimates by consuming drift directly upstream of nets) yet are slow enough to avoid filtering an excessive volume (which could clog sampling nets).

When setting drift nets, considerable care must be taken to minimize sediment disturbance upstream of the net so the user does not contaminate samples. If the user suspects contamination, the net should be reset after it is first emptied by turning it inside out and rinsing it in the water. Nets should not be set downstream of sites where substrate has been recently disturbed by setting of another drift net. The number of invertebrates collected in the drift is typically low, so that even minor contamination of drift with benthic invertebrates can seriously bias a sample. Upstream sample sites should be set before sites further downstream, and nets should be set while standing downstream of the net opening. Where possible, setting drift nets from shore may minimize stream bed disturbance. Samplers should be deployed so the top edge of the net is above the water surface to ensure representative sampling of drift organisms in the water column and on the water surface.

Five replicate samples should be collected at each site on each sampling day. Sites should be sampled at least twice during the main growing season (usually May through September), at low to moderate flows. Samples should be separated by at least one month. One sample should be taken during base flow conditions; the other sample should be taken within the growing season prior to the period of lowest flows because the early growing season tends to be most

important for fish growth. Drift samplers should be deployed simultaneously across the channel to ensure within-site spatial coverage. Thus, replication will occur both spatially and temporally. The following data are required to calculate volume of water filtered: water velocity at mid-opening of the sampler at start and end of set, duration of sample set, and area of submerged orifice (i.e., depth of water in the drift net opening and width of the opening). Note: since velocity fields vary considerably around the drift net it is important to ensure accuracy of calculations by measuring velocity right at the opening and not some distance ahead of the net. Current meters should be calibrated prior to each field trip. Other required data include date, start and end time of set, stream discharge, water temperature, and clarity.

Figure 1. Photos of conventional and Mundie-style drift samplers. (photos: left, J. Rosenfeld, middle and right, J. Sneep)

Samples should be preserved (see Cavanagh et al. 1997) for analysis in the lab, where they should be filtered, sorted into size classes, identified to family or genus, enumerated and weighed. Enumeration may rely on subsamples depending on the abundance of invertebrates in each sample. Taxonomic identification should be performed on at least one sample, with identification to the level of genus, where possible. Note that determination of size classes is more appropriately done by digitizing length and width of individual drift organisms, but this may be considerably more costly than using graduated mesh filters, and is therefore not required.

Deliverables

All project assessments will require at least one year of data on macroinvertebrate drift. Additional pre- and post-project sampling may be required as part of a monitoring program.

Abundance and biomass data should be expressed as units per m^3 of water, where volume is the amount of water filtered through the net during the set as calculated by, area × velocity × duration, with:

area = submerged area of sampler opening
velocity = (water velocity at start of set + water velocity at end of set) / 2
duration = time at end of set - time at start of set

Units of measurement are thus defined as $(m^2) \cdot (m\ sec^{-1}) \cdot (sec) = m^3$. Note: the equation for velocity assumes a linear decay in filtering efficiency. The equation may need adjustment if multiple sets are used or if the user wishes to assume a nonlinear decay in filtering efficiency.

Drift sample data should be tabulated and graphed for presentation to show seasonal and locational patterns in diversity, abundance and biomass. Taxonomic data should be used to characterize the taxonomic makeup of the drift. Analyses of invertebrate abundance and biomass will examine within- and, where possible, among-year trends. It is expected that the primary measure of invertebrate abundance will be biomass and quantity rather than diversity. Variance in seasonal and locational abundance must be estimated and discussed.

It is expected that an assessment of invertebrate production will be primarily descriptive and provide a reference point for biological productivity in a stream. Invertebrate sampling will also create a baseline for post-project monitoring and comparison. In some cases, regulators may require impact assessment procedures based on invertebrate habitat suitability methods.

MONITORING

Monitoring allows post-implementation assessment of management decisions and programs. There are essentially two types of monitoring, compliance monitoring and biotic response monitoring. Compliance monitoring measures water use to ensure a user is complying with the conditions of a water license, or it may include monitoring of water quality, channel morphology, or other physical states where conditions have been articulated in regulations and permits. Compliance monitoring may also apply to habitat compensation works to ensure that they are physically stable and performing adequately.

Biotic response monitoring is often conceptually more difficult, involving a test of whether compliance with flow decisions results in the expected outcomes on the target ecological resources (e.g., fish populations, fish habitat, and invertebrate production). Biotic response monitoring is essentially an experiment. Since biological responses are difficult to measure and variable in space and time an effective monitoring program must be designed to address the complexity of relationships between biological responses and flow, and to account for external factors (i.e., non-flow related) and natural temporal variations. The overriding argument for implementing a biotic response monitoring program is recognition of the current uncertainty in predictions of biological response (e.g., fish abundance) to changes in environmental conditions (Ludwig et al. 1993; Castleberry 1996). Any justification for exceeding current water use standards should be evidence-based and built on the foundation of a rigorous monitoring program.

This section lays out methods and deliverables for biotic response monitoring of small hydropower projects. The suggested monitoring methods rely on data collected for the project impact assessment and similar data that would be collected following project approval and implementation. Continuous measurement of stream discharge in the diversion reach will be required as a component of compliance monitoring, but data requirements associated with biotic response monitoring differ depending on the presence or absence of fish in the project area. Project streams with fish present will require at a minimum collection of fish abundance and invertebrate drift abundance during base flow conditions. Where specific concerns arise

during the project assessment (e.g., water quality) at least one additional variable will need to be monitored. In project streams with no fish present, the monitoring program will consist of a minimum collection of invertebrate drift abundance during base flow conditions. Where specific concerns arise during the project assessment (e.g., water quality) at least one additional variable will need to be monitored. Thus, a minimum of two or three variables will be monitored in fish-bearing streams, and one or two variables will be monitored in non-fish bearing streams. The number of variables required for monitoring will be determined in consultation with regulatory agencies. Where high value anadromous fisheries are present, required monitoring effort may increase.

Recommended Methods

General Program Design

The most appropriate design for a biotic response monitoring program is a Before-After, Control-Impact (BACI) design, in which "control" sites (i.e., streams or reaches without water withdrawal projects) are monitored simultaneously with "impact" sites for a predetermined period both before and after project implementation. Control sites will generally be chosen upstream of the POD, and impact sites will be within the diversion reach. At a minimum, biotic response monitoring should be conducted for two years prior to construction and flow diversion and five years post construction. The suggested monitoring design is based on a power analysis assuming the following: coefficient of variation in samples = 50%, alpha = 0.05, power = 0.8, effect size = 50%. Some details of the monitoring program will require consultation with regulators, but the following sections lay out the primary monitoring variables and methods. Proponents should use the web-based tool at: http://www.stat.sfu.ca/~cschwarz/Consulting/Babakaiff/ to incorporate statistical considerations into the experimental design.

Considerable effort should be expended to ensure that sampling conditions are as similar as possible among years because results vary with differences in flow, time of day, time of year, temperature, weather, habitat type, water clarity, net placement, etc. Comparisons among sampling dates will be more meaningful if conditions are similar. Project planning and timing of field studies can be facilitated by targeting a specific stream discharge within a particular calendar period rather than aiming solely for a particular calendar date each year. Gauges are typically installed early on for most projects (see LWBC 2004), so these data are usually readily available for planning purposes.

Primary Monitoring Variables

The primary variables for project monitoring are biomass and abundance of fish and drifting macroinvertebrates. To be maximally useful, monitoring indicators must be relevant, reliable, responsive, comprehensible, and defensible. The rationale for selecting population-level monitoring indicators is that they meet all of these criteria and no alternative indicators are superior at this time. In the past, some proponents have suggested programs to monitor fish habitat, but this is generally inferior to measuring fish abundance since the aspects of fish habitat that limit fish abundance are poorly understood and generally do not transfer well from one watershed to another. The rationale is discussed at length in Hatfield et al. (2003).

Just as modern cars come equipped with several gauges for monitoring speed, engine temperature, oil pressure, etc., one generally seeks to construct a suite of indicators to monitor several aspects of the environment. The program proposed here suggests monitoring a minimum of two variables on fish-bearing streams, and only one on non-fish bearing streams. Additional variables may be required, as determined through the impact assessment and permitting process.

Fish Abundance and Biomass — The primary question to be addressed through monitoring of fish is whether biomass and abundance of fish change significantly following construction and operation of a small hydropower project. This question is relevant only to fish-bearing streams. Methods for collection and analysis of fish data are presented in more detail in Section 0 and the reports and standards cited there; these methods are expanded briefly here to account for the needs of the monitoring program.

Monitoring of fish abundance and biomass will focus on the target species selected in the project impact assessment (see Section 0). There should be a minimum of two reaches selected for study: a "control" reach upstream of the proposed POD, and an "impact" reach in the diversion section. Additional reaches may be required depending on the resources being affected or the proposed project configuration. Sampling in the impact reach should focus on high quality fish habitats that are most likely to be affected by the project. For this reason, the most appropriate experimental sites are likely to be near the POD. A control site below the diversion reach should only be selected if fish are not present above the proposed POD.

It is expected that fish sampling will be conducted using multiple-pass electrofishing as the primary method. Stop nets should be used to encompass individual sample areas of at least 100 m^2. In systems where fish are scarce smaller areas may not have sufficient densities for analysis; where fish are more abundant sub-sampling may be required for collection of individual fish data. There should be a minimum of five replicate sample sites in each of the control and impact reaches.

It is important to use the same sampling sites each year, which will allow paired comparisons in statistical tests and thereby greater statistical power. All sampling sites should therefore be georeferenced, photographed and marked in the field to allow the same location to be used repeatedly across years. Timing of sampling programs will be dependent on the species and life stages being targeted for study and the local geography and climate, but typically it is expected that sampling will occur during low flow periods in the primary growing season for fish. Sampling should occur at least once per year.

Considerable effort should be expended to ensure that sampling conditions are as similar as possible among sampling dates because results may vary with differences in flow, time of day, time of year, temperature, habitat type, net placement, etc. Comparisons among sampling dates will be more meaningful if conditions are similar. Proponents should ensure consistency among sampling dates by establishing a transect within each sampling unit and measuring weighted useable width (see Section 1.4) on each sampling date. Sampling units should have consistently high usability and be within 10% of useable width values across all sampling times. Project

planning and timing of field studies can be facilitated by targeting a specific stream discharge within a certain time period rather than aiming solely for a particular calendar date.

To address the research question, biomass and abundance of fish should be compared before and after the project is built. Standard statistical techniques, such as ANOVA can be used to assess whether fish biomass and abundance have changed significantly as a result of the project.

Invertebrate Abundance — The primary question to be addressed through monitoring of invertebrate drift is whether biomass and abundance of drift organisms change significantly following construction and operation of a small hydropower project. This question is relevant to both fish-bearing and non-fish bearing streams, so invertebrate monitoring will be required in both stream types. To address the question, biomass and abundance of invertebrate drift organisms should be measured twice per year at three sites within the project stream. There should be five replicates per site. Methods for collection and analysis of invertebrate drift are presented in Appendix A.

To address the research question, biomass and abundance of invertebrate drift should be compared using standard statistical techniques, such as ANOVA.

Secondary Monitoring Variables

During project assessment and review it is possible that specific ecological variables will be identified that are deemed to directly affect stream productivity. Such variables may include temperature, ice cover, turbidity, nutrients, riparian conditions, or others. It may also be appropriate to monitor variables associated with stream channel morphology in the diversion reach if the proposed project has the potential to impact channel form and processes via altered transport of sediment and large woody debris.

Where such variables are identified and deemed important, one or more of these may be selected for inclusion in monitoring programs. Methods for assessing these variables are not addressed here, but in designing an appropriate program proponents should use designs and logic similar to that proposed for primary monitoring variables (e.g., similar targets for statistical power and spatial coverage).

Deliverables

Monitoring will be carried out annually for a period of at least 7 years: two years of pre-project data and five years of post-project data. Sampling will be carried out in a standardised manner and follow a specified schedule to ensure consistency among years in data quality and collection procedures. A data report will be prepared annually, summarising the year's findings, data collected to date, discussing inferences and presenting conclusions. All raw data will be included in appendices and submitted to MOE in pdf format for archiving. A final report will be prepared at the end of the monitoring program that summarises the results of the entire program, discusses inferences that can be drawn pertaining to project impacts, and presents conclusions concerning the management questions posed for the monitoring program.

Monitoring questions should be stated as hypotheses and tested separately for each monitoring variable on each target stream. Standard statistical tests (e.g., ANOVA) should be used to test for significant differences between control and impact sites, and between "before" and "after" samples.

Failure to reject the hypothesis of no change among sample groups would suggest that project-related changes had no measurable impact on variables being tested. There may be a number of reasons for such a result:

1. There was only a minimal response to project-related environmental changes,
2. The resolution of the monitoring program was too low to detect a change (too small a sample size),
3. The environmental change (e.g., flow changes) was too small to illicit a measurable ecological response (too small a treatment effect),
4. There is some other limiting factor that masks the ecological response to operational changes,
5. There were errors in methods or analysis, or
6. Some combination of the above.

The statistical resolution of the monitoring program should be determined through power analysis at the conclusion of the program when estimates of sampling error can be made. Results of the analysis will indicate the limits of detection for a change in fish and invertebrate population response and will put the results of the monitoring program into the proper statistical context.