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REPORT ON

PACIFIC SALMON FOUNDATION STRATEGIC SALMON RECOVERY PLAN SQUAMISH RIVER WATERSHED SALMON RECOVERY ASSESSMENT FRAMEWORK

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Strategic Salmon Recovery Plan Working Group

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was contracted to develop species-specific assessment frameworks (AF) to guide Pacific salmon and steelhead stock assessment initiatives in the Squamish River Watershed. The need for a conceptual AF was identified by the Squamish River Watershed Recovery Technical Advisory Committee. The Squamish River Watershed Recovery Plan identified that current stock assessment programs being conducted in the watershed serve different objectives that do not necessarily reflect the objectives, targets and goals of the Recovery Plan. As such it is currently difficult to assess the status of salmon and steelhead populations to enable the provision of advice regarding their recovery. These AFs will address goals and objectives specific to the Squamish River watershed but will be able to be incorporated into regional frameworks. They will provide guidance as to the level of effort and priority of stock assessment initiatives to be conducted in the watershed to achieve recovery of the target species.

2.0 PROJECT SCOPE

For the salmon and steelhead populations to recover there needs to be a means of assessing how many adult salmon return to the watershed each year and how many fish are needed for spawning to maintain a sustainable population over the long term. A major focus to achieve salmon and steelhead population recovery involves developing assessment strategies that are responsive to existing monitoring information regarding population trends within the watershed. Therefore, the first task is to develop an AF to describe the type of information required to provide advice on salmon recovery, describe a means of acquiring the information, and describe procedures that will be used to generate advice from the information gathered. All assessment programs will need to incorporate Recovery Plan goals and objectives. General population objectives for Squamish River watershed salmon and steelhead as stated in the Recovery Plan (PSF 2005) include:

- Enough spawners return each year to the watershed to sustain salmonid populations in future years; and,

- Maintain healthy, wild origin spawning populations within the watershed.

The project scope included a review of regional management frameworks, including the Wild Salmon Policy (WSP), with particular focus on the use of Conservation Units (CU), the Pacific Salmon Treaty (PST), and the Draft Pacific Salmon Regional Assessment Framework (PSRAF). Review of these existing assessment frameworks provided a synopsis of general concepts and tools used in developing stock assessment and monitoring frameworks elsewhere. Applicable concepts from these existing documents were used to develop AFs for each target species in the Squamish River Watershed to meet specific objectives and goals outlined in the recovery plan.

Each AF defines general goals and corresponding stock assessment objectives that are inline with defined Recovery Plan objectives. Information requirements for each species was assessed and prioritized based on meeting Squamish steelhead and salmon stock objectives, targets and goals. Subsequently, procedures to be used in determining status (e.g., differing levels of assessment (intensity and financial), use of effective management units, indicator systems and reference points etc.) for each species was evaluated and provided when appropriate. A protocol for data management and information handling was also developed. It is intended that the AF be a living document with many elements provided at a conceptual level and will need to be modified and updated as information becomes available.

3.0 SUMMARY OF EXISTING ASSESSMENT FRAMEWORKS

The following documents were reviewed: DFO's Draft Pacific Region Salmon Assessment Framework (PRSAF), the Pacific Salmon Treaty (PST), and the Wild Salmon Policy with specific focus on the use of "Conservation Units". A brief overview of each document and its applicability to the development of an AF for the Squamish River Watershed are provided below.

3.1 Pacific Region Salmon Assessment Framework

The main objective of the draft PRSAF is to provide "…a description of the information required to provide advice for Fisheries Management, a description of the means of acquiring the information and a description of the procedures to be used for generating advice from the information gathered." (DFO 2005). The goal is to provide advice that encompasses requirements to protect biodiversity as well as manage the resource at an ecosystem level. The framework is primarily used by government, local non-governmental organizations and private consultants involved in providing advice on permissible harvest rates, management of fisheries and stock assessment programs. Once the AF is established, an operational assessment plan (OAP) is implemented which consists of a suite of projects and standards that will provide the necessary information identified in the AF.

3.1.1 Assessment Framework

The template for the PRSAF has the following sections:

- Assessment Unit & Resource Profile;
- Resource Management Goal;
- Resource Management Objectives;
- Information Requirements;
- Procedural Specifications;
- Data Management;
- Development of Communication of Advice;
- Performance Measures; and,
- Summary and Recommendations.

The Assessment Unit (AU) section describes the AU (and its multiple population units of relevance) covered by the AF. As well it can describe the relationships between all population units of interest (e.g., WSP Conservation units, PSC management units). Resource Profiles will not be provided in the AFs as a thorough review of the biological (e.g., distribution, population structure, habitats), genetic and geographic distinctiveness of each species is provided in the Squamish River Watershed Salmon Recovery Plan

(PSF 2005). In addition, it provides a brief overview of the fisheries that exploit the unit and socio-economic importance of the unit to those fisheries. A generic overall resource management goal is then provided followed by a prioritized list of specific management objectives which includes a categorical target exploitation rate to establish the planned intensity of harvest.

For the Information Requirements, four types are deemed necessary regardless of management objectives. These are:

1. Estimates of Permissible Exploitation Rate – measure of the AU productivity. If the AU is comprised with populations of differing productivities, then this needs to be characterized in the statement of minimally viable populations.

2. Biological Reference Points – these will be used along with escapement measures to determine the status of the AU. Again, heterogeneous productivity must be taken into account if applicable.

3. Unit-Specific Escapement – Temporal and spatial patterns of escapement will be the primary measures to determine status. Precision of measure will depend on current status of the unit and intended harvest intensity (i.e., these should increase proportionally). The rationale is to give sufficient warning of further declines and allow for timely interventions.

4. Unit-Specific Fisheries Mortality – This should include a description of the fisheries that directly and indirectly impact the stock unit.

The Procedural Specifications section will provide guidance in establishing methodologies required to fill information gaps and monitoring programs required and identified in previous sections. Status is usually determined by comparing the abundance of mature animals that spawn in a year with reference points (e.g., target and limit reference points) that describe future fishing opportunity. Alternately, status can be equated to the AU's probability of long-term persistence (i.e., estimated from abundance, population processes and possibility of adverse environmental conditions in the future). Regardless of what scheme is used at least one reference point must be specified, although most schemes will define four abundance zones: optimal, moderate, low and critical. This section includes specifications of methods.

The Data Management section will address issues of ownership, storage and dissemination of data as these are vital as the basis of all assessments. This is particularly important given the trend towards partnerships and joint stewardship in dealing with fisheries management. The draft PRSAF contains a list of specific data types, ownership, data systems and a general outline of where responsibilities lie for data and assessment tasks.

3.1.2 Operational Assessment Plan

The draft PRSAF's OAPs are prepared on an annual or multi-year basis. At minimum they outline the assessment programs and the responsibilities and accountabilities associated with them for each AU. Much of it requires either no annual changes or only updating and could be replaced by a reference to the AF. Components of an OAP include: area and population descriptions; status of AU; current assessment activities; current pattern of fisheries exploitation; management objectives and framework; mandatory and optional reference points; enhancement activities; summation of species habitat status; developing problems/conflicts; and bibliography. The OAP also requires an assessment plan which includes descriptions of all assessment projects (includes description of data generated and schedule of collection and availability) and a reporting plan.

3.1.3 Application to the Squamish River Watershed

Of the existing frameworks reviewed, the general approach and organizational structure of the PRSAF provides the most suitable set of guidelines upon which to base the Squamish River watershed AF. This is primarily due to its nature as an AF rather than a management framework. It allows for a focused definition of recovery objectives and goals and provides guidelines for assessing which information is available, lacking or required. The procedural specifications then define what methods and level of assessment will be required to fill those information gaps. The OAP then provides a means for implementation of the AF. Annual collaborative updating of the OAP will allow for rigorous analysis of current works as well as reiterations of roles, responsibilities and accountabilities associated with the AF. A few modifications to the PRSAF were considered in developing the AF specific to target species in the Squamish River Watershed and are described in Section 4.0.

3.2 Pacific Salmon Treaty

The PST is a salmon fisheries management framework originally signed by Canada and the United States in 1985, and revised in 1999 and 2002 and is based, in part, on the following two principles:

- Sustainable Use: aimed at preventing overfishing and providing for optimum production of Pacific salmon.

- Equity: intended to ensure that each party receives benefits from Pacific salmon stocks "equivalent to the production of salmon originating in its waters."

These two principles contribute to a framework that allows both the US and Canadian federal, state/provincial and tribal government officials to negotiate long-term agreements regarding commercial and recreational fisheries. As such this document does not provide specific recommendations for setting up a stock AF such as the PSRAF does. However, it does provide some insight as to how catch ceilings are related to abundance, thereby linking abundance estimates obtained through stock assessment programs to management.

In 1999, government-to-government negotiations culminated in the successful renewal of long-term fishing arrangements under the PST. Some of the key elements introduced with the 1999 Agreement include a move from fisheries based on negotiated catch ceilings to aggregate abundance-based management (AABM) fisheries. Under the AABM rules, target catches are made a function of an index of abundance, such that catch would decrease as the abundance index decreases. However, if the ocean abundance increased, then target catches could increase, but only to a level that still protected spawning escapements. The "abundance index" is a standard term used by the Pacific Salmon Commission to estimate the number of fish available to be harvested in a region (Peterman and Pyper 2000).

In addition to these standard rules, the AABM establishes criteria under which target catches must be further reduced. The PST defines several "escapement indicator stocks" with corresponding acceptable lower bounds. When the total escapement summed across all the indicator stocks *as well as* escapement of at least one other stock group fall below the lower bound for two consecutive years, then the reductions in target catches are triggered. The more stock groups that meet their criteria for low abundance, the greater the reduction in target catches for a given AABM fishery. There is also a clause that permits for "…additional reductions as necessary to meet the agreed escapement objectives". However, the PST does not specify those other objectives nor does the document determine what reductions in catch are needed.

In applying the AABM, the PST aims to fulfill its objectives of:

1. "…regulat[ing] the harvest of salmon in order to rebuild naturally reproducing stocks and sustain them at optimum production" (p. 2 of the cover letter signed by the two negotiators);

2. establishing a management program that: "... halts the decline in spawning escapements in depressed chinook salmon stocks, sustains healthy stocks and rebuilds stocks that have yet to achieve Maximum Sustainable Yield (MSY) or other biologically-based escapement objectives" (p. 12);

3. "...prevent[ing] further decline in spawning escapements..." (p. 31); and

4. "...achiev[ing] maximum sustainable harvest for a set of agreed key natural stock management units while maintaining genetic and ecological diversity... and... promoting rebuilding" (p. 33).

3.2.1 Application to the Squamish River Watershed

Based on the above review, the PST provides limited guidance towards the development of an AF for the Squamish River watershed, primarily because it was development as a management framework rather than a stock assessment framework. Given the current limited information on Squamish River watershed salmon and steelhead stock status, the use of the indicator systems alone may be inadequate from a conservation perspective. The use of indicator systems requires further evaluation to determine whether one system would be representative of stocks/watercourses that may be at risk in the watershed. If they are found to be highly correlated, than declining abundance of the indicator system may adequately protect stocks within the entire watershed. However, if this is not the case then situations could arise where an indicator stock is stable but other stocks that it is representing do poorly, therefore resulting in erroneous projections. To address these issues, supplemental monitoring programs of the entire system can be run concurrently for a specified period of time.

The PST mentions escapement goals that will produce the MSY, but it is known that this is not a desirable target reference point from a conservation point of view, although it may be appropriate for productive, high-abundance stocks (FAO 1994). Past research has shown that biological risks are greater for a population with its average escapement at the MSY escapement level rather than at a larger abundance. Although the PST states that the goal for spawner abundance should be "...MSY or other agreed biologically based escapement objectives" there is no guarantee that those "other" objectives will be more conservation-oriented, nor is there any statement forcing agreement on such objectives. Furthermore, as previously mentioned, the limited stock-specific data hinders establishing escapement goals for rebuilding (i.e., target reference points) as well as limit reference points.

The specification of limit reference points is also hindered by insufficient data and the PST does not define any limit reference point in terms of the specific objective of maintaining genetic and ecological diversity, in part due to the lack of defined management units. Instead, only a general reference point (i.e., the "lower bound" on the escapement) that is used to trigger additional reductions in target catches is defined. This "lower bound" is defined as the escapement at which the sustainable harvest is reduced by more than 15% from the MSY level. Given the difficulty of defining this escapement in the first place due to lack of data, placing an *ad hoc* lower bounds on escapement goals that are already imprecisely defined may be risky for the Squamish River watershed stocks from a conservation perspective.

In terms of application to the Squamish watershed, it is recommended that if target reference points are used in the form of escapement goals, or other measures of rebuilding, that they be defined in terms that adequately reflect the variability in productivity and abundances among groups of stocks. It is also suggested that, if target reference points are used, that effort be put into collecting more extensive and reliable data for stocks, especially those currently or potentially at risk, with an emphasis toward better estimation of target and limit reference points.

3.3 Wild Salmon Policy Conservation Unit

The WSP presents a management framework to guide future decisions about conserving wild salmon populations in B.C. and the Yukon. It defines the specific elements of wild salmon that should be preserved and discusses the nature of appropriate conservation limits. Most important, this policy identifies and describes processes for making management decisions about wild Pacific salmon. It stipulates an overall policy goal for wild salmon, identifies basic principles to guide resource management decision-making, and sets out objectives and strategies to achieve the goal. As such this document does not provide an AF for stock assessment but rather for stock management as a whole. A synopsis of the conservation units (CU) provides some insights as to how salmon populations are aggregated.

A main approach of the WSP is the use of CUs defined as aggregates of closely related populations with similar productivity and vulnerability to fisheries. These are used to ensure that evolutionarily distinct lineages are protected within geographic areas and are based on biological information including genetic variation, phenotypic traits (e.g., run timing, life history traits, ocean distribution), and aboriginal traditional knowledge if available. Since the requirements and needs of First Nations and others may be at finer geographic scales than some CUs, management objectives to address these may be recognized in the "Integrated Strategic Planning" component.

Further partitioning into smaller CUs is also an option if differences in habitat lead to significant differences in productivity or life history among populations that preclude their management as an aggregate. Conservation units may, therefore, comprise a single local population, an aggregate of many neighbouring local populations, or populations exhibiting a particular life history. Initially, identification of CUs are based on available information of genetic stock structure and the desired level of diversity to be maintained. The criteria for delineating CUs within each species are then reviewed and updated through scientific research.

It should be noted that the WSP places priority on maintaining genetic diversity within CUs, not on preserving individual populations that are at risk of extirpation due to random events. Straying from genetically similar populations within the CU is essential to replace genetic diversity lost through random genetic drift, or to repopulate habitat following extirpation from random demographic events. Thus, conservation of an aggregate of populations connected by straying is necessary to maintain genetic diversity and production in the longer term.

Once CUs are established, minimum and target levels of abundance are then determined for each CU. What is currently referred to as the spawning escapement goal (i.e., the desired abundance of spawners in a population) is termed the “target reference point.” This number of spawners would be identified for each CU and expected to meet ecosystem needs and provide as much sustainable catch as feasible in a year. The minimum acceptable spawning escapement required to ensure the long-term viability of each CU is defined as the “limit reference point”. Declines in escapement to levels approaching it would trigger fishing restrictions or other measures to ensure that the CU would not be put at risk of extinction.

3.3.1 Application to the Squamish River Watershed

A primary concern for the application of the WSP’s CU to the Squamish watershed is that the concept would not afford protection to local spawning populations of salmon given the large CU area. Instead, the objective appears to be a grouping of local spawning populations into relatively few and large CUs (i.e., there are believed to be over 9,000 spawning populations in BC to be grouped into fewer than 500 CUs – a level of diversity that does not take into account the distribution, status, genetic characteristics or spatial distribution of the spawning populations [PFRCC 2000]). Therefore, scenarios such as the elimination of a given Squamish-origin coho population would result in little or no action since the overall status of the larger CU (perhaps including other watershed areas) would not have declined enough to be a serious concern. Again, this is of particular concern since the implementation of the CUs is limited by the lack of current information and resources required to define the CUs and set the most appropriate and valid reference points.

4.0 SQUAMISH RIVER WATERSHED ASSESSMENT FRAMEWORK– GENERAL SETUP

Upon review of the above frameworks and stock assessment and management tools, an outline was developed for the Squamish River watershed AF. The outline generally follows the PSRAF as it provided the most explicit and comprehensive review of the AF strategies and was the most applicable on a local level.

The conceptual AF for guiding stock assessment initiatives in the Squamish River watershed consists of the following components:

- Assessment Unit (AU) – Description of the geographic management unit in which the stock is being assessed.
- Resource Recovery Goals – A statement of the overall goal of resource recovery for the unit.
- Resource Recovery Objectives – A prioritized list of the recovery objectives specific to the AU.
- Information Requirements – Information required to determine stock status in the watershed:
    - Reference Points – Biological reference points to which abundance is compared to assess recovery; and
    - Stock Abundance – current and historical stock status in terms of actual or relative estimates (e.g., escapement).
- Procedural Specifications – Procedures that will be used to assess stock status.
- Operational Assessment Plan – outline of assessment programs and responsibilities and accountabilities associated with them.
- Data Management - Procedures defining ownership, storage and dissemination of data.
- Development and Communication of Advice – Outline of document types and other communications required as a result of the AF process.

4.1 Assessment Units

Squamish salmon and steelhead stocks are currently managed as part of a larger DFO management unit (e.g., Strait of Georgia or Lower Fraser River aggregate). The lack of distinction of Squamish stocks in the management scheme makes it impossible to manage or assess recovery effectively. As such, assessment units based on biological units of relevance should be established for stocks in the Squamish River watershed. This circumstance clearly elucidates the need to find out as much about Squamish watershed stocks as possible in order to make a case for managing it as a distinct unit from Georgia Strait or Lower Fraser River aggregates. Therefore, initial stock assessment priorities will need to focus on determining the intra- and inter-distinctiveness of the Squamish stocks upon which management goals can be based and monitoring programs implemented as a way of assessing recovery. It may also be that stocks within the Squamish watershed comprise different units. As this is unlikely, the Squamish River watershed should be managed as one assessment unit until sufficient biological and/or genetic information becomes available to defend alternative management unit designation (i.e., the presence of distinct stocks within the watershed). Any future data that provides convincing evidence of discrete stocks within the watershed will be assessed and incorporated into the AF at that time.

4.2 Resource Recovery Goals

This statement will be general in nature and will present the overall goal of resource management for each species and each AU. The statement will likely be generic such as:

> “The goal is to allow for the recovery and subsequent maintenance of healthy, wild origin spawning salmonid populations within the Squamish River watershed. Spawner returns should allow for use by Squamish Nation and stakeholders as well as the establishment of long-term sustainable populations.”

4.3 Resource Recovery Objectives

Resource recovery objectives should include defined time frames by which each objective is to be attained. By identifying a time frame, the AF will provide a clear guidance structure to aid in providing a realistic framework for completion of the objectives. Identification of these objectives should be specific enough for a given group of knowledgeable people, given the description of the issue, to agree whether the goal had been met (Peterman and Pyper 2000). For example, all abundance goals should be stated in terms of a numerical goal and a timeframe. For chinook, if the interim population goal as stated in the recovery plan is deemed to be 5,000 fish, then a timeframe of perhaps 10 years should be stated. The goal then would be to obtain

5000 chinook in 10 years. It may then be sufficient to assess the population every 2-3 years. All freshwater habitat or process oriented objectives should also be specific in time, space and relative amount.

4.4 Information Requirements

Information gaps identified in the Squamish River Watershed Recovery Plan, in order of priority are as follows:

1. Determination of stock status
2. Determination of freshwater habitat status
3. Determination of estuarine habitat status
4. Level of community knowledge, support for salmonid resources
5. Assessment of key watershed processes influencing salmon stocks
6. Effects of climate change on salmon stocks

Although habitat, community education, and climate change issues are identified as requiring additional information, the priority of the AF, as previously stated, is to provide guidance for selecting stock assessments initiatives that will supply inputs for the determination of stock status. However, it is evident that stock assessment initiatives cannot be separated from habitat issues and therefore assessments/monitoring as proposed by the AF will undoubtedly also address some habitat issues (e.g., freshwater productivity).

Different levels of effort can be expended to fill in information gaps regarding stock status. More money and more detailed assessments would be required initially if none to little information is know about the status of a stock. Once adequate information is collected and an understanding of stock status is acquired, the level of effort and cost of assessments can be reduced. Field efforts then become focused on monitoring over the long-term. Figure 1 depicts this long-term shift in effort from detailed assessments to monitoring.

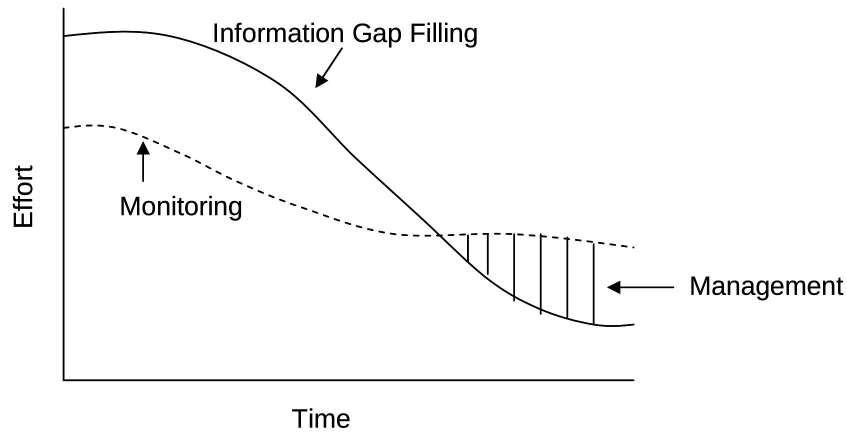

Figure 1. Effort required over time of information assessment versus monitoring to achieve appropriate management/recovery efforts (R. Bocking, pers.comm., September 2005).

The collection of information within the assessment and monitoring phases can be further defined into additional levels. One system was referred to as the Hierarchy of Assessment and was proposed by Dr. Kym Hyatt for the Nimpkish Watershed Salmon Recovery Process (McCorquodale, pers. comm., May 2005 Nimpkish Watershed Expert Advisory Team Meeting). Level 1 assessments provide information on indexes and trends of all species present in the watershed. Level 2 assessments provide information on productive capacities and life history characteristics (e.g., run size, timing, age structure). Level 3 assessments would be focused on species specific projects. DFO also has a level system for determining stock abundance with varying degrees of accuracy (e.g., relative vs. true abundance) and effort (T. Cone, pers. comm.., 2004). As such, assessment levels from the Hyatt model and DFO's model were combined to define assessment levels applicable to assessing stock status in the Squamish watershed. Here stocks assessment can be divided into two main areas: assessment and monitoring (Figure 2). Assessment is defined as the implementation of tools used to define a population status whereas monitoring is used to monitor its status.

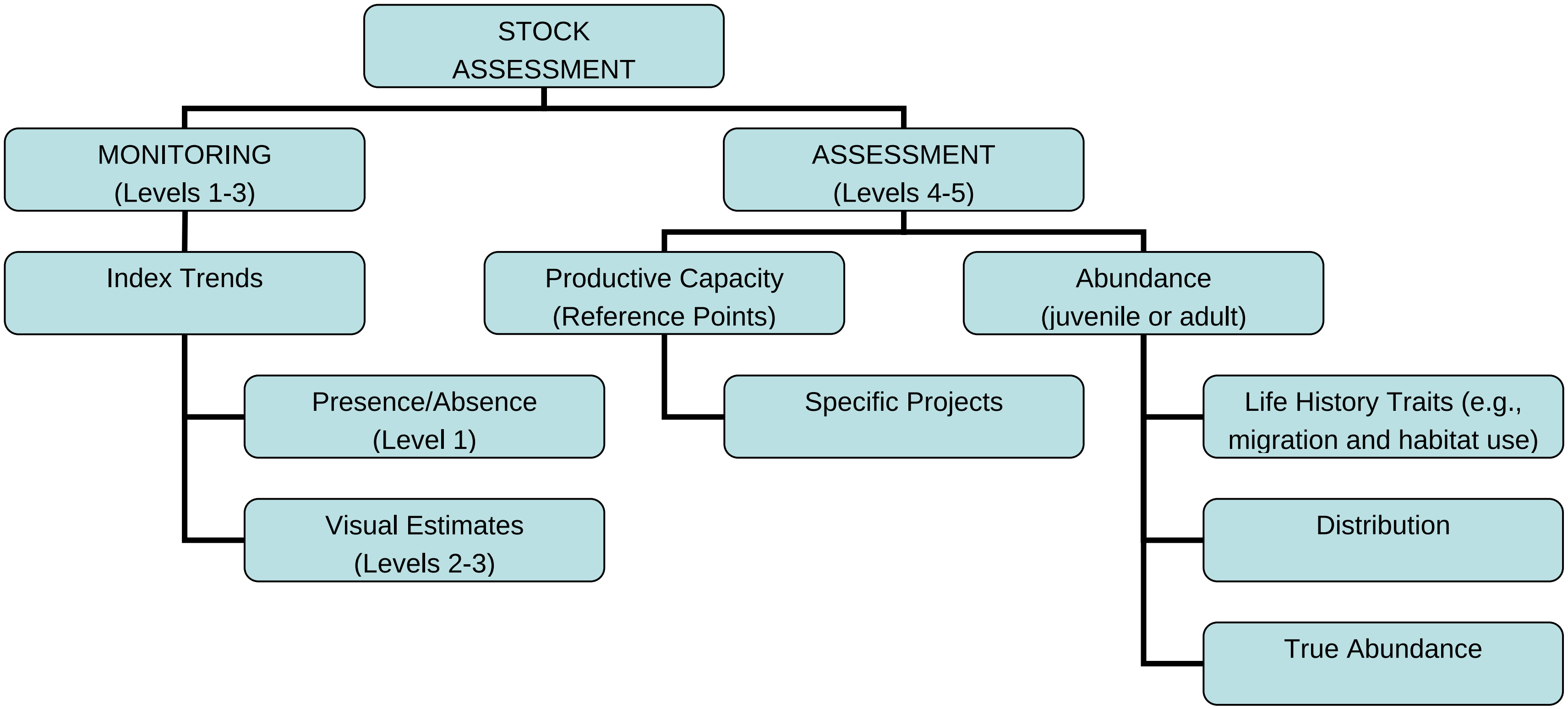

Figure 2. Flow chart of assessment levels and corresponding project types

Stock assessment includes the use of intensive assessments (Level 4-5) and extensive monitoring (Levels 1-3) programs. Intensive assessments are comprehensive programs that use indicator systems that are intended to be representative of other streams in the area. These programs may include quantitative temporal trends in spawning adults and/or juvenile production for that specific system that can be replicated annually to provide consistent indices between years (DFO 2004a). The accuracy and precision of the estimates will vary with methodologies and habitats but the essential component is that there is a high degree of confidence that inter-annual trends are accurately assessed. For example, methods may involve in-river test fisheries, counting weirs, mark-recapture programs, area-under-the-curve estimators, and surveys of juvenile production in streams and lakes.

These intensive programs are the most information rich and expensive but provide critical information for management such as productivity and survival rates for major life history phases (e.g., freshwater and marine survival). It should be noted, however, that an indicator system may not accurately represent the other streams in the assessment unit. Such uncertainty is addressed by combining detailed intensive abundance surveys with less rigorous extensive surveys of other streams in the system (i.e., the "intensive/extensive model").

Surveys that are generally the least expensive but enable the broadest coverage of streams or other habitats within a geographic area are referred to as extensive monitoring programs. These surveys are useful for examining salmon distribution, consistency of patterns throughout the region, and checks on habitat changes. They are usually visually based, may be repeated within a year, and may include randomly selected samples of the streams or habitats in a large geographic area. Examples of these surveys are visual counts using over-flights, stream walks or floats. The extensive monitoring programs are generally not sufficient to monitor recovery, except on broad geographic scales (i.e. multiple watersheds).

It is likely that different initiatives in the Squamish Watershed would encompass many levels of assessment, and that some of these projects would be conducted simultaneously. It is also likely that some of these assessments would focus on more than one of the target species, thereby reducing program costs. Still other projects currently underway could be modified to incorporate additional data collection thereby also providing cost reductions. The decision as to which assessment levels would be implemented would be based on the information available and would differ for each target species.

There are particular tools or methods that will provide information on all levels and thus cut down expenses. The key will be to consider available technologies and to define the frequency and intensity of monitoring within the context of existing enumeration, habitat and stewardship initiatives already underway.

The frequency of monitoring adopted should depend on cost but also on:

1. Recovery timeframes (short and long term objectives);

2. Timeframe for feedback and adaptive management; and

3. Timing and nature (intensity) of management or intervention activities.

Monitoring intensity can be defined in a number of ways:

1. Number of species, life stages monitored;

2. Amount and type of demographic information collected;

3. Accuracy and precision of information (presence/absence to high accuracy); and

4. Extent of non-population monitoring (process, habitat, etc.).

Monitoring intensity and level designation will clearly correspond to differing levels of funding (e.g., 25%, 50%, 75% of funding), therefore information requirements and corresponding methods will be provided for all levels in order to provide a complete analysis upon which to base management decisions and to allow for interannual fluctuations in budget and objective priorities.

4.4.1 Determination of Stock Status

Typically, determining status of a population is conducted by comparing abundance values to selected reference points (PRSAF, 2004). Reference points and salmonid abundance in the context of the Squamish stocks are discussed below.

Reference Points

Reference points can take many forms. From a fisheries management perspective, stock status is determined by comparing escapement to a reference point or points that describe future fishing opportunities (e.g., optimal, moderate, low or critical) (PRSAF, 2004). A possible reference point to the assessment of recovery of Squamish stocks would be to define escapement targets of adult spawners. In this case, though, capacity defined based on adult spawners would be subject to continually varying marine survival rates. As such, it might be better to base productive capacity on juvenile production, which would not be sensitive to marine conditions and would provide a better assessment of freshwater conditions many of which can be modified by human actions to promote recovery.

Other reference points that may be applied to determine status may provide an indication of ecological diversity, index of ecosystem function, ecosystem health, or stock recovery. The applicability or usefulness of these other reference points for Squamish stocks may be assessed in the future.

Stock Abundance

Stock abundance can be assessed at five different levels that differ in estimate type, methodology and degree of effort (Table 1). These levels all have corresponding recommended uses that depend on the desired outcome and resolution required.

Table 1
Stock assessment levels, survey methods and recommended use

Effort Level	Extensive vs. Intensive	Estimate Type	Survey Method	Method Example	Recommended Use
1	Extensive	Relative abundance, low resolution	Low effort (e.g., 1 trip), use of vaguely defined, inconsistent or poorly executed methods	Presence/absence surveys	Not recommended but if used should be in situations of: - low exploitation rate and - No known or suspected threat
2	Extensive	Relative abundance, medium resolution	Low to moderate effort (1-4 trips), known survey method	Visual peak counts	Provides an index of abundance. Used only under situations of: - low exploitation rate and - no known or suspected threat
3	Extensive	Relative Abundance, high resolution	High effort (≥ 5 trips), standard methods (e.g., equal effort surveys executed by walk, swim, overflight etc.)	Visual Counts	Provide either index or total estimates of low precision and low accuracy. Should be used only under situations of: - low exploitation rate and - no known or suspected threat

Effort Level	Extensive vs. Intensive	Estimate Type	Survey Method	Method Example	Recommended Use
4	Intensive	True abundance, medium resolution	High effort (≥ 5 trips), standard methods (e.g., mark-recapture, serial counts for AUC)	Mark/recapture, AUC estimates	Provide total estimates of low precision and accuracy. Escapements estimates by themselves cannot be used to partition fresh water and marine survival. Can be used in all situations.
5	Intensive	True abundance, high resolution	Total, seasonal counts through fence or fishway; virtually no bypass	Weir or equivalent acoustic count	Provide total estimates of high precision and accuracy. Escapement estimates by themselves cannot be used to partition fresh water and marine survival. Can be used in all situations

Juvenile abundance methods are presented in Table 2. According to the level designations shown in Section 4.4, juvenile assessment methods are primarily estimated at the intensive assessment Level 4. This is primarily due to size constraints that limit the applicability of both low level visual methods and higher level weir and hydroacoustic methods.

Table 2
Methods, technical demand, and limitations for juvenile Level 4 estimates

Estimate	Assessment Level	Method	Technical Demand	Limitations	Reference
Fry emergence timing and abundance	4	Inclined plane trap (IPT)	Moderate[1]	low spatial and temporal resolution	BC MoE et al. 2005
	4	Mark recapture - Fyke netting	Moderate	Underestimates escapement due to limited recapture effort; low spatial and temporal resolution	Lawrence 2003; DFO et al. 2003;
Juvenile Outmigration Abundance	4	Rotary Screw Trap (RST)	Moderate	Site suitability	Craig and McCubbing 2002; Triton 1998
Juvenile Index Sampling (relative abundance and distribution)	4	Electrofishing Catch Per Unit Effort (CPUE) surveys	Moderate	Temporally and spatially selective	BC MoE et al. 2005; Triton 1991, 1998; Lucas and Baras 2000
Smolt Marine survival	4	Code-Wire Tag (CWT)	Moderate	Low temporal resolution depends on marine catch	Magnuson and Hilborn 2003; Johnson 1990
	4	Passive injectable transponder (PIT) Tag	Moderate – High	Very low range, data limited to recaptured fish depends on catch	McCormick et al. 2000

[1]Moderate = based on field experience and technical familiarity with equipment required

4.5 Procedural Specifications

The Squamish River watershed AF will provide guidance in determining the procedural specifications required given the current understanding of the status of each target species. Procedural specifications are likely to change over time as new information becomes available and particularly if distinct abundance changes occur (e.g., Cheakamus spill). Survey methods and corresponding estimate type based on abundance and resolution will be provided and suggested given the information gaps identified for each species in the recovery plan.

4.6 Operational Assessment Plans

Operational assessment plans (OAPs) for each species should be prepared on an annual or multi-year basis. At a minimum these will outline the current assessment programs and the responsibilities and accountabilities associated with them. The development of OAPs and their implementation will be a collaborative undertaking involving the SRWS, Squamish Nation, DFO and MoE. The OAP is meant to provide a summary of stock assessments projects in the context of the goals and objectives of the recovery plan as well as this AF. The main components are outlined below:

1. Assessment Plan for Defined Time Period
    a. Overview – summary of all assessment activities
    b. Assessment Projects
        i. Full reference – Project name, location, group, contact person
        ii. Description – what is planned, methodologies, level of assessment
        iii. Data – what data are being produced, how are data handled, schedules of collection, data management and access protocols
        iv. Links to other assessment projects
        v. Link to recovery of target species.

4.7 Data Management

Rather than developing data management and communication advice protocols for each species, these will be amalgamated for all species as requirements are predicted to be similar if not the same for each species within the watershed.

5.0 SPECIES-SPECIFIC ASSESSMENT FRAMEWORK

5.1 General Squamish River Watershed Objectives

Squamish River Watershed stock assessment programs should be designed to address the following long-term objectives:

- Recovery of salmon (i.e., coho, chinook, chum, pink) and steelhead species to enable use by the Squamish Nation and stakeholders and allow for long-term sustainable population;
- In-season fisheries management to assess abundance; and
- Effective monitoring to assess ongoing watershed programs.

Short-term objectives:

- Prioritize information gaps identified in the Squamish River Watershed Recovery Plan;
- Update and improve existing stock assessment programs to address recovery information gaps in stock status and AFs objectives;
- Development of additional assessment programs, if required; and
- Establishment of effective monitoring programs in identified systems.

The sections below provide a description of the AF for stock assessment initiatives for each of the target species in the Squamish Watershed in an attempt to fulfill the short and long-term objectives of recovery of each species.

5.2 Chinook

5.2.1 Assessment Unit

North American chinook salmon are currently managed and assessed according to a framework established under the PST. Squamish chinook are part of the Lower Georgia Strait aggregate, a group of small and medium size rivers on Vancouver Island from the Puntledge River south to the Cowichan Peninsula and along the southern mainland coast (Golder 2005). The aggregate is assessed from harvest (coded wire tag analysis) and escapement trends for the Cowichan and Nanaimo populations (PSC 2003).

While Squamish chinook are included in this aggregate because of similar marine distributions and exploitation patterns, differences in run timing and other attributes suggest that they should be aggregated as part of a mainland inlet summer chinook group (N. Schubert, *pers. comm*., April 2005 in Golder 2005). The Pacific Fisheries Resource Conservation Council suggested that Squamish chinook have the potential to be the largest population in this region, but concluded that "the current assessment programs in the Squamish River are inadequate to effectively manage this potentially important stock." (PFRCC 2002). Management of Squamish chinook as a distinct unit is required to assess recovery of the stock.

At this stage, it is suggested that Squamish chinook be managed as one assessment unit as insufficient biological and/or genetic information is available to defend alternative management unit designation (i.e., the presence of distinct stocks within the watershed). Assessment initiatives should focus on determining unit designation of the stock. Any future data that provides evidence of discrete stocks within the watershed will be assessed and incorporated into the AF at that time.

5.2.2 Resource Recovery Goal

The goal is to allow for the recovery and subsequent maintenance of healthy, wild origin spawning chinook populations within the Squamish River watershed. Chinook spawner returns should allow for use by Squamish Nation to meet traditional use requirements and for stakeholders and as well as the establishment of long-term sustainable populations.

5.2.3 Resource Recovery Objectives

The following chinook population targets were set in the Squamish River Recovery Plan:

- Adopt a long-term system-wide interim adult escapement target of 5,000 chinook as determined by the habitat-based productive capacity model. Because current abundances are well below that level, planners should attempt to achieve cycle-over-cycle growth of the spawning population.

- Once the 5000 escapement target has been reached, meet or exceed the above interim habitat-based escapement goals for wild chinook salmon spawning in key areas on an annual basis.

- Revise above "interim" escapement target as information on productive capacity of the watershed becomes available.

- Establish reference points and/or productive capacities for juvenile chinook and update as information becomes available.

- Increase the proportion of natural origin to hatchery origin chinook salmon in key spawning populations and in the total escapement on a cycle-over-cycle basis. This should incorporate DFO Salmon Enhancement Policy guidelines which state that not more than 20% of a population will be of hatchery origin (DFO 2006).

5.2.4 Information requirements

Juvenile – Reference Point and Abundance

Juvenile chinook abundance goals have not been set and the productive capacity of the Squamish River watershed to support chinook has not been quantified. Chinook are considered a high priority for recovery in the watershed, and thus, reference points should be established. Establishment of the productive capacity through habitat capacity studies (e.g. Parken et al. 2002) is recommended as it will allow for a setting of appropriate recovery goals and reference points for which subsequent abundance estimates can be compared. As such, the establishment of robust baseline data for chinook smolt is required and should be a focus in future studies given the PSF and SRWS priorities.

Limited data are available regarding the status of juvenile chinook in the Squamish River watershed primarily due to limited data, the differences in study objectives, target species, methodologies, and timing of sampling between studies. All available juvenile abundance data has been extracted from Level 4 steelhead-focused studies and, therefore, do not provide adequate understanding of stock status as timing of studies and habitat surveyed were not typical of chinook stocks. Given these limitations, we suggest a minimum of Level 4 assessment focused specifically on assessing juvenile chinook status in the watershed. Procedural specifications are provided below.

Adults – Reference Point

Based on a simple-structured allometric model developed by DFO, the interim chinook productive capacity of the Squamish River Watershed is estimated at 5,000 stream-type spawners (Golder 2005). It should be noted that data collected between 1978 and 1981 indicate a shift to ocean-type for Squamish chinook, however, the habitat model used (Parken et al. 2002) to estimate chinook productive capacity assumes a stream-type life cycle. Consequently, the productive capacity generated by this model will underestimate the capacity by the proportion of the population that exhibits the ocean-type life history (Golder 2005).

Although limitations to the model's ability to accurately represent watershed productivities and escapement targets have been noted, the reference points are considered preliminary but helpful. The model provides an interim reference point, which can be updated as new information becomes available and as model applications are more developed.

Alternative habitat capacity models (i.e., spawning habitat capacity model – Parken et al. 2002) should be investigated in order to refine reference points in the future. These models have been developed to describe habitat-based methods to develop escapement goals for Fraser River chinook populations. These models perform well overall; however they have been limited in generating realistic estimates of spawner capacity for chinook in high gradient and confined-channel spawning systems (Parken et al. 2002).

Adult - Abundance

The available data, suggest that chinook populations were historically much more abundant, and that population abundance has been low since the mid-1970s. The data show a steady decline from 15,000 in the 1950s to below 500 in the mid-1980s and 1990s. While inconsistencies between current (visual observations) and historic assessment methods make a precise quantification of the trend difficult, the magnitude of the difference suggests that historic abundances were substantially larger than those currently observed. The Pacific Salmon Commission (PSC 2003) attributes much of the recent decline to reduced marine survivals, while overexploitation and habitat degradation played key roles in earlier decades.

A mark-recapture study in the Cheakamus River reported almost 1,000 fish per year from 1989 to 1992, and noted that concurrent visual surveys underestimated the populations by 50% or more (Schubert 1993). In Mamquam River and Ashlu Creek, escapements were generally below 500 fish in 1951 to 1993, with a peak of 1,500 to 2,000 reported in both systems in 1969 to 1970. A system-wide mark-recapture study was conducted in 1988 to 1992 in the Squamish River system with total return estimated at 7,300 to 9,300 adults, approximately four times the estimated escapement derived from visual observations for the same time period (Schubert 1993).

Currently, chinook entering the Squamish systems have been counted between July and December and data are available for years 1996-2006. This Level 2 (Table 1) assessment consists of spawner enumeration based on visual observations conducted by stream walks (Squamish Nation 2005). The relative abundance trends indicate further declines in chinook stocks.

Given the continued low trends observed for chinook, probable underestimation of populations, established priority by PSF and SRWS and the likely decline in marine survival, current enumeration methods are likely insufficient to assess recovery as they provide only relative abundance estimates with only medium resolution (Table 1 Suggestions for potential revisions and/or improvements to the current enumeration program are provided in the ensuing Procedural Specification section.

5.2.5 Procedural Specifications

Juvenile

Chinook juvenile productive capacities within the watershed need to be evaluated in order to obtain a reference point against which existing juvenile outmigration or fry emergence studies can be evaluated against. Productive capacity estimates could be made based on availability of rearing habitats. Several studies found high associations of juvenile chinook with depths of 20-80 cm, cobble substrate, cover (undercut banks) and where water velocities were less than 12 cm/s (Hillman et al. 1985).

Current smolt abundance studies on the Cheakamus River, Mamquam River side-channels, and on Meighn Creek have been conducted primarily for steelhead but chinook have also been caught in rotary screw traps (RSTs). Although these studies operate at a Level 4 (Table 1) assessment, they cannot be considered so for chinook as these are caught incidentally. Given the lack of information regarding juvenile abundance, poor marine survival and the low relative abundance of adult chinook spawners over the past several years, additional focus on chinook should be considered. Additional funding should be dispersed towards smolt outmigration and marine survival and fry abundance studies. Potential methods will vary in technical demand and time requirements and are provided in Table 2. Assessing the chinook population at these life-stages will separate the freshwater from the marine production components and provide valuable information on chinook stock status within the watershed.

In addition to smolt enumeration, studies that develop an index of fry emergence timing and abundance can serve as an indicator of the quality of the incubation environment and define the potential recruitment of chinook in the Squamish River watershed (BC MoE et al. 2005). Specific goals can include the use of inclined plane traps (IPT) methods for the collection of:

a) numbers of emergent chinook migrating downstream through the study area; and
b) weights and lengths (fry quality) of these fish to determine development condition factors.

These data could provide life history information that would aid in the overall knowledge and subsequent management of the Squamish River watershed chinook stock.

Marine survival studies are generally based on tag recoveries, either on a local scale in a short-term experiment to estimate the effect of a particular factor such as dam passage or estuarine predation, or on a larger scale based on coded wire tag (CWT) release and recovery data from hatchery operations. In the latter case, tagged individuals are recovered as adults some years after they were released from hatcheries as smolts, so the resulting estimate of smolt-to adult survival rate is a product of freshwater, estuarine, and marine survival rate (McCormick et al. 2000).

Advances in passive integrated transponder (PIT) tag technology, including the low cost of PIT tags, offer the opportunity to locate and individually identify large numbers of fish without disrupting their natural habitat choice, activity, and behaviours (McCormick et al. 2000). Because PIT tags are passive, remain viable for a number of years, and have a high retention rate when implanted peritoneally, tagged fish can be both recaptured within rearing habitats or detected as they emigrate downstream without trapping or handling the fish. Given that the PSC attributes much of the recent decline in chinook numbers to reduced marine survivals (PSC 2003), studies on juvenile marine survival should be evaluated and prioritized.

While a focus on assessing freshwater habitat for juvenile chinook is certainly warranted, chinook are commonly found spawning in main river and large side channel habitats, therefore opportunities to improve riverine habitat conditions are limited. Alternately, biological monitoring of chinook parr and fry estuary use is recommended and if applied, should include at minimum a Level 2 (e.g., presence/absence of fry in specific locations as a relative abundance index) but ideally a Level 4 assessment of fry abundance.

Adult

In order to more accurately and precisely monitor adult chinook stock, an “extensive/intensive” model is suggested. The “extensive/intensive” assessment model is defined as a model where each assessment unit has at least one indicator system (Level 4 or 5 escapement plus estimates of freshwater production) and a set of systems where Level 2/3 escapement enumerations would be conducted (DFO 2004b). This model may be appropriate for species like chinook where there are several spawning populations throughout the watershed (e.g., Mamquam and Cheakamus Rivers). For example, an intensive mark-recapture study (Level 4 from Table 1) could be used on a small portion of a run (e.g., shallower portion of a main reach or tributary system) providing more precise and accurate estimate, while the current enumeration program (i.e., Level 2/3 extensive program) could be obtained for the entire system or additional systems using more current enumeration methods. Options of Level 4 and 5 assessments are provided in Table 3.

Table 3
Methods, degree of robustness and financial requirements for adult escapement estimates

Estimate	Level	Method	Technical Demand	Disadvantage	References
Adult escapement	4	Mark recapture	Low-Moderate	Estimates can be imprecise due to limited marking or recapture effort	Manske and Schwarz 2000; Ricker 1975; R Bocking, Pers. Comm 2006
	4	Resistivity Counter	Moderate	ID issues when multiple species	Dunkley and Shearer 1982, McCubbing et al. 2000; R
	4	Hydroacoustic counter (e.g. DIDSON) , split beam)	High	High data processing requirement; species ID issues	Gregory et al. 2001, Gough and Gregory 1997
	5	Partial weir / Video	Moderate	Siting critical; requires marking;	R Bocking, Pers. Comm 2006

Resistivity counters, for example, have been shown to accurately enumerate fish stocks (e.g., coho, pink and steelhead) with minimal maintenance (McCubbing and Ward 1998) and have been used in the Deadman River (1999 and 2000) under Pacific Salmon commission escapement programs (PSC 2003). Trends in these estimates can then be comparatively evaluated against the current Level 2/3 enumeration methods to verify the validity of using the latter, and of conducting visual counts in all major systems.

Alternately, hydroacoustics counters have been increasingly utilized in freshwater habitats. A key feature is measurement of target strength, so that information on fish size and number can be obtained (Lucas and Baras 2000). DIDSON counters specifically work in rivers and streams with rocky, uneven beds where other acoustic measurement products are often ineffective. Fish are imaged and optionally counted and sized as they pass through the sonar's field of view. Although these methods provide high value for fish behaviour, the technical and financial demand ($USD 10,000-100,000) often make them ineffective tools.

Recently, the use of underwater digital video systems (DVS) has been successfully implemented on a number of river systems in Alaska, BC, and Washington State (R. Bocking, pers. comm. March 2006). A partial weir structure is typically installed to funnel adults through a counting area without impeding the migration. Imaging can be of sufficient quality to enable detection of adipose clips (CWT) and/or external marks applied for mark recapture studies.

If an extensive/intensive program is not possible due to financial and/or logistical constraints, AUC estimates should be calculated for chinook in all systems based on current foot survey enumeration numbers (J. Tadey, pers. comm. February 2006). Several levels of robustness based on the accuracy of residence time (RT)[1] and observer efficiency (OE)[2] estimates can be evaluated. One method is to use a range of OE and RT estimates based on literature values such as is currently used in estimating escapement for coho (Squamish Nation 2005). However, as RTs and OEs are the primary components of the AUC estimate equation, it has been suggested that estimates be specific to the population being sampled due to spatial and temporal variations between systems (Perrin and Irvine 1990; J. Tadey, pers. comm. February 2006). Possible alternative estimates will range in methodology, robustness and financial requirement (Table 4) and therefore, need to be evaluated given the information priorities.

[1]Residence time is defined as the length of time fish are present in the stream and visible to observers

[2]Observer efficiency is defined as the proportion of fish counted relative to the actual number of fish present in the stream during the survey (Perrin and Irvine 1990)

Table 4
Methods, degree of robustness and financial requirements for residence time and observer efficiency estimates to be applied to AUC escapement estimates

Estimate	Method	Technical Demand	Limitation	Reference
Residence Time	Literature values	Low	Temporally and spatially unspecific	NA
	Repetitive Counts of live and dead fish	Low	Statistical methods only; temporally unspecific	Perrin and Irvine 1990
	# days between peak live/dead counts	Low	Statistical methods only; temporally unspecific	Perrin and Irvine 1990
	Difference between equivalence points	Low	Statistical methods only; temporally unspecific	Perrin and Irvine 1990
	Mark-recapture	Low-Moderate	Underestimates due to limited recapture effort; low spatial and temporal resolution	Manske and Schwarz 2000; Lucas and Baras 2000
	Radio-tagging	Moderate-High	Poor range in deep, lowland waters. May influence behaviour	J. Tadey, pers. comm.., 2006
	Petersen disc tag	Moderate-High		J. Tadey, pers. comm.., February 2006
Observer Efficiency	Literature values only	Low	Temporally and spatially unspecific	Perrin and Irvine 1990/ Manning et al 1999
	Literature values + environmental conditions	Low	Technique not yet established	J. Tadey pers. comm., January 2006
	Aerial counts (Helicopter photographs)	Moderate-High	Temporally limited due to cost	Trouton 2005
	Tag Counts vs. Observer counts	Moderate	Potentially small sample size; spatially limited; increased chance of tag shedding	Hetrick and Nemeth 2003; J. Tadey, pers. comm. February 2006

Several alternatives are available to increase accuracy of current RTs. Some of these have been evaluated by Perrin and Irvine (1990) and include statistical analyses (i.e., use of equivalence points, peak live/dead count differences) which could be run without the costs associated with significant field components. More stringent estimates of residence time use mark-recapture techniques (Manske and Schwarz 2000) or radio tagging methods (J. Tadey, pers. comm. February 2006). For the former, underestimates due to limited recapture effort and low spatial and temporal resolution may limit its use. The efficacy of this technique would need to be evaluated by reviewing population estimates and area to be sampled (J. Tadey, pers. comm. February 2006).

Current OE can be refined by using environmental conditions obtained on a routine basis for each system. These parameters include, for example, water clarity, cloud cover and precipitation. As environmental conditions directly affect the ability of the observer to accurately count fish, incorporating these will refine the OE (J. Tadey, pers. comm. February 2006).

Alternately, obtaining OE from tag counts involves marking a known number of salmon with highly visible streamer tags, allowing the marked fish to disperse for a minimum of three hours, and then counting newly-tagged fish during a foot survey conducted later that day (Hetrick and Nemeth 2003). These can be repeated for different species, systems and under different environmental conditions. Obtaining OE from aerial counts entails comparing the counts of spawning salmon made by individual observers on foot surveys to the mean counts of spawners from photographs obtained from overhead flights to determine each individual counter's observer efficiency. Similar to tag counts, this method can be repeated for different species, systems and under varying environmental conditions, however, cost increases with each additional parameter.

Given the low relative abundance of chinook spawners it is highly recommended that a robust methods of assessing RT and/or OE be integrated if AUC estimates are to be adopted. These methods should be based on information gathered from an indicator system and can be funded for a short period of time. Results can then be compared to less stringent methods which are less costly to assess (e.g., equivalence points, compilation of literature values) and levels of accuracy can then be compared. The use of an indicator system would allow for a focused effort on one representative system in which fry abundance, smolt migration and adult escapement estimates can be generated, allowing for an increased understanding of the relationship between life history stages. Several criteria should be considered when systems are initially selected as an indicator system:

- Indicator stocks should represent stocks with similar life history and distribution patterns in all regions of interest;

- The stock must be sufficiently abundant and easily tagged so that the long-term commitment to stock assessment programs can be made; and

- Reliable estimates of catch and escapement must be considered obtainable.

The use of indicator systems would require Level 4-5 projects that would provide true abundance estimates of medium-high resolution.

Chinook are currently in sharp decline due to poor marine survival, therefore in addition to freshwater studies, marine survival estimates are also recommended (J. Tadey, pers.comm., February 2006). The marine distribution can be inferred from coded wire tags (CWT) applied to wild or hatchery chinook. Effort required to conduct these studies could be reduced by piggy-backing onto ongoing tagging studies such as those conducted to trap steelhead in the Cheakamus River. Since trapping methods do not discriminate by species, chinook caught using programs already in place could provide the smolts necessary for CWT. These tagged fish would then subsequently be recovered in off-shore fisheries. These studies could provide information regarding Squamish chinook's exploitation rates and ocean catch distribution.

Options for juvenile and adult coho assessments are summarized in Table 5.

Table 5. Summary Table of Future Assessment Options for Squamish chinook Stocks

Stage	Current Assessment	Suggested	Examples
Juvenile	Indirect[1] Level 4	Level 4	IPT, RST, CWT
Adult	Level 2	Level 2 (continue)	Relative abundance through visual surveys
		Level 4	AUC estimates
		Level 5	Resistivity or hydroacoustic counters
		Level 4	CWT to address marine survival

[1] Indirect meaning that information is collected through programs that are currently targeting other species

5.2.6 Operational Assessment Plan

Squamish Nation Salmon Enumeration Program

Location: Squamish River Watershed

Groups: Squamish Nation, DFO, Golder

Contact Persons: Randy Lewis (Squamish Nation), Joe Tadey (DFO) and Bettina Sander, (Golder)

Description: Currently completing its 10th year of collecting enumeration data for chinook using standardized visual survey estimates. Operating at a Level 2 assessment.

Data: Data generated for chinook include relative abundance (live and dead counts), catch hail, male:female ratios, mean length, and run timing. Data is available for systems throughout the watershed, and are collected from July-February. Data are provided by Squamish Nation enumerators to Golder Associates for QA/QC, handling, compilation, and report processing. Data in the form of a final report is provided to Squamish Nation. Raw data are provided to DFO for incorporation into regional frameworks.

Links to other assessment projects: This project is linked to enumeration also being conducted for coho, pink and chum salmon.

5.3 Coho

5.3.1 Assessment Unit

Squamish coho has been considered as part of a larger Strait of Georgia "metapopulation" (*i.e*., stock group) and, under the PST, is considered part of the Strait of Georgia Mainland (or Georgia East Basin) Management Unit (J. Tadey, pers. comm., September 2004 in PSF 2005). This unit excludes coho stocks returning to the Fraser River watershed. Squamish coho contribution to the Strait of Georgia stock group is unknown. Management of Squamish coho as a distinct unit is required to assess recovery of the stock.

At this stage, the Squamish River watershed will be managed as one assessment unit as insufficient biological and/or genetic information is available to defend alternative management unit designation (i.e., the presence of distinct stocks within the watershed). However, any future data that provides convincing evidence of discrete stocks within the watershed will be assessed and incorporated into the AF at that time.

5.3.2 Resource Recovery Goal

The goal is to allow for the recovery and subsequent maintenance of healthy, wild origin spawning coho populations within the Squamish River watershed. Coho spawner returns should allow for use by the Squamish Nation to fulfill traditional use requirements and by stakeholders, and for the establishment of long-term sustainable populations.

5.3.3 Resource Recovery Objectives

The following coho population targets are recommended:

- Determine juvenile productive capacities and corresponding reference points as current numbers based on published biostandards (e.g., Bradford *et al.* 1997; Marshall and Britton 1990) underestimate the weighted importance of side-channel vs. mainstem habitats;

- Once reference points have been established, meet or exceed juvenile productivity goals;

- Establish interim escapement goals based on historical estimates rather than bio-standards;

- On an annual basis, meet or exceed the interim escapement goals for wild adult coho salmon spawners; and

- Increase the proportion of natural origin to hatchery origin coho salmon in key spawning populations and in the total escapement on a cycle-over-cycle basis.

5.3.4 Information requirements

<u>Juvenile – Reference Points</u>

A number of publications exist that have attempted to estimate juvenile smolt productivities based on fish numbers per length of stream (Bradford et al. 1997; Holtby et al. 1990; Marshall and Britton 1990). A comparison of these estimates is provided in Table 6. When applied to the Squamish River watershed total smolt productivity estimates have ranged from 4,740 to 8,382 smolt/km (Table 7). Studies by Melville and McCubbing (2001), Simpson et al. (2000) and D. Celli (pers. comm. in Golder 2005) found smolt productivity at 4,700 smolts/km in the Cheakamus, 6,333 smolts/km in Little Stawamus, and >5,000 smolts/km in the Mamquam River, respectively.

Comparisons of the biostandards to these smolt data would indicate that coho are well above carrying capacity in these systems. This would then imply that coho stocks in the Squamish watershed have recovered. However, it is unlikely that this is an adequate representation of current conditions given the amount of habitat destruction that has occurred in the past due primarily to logging and urbanization. The loss of prime coho habitat such as side-channels has been significant. Habitat restoration efforts and restrictions on the commercial fishery have been effective in increasing coho abundance, however, numbers have not reached historical highs (PSF 2005). If the systems are now operating at carrying capacity, additional habitat restoration efforts would not result in more fish. It is more likely that these seemingly high smolt abundances are as a result of the inapplicability of the models to the Squamish systems. The models and their applicability are limited by the data they are based on. For example, Marshall and Britton (1990) based their model primarily on data obtained from three small headwater streams in Oregon. As such, there would be significant difference in habitat types between small mountain streams and the larger systems (i.e., Cheakamus and Mamquam rivers) in the Squamish watershed. Although Bradford et al.'s (1997) model is based on data collected from 86 systems, they still conclude that the model should only be applied at the regional scale, and that site-specific information should be obtained at the local scale to accurately determine smolt productivity.

Table 6. Coho smolt productivity models for streams in the Pacific Northwest

Model	Equation where sp=smolt produced per km of stream length (L)	Sample Size
Marshall & Britton 1990	$Sp=1924.6*L - 894.75$	24
Holtby et al. 1990	$Sp=941.1*L^{1.074}$	36
Bradford et al. 1997	$Ln(sp)=6.90 + 0.97*ln(L)$	83

X is stream length in km; y is smolt abundance

Table 7. Smolt abundance (smolt/km) using different models and information sources for the Squamish River watershed

Watercourse	Enumerated/Anadromous Length	Marshall & Britton (1990)	Holtby et al. (1990)	Bradford et al. (1997)
Cheakamus River	14.5 km	1,863	1,147	916
Mamquam River	8.7 km	1,822	1,105	930
Stawamus	2.8 km	1,605	1,016	962
Little Stawamus	2.1 km	1,499	995	970
Shovelnose	2.7 km	1,593	1,013	963
TOTAL		**8,382**	**5,276**	**4,740**

It is important to note that length data are very conservative estimates of coho utilization as they are not based on GIS maps but rather on coarser maps (TRIM, aerial photos). In addition, secondary and tertiary tributaries that feed into mainstem habitats may not have been included in some estimates; therefore total lengths (mainstem and tributaries) and subsequently smolt abundance may have been underestimated in these models.

Alternate models, such as those presented by Bocking and Peacock (2004) should be evaluated against these models to assess their validity and/or applicability towards the Squamish watershed. In these models, smolt number per kilometer were derived using log-linear predictive regression of smolt yield and stream length for Alaskan and BC streams and recent decadal smolt yield and stream length for three northern BC coho indicator streams.

The application of existing biostandards for the determination of juvenile smolt production seems misleading in the case of Squamish coho stocks. As such, establishment of site-specific productive capacity for juvenile coho should be assessed so that appropriate recovery goals and reference points can be set. . While validation of a model will require many years of reliable estimates to one or more tributaries a focus on establishing appropriate smolt reference points for the Squamish watershed should be a priority for coho.

Juvenile - Abundance

An assessment of juvenile coho stock status was not provided in the Squamish River Watershed Salmon Recovery Plan (2005) primarily due to differences in study objectives, methods used, seasonality, and systems surveyed between studies. Data generated were not directly comparable since coho data originated from Level 4 steelhead-focused studies that did not incorporate timing of studies and habitat surveyed typical of coho stocks. Appropriate abundance studies should be initiated in order to assess the variability of the juvenile population relative to productivity estimates for the watershed.

The Tenderfoot Creek Hatchery located 15 km north of Squamish is used to enhance stocks of coho in the Squamish River watershed. Currently, the hatchery produces approximately 300,000 coho smolts depending on the escapement levels and fishery requirements. Broodstock are captured and their progeny are reared in ponds at the hatchery for 15 months before they are released into their stream of origin as fry or smolts. From 1984 to 1995 fry and smolts were released into the Mamquam River, Squamish River, Ashlu Creek, Tenderfoot Creek and Lake, Dryden Creek, and/or Shovelnose Creek. After 1995, coho were released into Tenderfoot Creek only as it was deemed that survival rates and distribution in fisheries between the systems were similar (R. Cook, pers. comm. October 2004). Hatchery coho have been intermittently marked with adipose fin clips over the years. Prior to 1996, when coho were showing poor survival (R. Cook, pers. comm. October 2004) they were marked sporadically. Between 1996-2003 they were not marked at all so that all coho could appear “wild” and therefore, be protected from fishing pressure. Marking was re-introduced in 2003 as coho populations increased (J. Tadey, pers. comm. September 2004 in PSF 2005) and conservation concern subsequently decreased. The inconsistent marking schedule makes it difficult to track the influence of hatchery-reared vs. wild coho in the watershed.

Adults – Reference Points

A number of publications exist that have attempted to estimate adult spawner productivities based on fish numbers per length of stream. Marshall and Britton (1990) in their report “Optimum Spawning Density for Coho Salmon” attempted to calculate the numbers of spawners per stream length that would be required to produce enough fry to fill all available habitat to capacity. They proposed that approximately 60-100 spawning coho salmon per kilometer of stream would be adequate to produce enough fry to ensure the habitat would be filled each year. Larger streams would require more spawners. Based on the level of wild coho smolt productivity measured in the Cheakamus River in the spring of 2000 (Melville and McCubbing 2001), a 3% smolt-adult spawner survival rate would return approximately 141 wild coho spawners per kilometer. Squamish Nation coho spawner estimates suggest that total coho spawner escapement to the

Mamquam River may be approaching 300 spawners per kilometer (Squamish Nation 2000).

Similar to smolt estimates, the estimated adult spawner carrying capacity is above the Marshall and Britton (1990) biostandard estimate. However, since most spawning coho are found in constructed side-channels, exceedances should be interpreted with caution. As such, the productive capacity of the overall Squamish River watershed should be further improved by incorporating effects of continued restoration efforts. Extreme caution should therefore be taken in adopting current biostandard based productive capacities. More accurate productive capacities incorporating high-productivity habitat such as is found in side-channels will need to be estimated. However, it should be noted that this method would be very challenging in applying to a watershed-wide estimate of capacity, which is why previous models (e.g., Marshall and Britton 1990) are used, despite its shortcomings (R. Bocking, pers. comm. March 2006).

Adults - Abundance

While historical Squamish River coho escapement data (1951-1985) are poor in quality and caution must be exercised when deriving conclusions, recent trends suggest that the coho populations in the Mamquam, Cheakamus, and Stawamus systems are generally increasing from lows reached in 1998. The observed increases are thought to primarily be as a result of reduced fishing pressures and improvement in habitat and marine survival. However, these data are extremely variable and longer term trends in abundance are needed to assess the sustainability of these stocks in the Squamish River watershed.

Currently, Level 2/3 assessments of coho populations consists of spawner enumeration based on visual observations conducted by stream walks (Squamish Nation 2005). Given the variability in abundance trends, current enumeration methods and AUC estimates need to be revised and improved upon in future years.

5.3.5 Procedural Specifications

Juveniles

Additional studies focused on determining coho smolt densities are required to gain a more accurate picture of current smolt abundance (*e.g.,* an indicator system located in the lower watershed or lower Squamish River smolt trap) and a more comprehensive and complete assessment of coho status. Tenderfoot Hatchery data should also be included in this assessment, and re-assessment of fish culture practices should be considered to promote the recovery of wild populations. Where uncertainty exists, the hatchery releases should be used to test alternative hypothesis by varying stocking practices using experimental protocols. Coho released from the hatchery should be marked with CWT, adipose fin clip or other alternative (e.g., calcein tags) on a regular basis. These studies should be conducted in conjunction with the establishment of juvenile coho reference points.

Reference points can be obtained through rearing habitat productive capacity estimates. However, in order to adequately derive productive capacities of juvenile coho salmon in the Squamish River watershed, assessment of distribution of coho and rearing habitat in watershed and completion of habitat modeling to develop interim goals should be a priority (R. Bocking, pers.comm. March 2006). Alternately, if an appropriate model can be found to apply an interim reference point, this should be immediately adopted.

Given the lack of focused studies on coho juveniles, additional funding (at least temporary) should be allotted to Level 4 fry emergence and abundance, and juvenile outmigration studies (R. Bocking, pers. comm. March 2006). Potential methods which vary in effort and time requirements are provided in Table 2 and include:

- Fry Emergence/Abundance
    - Inclined Plane Traps
    - Mark-recapture – fyke netting
- Juvenile Outmigration
    - Rotary Screw traps
    - Electrofishing/CPUE

As previously mentioned, studies that develop an index of fry emergence timing and abundance can serve as an indicator of the quality of the incubation environment and define the potential recruitment of coho in the Squamish River watershed (BC MoE et al. 2005). These data could provide life history information that would aid in the overall knowledge and subsequent management of the Squamish River watershed coho stock.

Adults

For the past 10 years trends in relative coho abundance and escapement estimates have been determined using Level 3/4 assessments with the escapement estimates derived from the AUC method. Although considered a Level 4 assessment, the AUC method is only as good as the information that goes into it. Currently, AUC estimates for coho in selected systems are based on visual observations conducted by foot while OE and RT estimates are based on literature values (Squamish Nation 2005). In order to better monitor this stock, improvement to the current AUC escapement estimates are suggested which would increase the resolution of the escapement estimates.

In an effort to provide more accurate AUC escapement estimates, the impact of environmental parameters on OE estimates will be incorporated into escapement estimates for the 2005/2006 enumeration season. As these are a primary component of the AUC estimate equation, it has been suggested that estimates be specific to each population being sampled due to spatial and temporal variations between systems (Perrin and Irvine 1990; J. Tadey, pers. comm. February 2006).

Other assessments recommended to better assess the status of coho stocks and in methodology, robustness and financial requirement. These were described in Section 5.2.5 and Table 2. For example:

- Residence time improvements
    - Statistical Methods
    - Mark-recapture
- Observer Efficiency
    - Aerial counts
    - Tag counts

As for chinook, these methods can be funded for a year and compared to less stringent methods which are less costly to assess (e.g., equivalence points compilation of literature values, see Table 4) and levels of accuracy can be compared.

Existing enumeration programs do not provide a means of linking adult counts to juvenile counts. As such, future intensive adult and juvenile smolt assessments should occur on the same system (e.g., selected appropriate indicator system) as this will provide an estimate of productive capacity, marine survival and exploitation rates (R. Bocking, pers. comm. March 2006). Options for these assessments are provided in (Table 8).

Table 8. Summary Table of Assessment Options for Squamish Coho Stocks

Stage	Current Assessment	Suggested	Examples
Juvenile	Indirect Level 4	Level 4	Fry emergence studies - IPT, MR
		Level 4	Juvenile smolt monitoring – RST/MR
Adult	Level 4	Level 4 (continue)	Relative abundance and AUC estimates through visual surveys
		High Level 4	Improve AUC estimates for at least 3-5 systems (account for ≥50% production)
		Level 4-5	Resistivity or partial weir/mark-recapture, DVS

5.3.6 Operational Assessment Plan

Squamish Nation Salmon Enumeration Program

Location: Squamish River Watershed

Groups: Squamish Nation, DFO, Golder

Contact Persons: Randy Lewis (Squamish Nation), Joe Tadey (DFO) and Bettina Sander, (Golder)

Description: Currently completing its 10th year of collecting enumeration data for coho using standardized visual survey estimates. Operating at a Level 4 assessment (although with low precision) as AUC estimates are provided for coho.

Data: Data generated for coho include relative abundance (live and dead counts), catch hail, male:female ratios, mean length, and run timing. Data are available for systems throughout the watershed, and are collected from July-February. Data are provided by Squamish Nation enumerators to Golder Associates for QA/QC, handling, compilation, and report processing. Data in the form of a final report is provided to Squamish Nation. Raw data are provided to DFO for incorporation into regional frameworks.

Links to other assessment projects: This project is linked to enumeration also being conducted for chinook, pink and chum salmon.

Small-scale assessment of early marine survival of juvenile coho salmon in the Squamish River watershed

Location: Squamish River Watershed

Groups: UBC

Contact Persons: Mike Melnychuk (UBC)

Description: Hatchery-reared coho smolt migration and survival data were obtained from small-scale mobile tracking in Howe Sound and the Strait of Georgia as well as information gathered from the larger network of stationary acoustic arrays from the Pacific Ocean Shelf Tracking Project (POST).

Data: Data provided included information on ocean migration patterns and distribution for smolts originating specifically from Howe Sound. Data will be provided to PSF upon project completion (2007?) and will likely be published in a peer-reviewed journal. This project is currently operating at a Level 5 assessment.

Links to other assessment projects: This project is linked to steelhead migration and survival study conducted simultaneously.

Meighn Counting Fence

Location: Meighn Creek

Groups: Instream Fisheries Research Ltd.

Contact Persons: Caroline Melville (Instream)

Description: Monitor coho smolt outmigration using trapping methods established as time series.

Data: Data includes annual coho smolt counts.

Cheakamus River coho smolt outmigration studies

Location: Cheakamus River

Groups: BC Hydro; Instream Fisheries Research Ltd.

Contact Persons: Don McCubbing and Caroline Melville (Instream)

Description: Monitor coho smolt densities and migration using RST trapping methods established as time series.

Data: Data includes annual coho smolt counts. Data will be provided to BC Hydro under their Water Use Plan program.

Links to other projects: The studies are primarily focused on juvenile steelhead; however, incidental coho and chinook captures are also reported.

5.4 Pink

5.4.1 Assessment Unit

Squamish and other southern Strait of Georgia pink stocks are not directly managed; however, these stocks are indirectly influenced by Fraser sockeye and pink management regimes (B. Fanos, pers. comm. November 2004 in Squamish River Watershed Recovery Plan 2005). Fraser River pink stocks comprise over 99% of pink salmon production in the Lower Fraser Area, and as such, pink salmon management is largely focused on this area. Non-Fraser River pink stocks are not actively managed beyond addressing basic conservation principles (B. Fanos, pers. comm. November 2004 in Squamish River Watershed Recovery Plan 2005). Management of Squamish pink stocks as a distinct unit is required to assess recovery of the stock.

In recent years, Squamish pink salmon have shown a significant increase in numbers (i.e., close to 25,000) at least prior to the CN caustic soda spill in the Cheakamus River in August 2005. Due to the increase in abundance and the goal of recovery within the Squamish watershed, pink salmon should be managed as a unit within the watershed. Insufficient biological and/or genetic information is available to defend alternative management unit designation (i.e., the presence of distinct stocks within the watershed). However, any future data that provides convincing evidence of discrete stocks within the watershed will be assessed and incorporated into the AF at that time.

5.4.2 Resource Recovery Goal

The goal is to allow for the recovery and subsequent maintenance of healthy, wild origin spawning pink populations within the Squamish River watershed. Pink spawner returns should allow for use by the Squamish Nation to meet traditional use requirements and by stakeholders, as well as the establishment of long-term sustainable populations.

5.4.3 Resource Recovery Objectives

The following pink population targets are recommended:

- Set interim habitat-based escapement and fry production goals.
- On an annual basis, meet or exceed the interim habitat-based escapement and fry production goals for wild pink salmon spawning in key areas. Because current abundances are well below historic levels, planners should attempt to achieve cycle over cycle growth of the spawning population.

5.4.4 Information requirements

Juvenile - Reference Point

Interim productive capacity for juvenile pink salmon in the Squamish River watershed have not been determined. DFO has not conducted quantitative assessments of Squamish pink salmon in recent years so accurate and reliable information on juvenile outmigration, timing and biological traits is unavailable. Surveys are required to provide adequate data for estimating juvenile productive capacity.

Juvenile – Abundance

Limited information was found regarding the status of juvenile pink salmon. Under BC Hydro's WUP for the Cheakamus River, population estimates for the odd-year run pink fry were counted in 2000 to 2002 (Melville and McCubbing 2000; 2002a and b; 2003). Pink fry population estimates were 195,000 in 2000 and ranged from 1.1 million to 1.3 million in 2002. Changes in fry population estimates may not necessarily reflect conditions in the river but rather changes in methods used, assumptions met, and the use of different methods to estimate populations. Establishment of a baseline set of data for pink smolt is required and should be a focus in future studies given the PSF and SRWS priorities. In addition, studies should focus on establishing life history traits.

Adult – Reference Point

Interim adult productive capacity for pink salmon in the Squamish River watershed has not been determined. DFO has not conducted quantitative assessments of Squamish pink salmon in recent years so accurate and reliable information on escapement, timing (migration and spawning), and biological traits is unavailable. Currently, no stock status report is available for Squamish pink salmon.

Adult - Abundance

Escapement data available for the Squamish system are based primarily on sporadic, low-precision visual estimates made by fisheries officers and hatchery staff (B. Fanos, pers. comm. October 2004 in Golder 2005) as well as Level 2 (Table 1) enumeration program conducted by the Squamish Nation (2005). Additional adult pink surveys are currently conducted in some of the NVOS side-channels on the Cheakamus River. Historical pink escapement data collected by DFO are available in odd years since the mid-1940s; however, there is a high degree of uncertainty associated with historical data due to differences in methods and fisheries observers over the decades. No data are available for even-year pink run as it is not measurable.

A directed enhancement program conducted by the Tenderfoot Hatchery on pinks in the Squamish watershed since 1985 may have contributed to recently observed increase in the population. A strong population of pink salmon has been established in the Mamquam River since 1987, based on returns from the enhancement program in 1985 to 1993. Similar improved pink salmon returns in the Cheakamus River after 1993 are also suspected to be the result of enhancement efforts by Tenderfoot Hatchery. More recent data indicated approximately 15,500 pinks present in new spawning channels at the NVOS in fall 2003 (Melville and McCubbing 2003). The virtual elimination of commercial fisheries directed at pink salmon in recent years due to conservations concerns with late run sockeye and Thompson coho may also play a factor in recent increases (N. Schubert, *pers. comm.*, April 2005 in Golder 2005).

Currently the only recent abundance estimates for pink salmon are obtained from the Squamish Nation enumeration program. Given the limited data and the established priority by PSF and SRWS current enumeration methods are likely insufficient and should be to assess stock status improved upon in future years.

5.4.5 Procedural Specifications

Juvenile

Few if any pink stocks are assessed on the basis of juvenile production due to level of difficulty and because of pink salmon life history (i.e., fry emerge and go straight to sea). Consequently, adult abundance should be considered as a good indicator of stock status (R. Bocking, pers. comm. March 2006). Juvenile studies on pink salmon are, therefore, a very low priority and investment in better adult escapement estimates is suggested.

Adult

In order to more accurately and precisely monitor pink stocks, an "extensive/intensive" model is suggested. For example, an intensive mark-recapture study (Level 4 from Table 1) could be used on one or more systems (e.g., a sidechannel) providing more precise and accurate estimates. This could be implemented in concert with intensive coho programs using the same indicator systems – e.g. multiple species weir/MR. The current enumeration program conducted by the Squamish Nation, DFO and Golder (i.e., Level 2/3 extensive program) could then supplement intensive programs by providing relative abundance estimates for the entire system.

Alternative Level 4/5 assessments should be considered for either Ashlu or Shovelnose creeks, which employ either resistivity counters or weirs/fishways (Table 4). Given pink salmon operate on a 2-year ocean cycle, intensive monitoring would only be required every 2 years while extensive monitoring should be conducted annually. Resistivity counters have been shown to accurately enumerate pink stocks with minimal maintenance (McCubbing and Ward 1998). These measures provide estimates of known accuracy and enable escapement trends to be tracked for the purpose of evaluating the performance of fisheries management. Trends in these estimates can then be comparatively evaluated against the current Level 2/3 enumeration methods to verify the validity of using the latter. Once these studies have been compared and sufficient data are collected, the level of effort can be focused on monitoring. Addition of Level 4/5 estimates should be considered given the conservation priority of pink salmon as recognized by the PSF and SRWS.

Assessment options are presented in Table 9.

Table 9. Summary Table of Assessment Options for Squamish Pink Stocks

Stage	Current Assessment	Suggested Assessment	Examples
Juvenile	Indirect Level 4	Level 4	IPT, mark-recapture/fyke netting, RST, CPUE
Adult	Level 2	Level 2 (continue)	Relative abundance
		Level 4	Add AUC estimates
		Level 5	Resistivity counters or fish weirs

5.4.6 Operational Assessment Plan

Squamish Nation Salmon Enumeration Program

Location: Squamish River Watershed

Groups: Squamish Nation, DFO, Golder

Contact Persons: Randy Lewis (Squamish Nation), Joe Tadey (DFO) and Bettina Sander, (Golder)

Description: Currently completing its 10^{th} year of collecting enumeration data for pink using standardized visual survey estimates. Operating at a Level 2/3 assessment.

Data: Data generated for pink salmon includes: relative abundance (live and dead counts), catch hail, and run timing. Data are available for systems throughout the watershed, and are collected from July-February. Data are provided by Squamish Nation enumerators to Golder Associates for QA/QC, handling, compilation, and report processing. Data in the form of a final report is provided to Squamish Nation. Raw data are provided to DFO for incorporation into regional frameworks.

Links to other assessment projects: This project is linked to enumeration also being conducted for chinook, coho and chum salmon.

5.5 Chum

5.5.1 Assessment Unit

There are two management units for chum in the Canadian Pacific Region: the Inner South Coast Chum Stock (ISC); and the West Coast of Vancouver Island (WCVI) unit. Chum in the Squamish area is managed within the ISC unit. This aggregate includes chum from Seymour to Belize Inlet, Kingcome Inlet, Burrard Inlet, Fraser River, Boundary Bay, Upper Vancouver Island, and Howe Sound/Sunshine Coast (PSF 2005). This unit includes all chum that move through the Strait of Georgia as opposed to the West Coast of Vancouver Island. Management of Squamish chum as a distinct unit is required to assess recovery of the stock.

At this stage, the Squamish River watershed will be managed as one assessment unit as insufficient biological and/or genetic information is available to defend alternative management unit designation (i.e., the presence of distinct stocks within the watershed). However, any future data that provides convincing evidence of discrete stocks within the watershed will be assessed and incorporated into the AF at that time.

5.5.2 Resource Recovery Goal

The goal is to allow for the maintenance of healthy, wild origin spawning chum populations within the Squamish River watershed. Chum spawner returns should allow for use by the Squamish Nation for traditional use requirements and by stakeholders, as well as for the establishment of long-term sustainable populations.

5.5.3 Resource Recovery Objectives

No chum recovery objectives were identified in the recovery plan, however at minimum cycle over cycle growth of the spawning population should be maintained.

5.5.4 Information requirements

Juvenile – Reference Point

Juvenile chum abundance goals have not been set and the productive capacity of the Squamish River watershed to support chum has not been quantified. Similar to pink salmon, this is due to the level of difficulty of the methods and because of chum life history (i.e., fry emerge and go straight to sea). This would suggest adult abundance to be a good indicator of stock status (R. Bocking, pers. comm. March 2006). Juvenile studies on chum salmon are, therefore, a very low priority and investment in better adult escapement estimates is suggested.

Juvenile – Abundance

Little information regarding juvenile chum salmon was available for the Squamish River watershed. Data were limited to the Cheakamus River where yearly juvenile migration studies were conducted under B.C. Hydro's WUP. Juvenile salmon migration studies were conducted using RSTs from 2000 to 2003 (Melville and McCubbing 2000; 2002a; 2002b; and 2003). Population estimates ranged from 2.1 million fry in 2001 to 2.9 million fry in 2003. These studies were heavily biased towards steelhead habitats and timing, and thus do not adequately address the status of juvenile chum. In addition, the bounds on these estimates were likely large which would make assessing status or recovery difficult (R. Bocking, pers. comm. March 2006).

Given chum's low priority relative to chinook and coho, there is no immediate need to develop juvenile abundance estimates for chum in the Squamish River watershed. If chum's priority changes over the years and abundance estimates are deemed necessary, they should be developed in accordance with, or after appropriate reference points have been established. In the meantime, it is possible that studies focused on other salmon species or steelhead will also provide information on the status of chum.

Adult – Reference Point

To our knowledge, adult chum abundance goals have not been set and the productive capacity of the Squamish River watershed to support chum has not been quantified. Given the abundant trends in chum adult escapement relative to other species, there is a lower priority to evaluate adult chum reference points. However, the establishment of interim targets are worthwhile as one would want to know if recovery actions affecting other species have a collateral effect on chum (R. Bocking, pers. comm. March 2006).

Adult – Abundance

Historical DFO chum escapement data are available from 1947 to 1996 for the Cheakamus, Mamquam, Ashlu, Stawamus, and Squamish mainstems. According to DFO escapement and Squamish Nation relative abundance data, chum salmon have not shown a steady decline as was observed for the other salmon stocks, but rather showed high variability between years. Chum escapements to the Cheakamus River have generally increased since the 1970s (KWL 1998 in Golder 2005).

Given these trends and chum's lower priority relative to depleted stocks such as chinook, enumeration studies beyond the current Squamish Nation program are not recommended.

It is suggested that information continue to be collected as is in order to provide long-term trends for this species.

5.5.5 Procedural Specifications

Although chum is a low priority species in the Squamish River watershed establishment of targets and continued monitoring using current approaches are recommended. The Squamish Nation enumeration program has provided relatively consistent enumeration data between 1996-2006 and this program should ensue with little change for the time being. Trends in relative abundance should be noted and any significant decrease in chum adult numbers (i.e., if abundance below 5,000 occurs over more than 1 year) should trigger a subsequent re-prioritization. If additional studies are to go forward, reference points for adults should first be established against which abundance levels can be compared. The assessment of life history characteristics of chum can be conducted in conjunction with other such studies for other species in the watershed, where appropriate.

Given chum's relative abundance numbers over the past 10 years, we suggest the Level 2 assessment currently underway through the Squamish enumeration program continue as a way of continuing to monitor the population over time with little or no additional study requirements. We do suggest, however, that a minimum relative abundance number over a determined number of years (i.e., under 10,000 for > 2 years) be established as a way to trigger the adaptive management process.

Options for assessment of Squamish chum stocks are provided in Table 10.

Table 10. Summary Table of Assessment Options for Squamish Chum Stocks.

Stage	Current	Suggested	Examples
Juvenile	Indirect Level 4	None	NA
Adult	Level 2	Level 2 (continue)	Relative abundance

5.5.6 Operational Assessment Plan

Squamish Nation Salmon Enumeration Program

Location: Squamish River Watershed

Groups: Squamish Nation, DFO, Golder

Contact Persons: Randy Lewis (Squamish Nation), Joe Tadey (DFO) and Bettina Sander, (Golder)

Description: Currently completing its 10th year of collecting enumeration data for coho using standardized visual survey estimates. Operating at a Level 2/3 assessment.

Data: Data generated for Chum include relative abundance (live and dead counts), catch hail, and run timing. Data are available for systems throughout the watershed, and are collected from July-February. Data are provided by Squamish Nation enumerators to Golder Associates for QA/QC, handling, compilation, and report processing. Data in the form of a final report is provided to Squamish Nation. Raw data is provided to DFO for incorporation into regional frameworks.

Links to other assessment projects: This project is linked to enumeration also being conducted for chinook, coho, and pink salmon.

5.6 Steelhead

5.6.1 Assessment Unit

Wild steelhead stocks are managed within the Greater Georgia Basin (GGB) defined as the east coast of Vancouver Island, adjacent mainland inlets, and the lower Fraser River). This basin is divided into 2 regions; Vancouver Island and Lower Mainland. These are subsequently divided into 4 sub-areas: NE Vancouver Island/Adjacent Mainland; East Vancouver Island – Campbell River South; Southern Mainland Inlets and Lower Mainland and; Lower Fraser Watershed and Delta (GGBSRAP 2002). The stocks appear to be managed at the subarea level, however, data are also provided on a watershed basis.

At this stage, the Squamish River watershed will be managed as one assessment unit as insufficient biological and/or genetic information is available to defend alternative management unit designation (i.e., the presence of distinct stocks within the watershed). However, any future data that provides convincing evidence of discrete stocks within the watershed will be assessed and incorporated into the AF at that time.

5.6.2 Resource Recovery Goal

The primary objective of the recovery plan is to stabilize and restore wild steelhead stocks and habitats to healthy self-sustaining levels. A secondary objective is to maintain and restore angling opportunities, which benefit both local communities and the provincial economy.

5.6.3 Resource Recovery Objectives

Recovery and management objectives were initially provided in the GGBSRP (2003), and reiterated in the Squamish Recovery Plan (PSF 2005). They are as follows:

- At a minimum, recover steelhead stocks to:
  - Cheakamus River: Conservation Concern Zone (stocks are 10% to 30% of habitat capacity - although status is set in between Resource Management and Conservation Concern zones, we apply the most conservative)
  - Squamish River: Extreme Conservation Zone (stocks at least 30% of habitat capacity).
  - Mamquam River: Conservation Concern Zone

5.6.4 Information requirements

Juvenile – Reference Point

Steelhead smolt productive capacity are based on extensive juvenile assessments conducted since the 1980s of fry/parr habitat capacity, mean annual discharge, and stream productivity (PSF 2005; GGBSRP 2003), and have been set at the following:

- Squamish River: 7,700 to 15,400 steelhead smolts;
- Cheakamus River: 5,400 steelhead smolts; and
- Mamquam River: 1,155 to 1,540 steelhead smolts.

Juvenile – Abundance

In the Squamish River watershed, Level 4 juvenile surveys have been conducted annually from 1999 to present (ARL 1998 to 2001, Hanson 2004a and b in Golder 2005). These studies focused on steelhead fry habitat and enumerated fry abundance using electrofishing in various Squamish tributaries. Juvenile data for streams sampled in 2003 and 2004 indicate densities have declined since 2001 (G. Wilson, pers. comm. November 2004.

Based on the juvenile data available, trends over time cannot yet be established. It is difficult to conclusively support declining trends in fry abundance over the last two decades. This is likely the result of the limited scope of work, different methodologies used to collect information, and different study objectives, all of which make comparisons and establishing trends difficult. However, information from snorkel surveys and angler surveys indicates that current steelhead populations have experienced a significant decline over historical abundances. The effects of the CN spill into the Cheakamus River in August 2005 on steelhead populations have yet to be determined.

Adult – Reference Point

Productive capacities for steelhead in the Cheakamus, Mamquam, and Squamish rivers based on marine survival are provided in the GGBSRP (2002). These were arrived at following regional workshop sessions with Ministry staff that reviewed relevant inventory data, habitat maps, models, and habitat capacity trends. However, due to the variability associated with these estimates (2-26% estimated from 1970s to present), interim steelhead productive capacities have been provided based on smolt production, which reflects freshwater conditions (PSF 2005). Assuming marine survival of 13%, estimated habitat capacities of returning adults are as follows:

- Squamish River: 1,000 to 2,000 adults;
- Cheakamus River: 700 to 1,000 adults; and
- Mamquam River: 100 to 200 adults.

Recent ocean survivals have been much lower according to Keogh River studies with current marine survivals are estimated to be below 4%. Given this discrepancy between the above habitat capacities based on 13% survival and numbers that would reflect a lower survival, current productive capacities would provide a very conservative reference point for steelhead. Although steelhead juveniles are considered a more desirable reference point due to its ability to reflect the full productive capacity of their freshwater habitat, these adult estimates are considered appropriate for the time being until more information on marine survival is available.

Adult - Abundance

The Greater Georgia Basin Steelhead Recovery Action Plan (GGBSRAP) provides a general overview of the status of steelhead populations in the Squamish, Cheakamus and Mamquam rivers (GGBSRAP 2002). Essentially, declines in steelhead abundance have been reported since the 1970s, with some slight increases observed in 2003 and 2004 (GGBSRAP 2002).

Steelhead escapements in the mainstem Squamish and other larger tributaries, such as the Ashlu and Elaho, are largely unknown. However, escapements for the Cheakamus River and, to a lesser extent, the Mamquam River are fairly well understood. Determining trends in steelhead escapement is difficult due to differences in methodologies, study objectives, and degree of precision. However, Level 2/3 assessments of steelhead adult status have been ongoing and the GGBSRAP have rated various steelhead stock statuses as:

- Cheakamus River: Conservation Concern Zone (stocks are 10% to 30% of habitat capacity - although status is set in between Resource Management and Conservation Concern zones, we apply the most conservative)
- Squamish River: Extreme Conservation Zone (stocks at least 30% of habitat capacity).
- Mamquam River: Conservation Concern Zone

5.6.5 Procedural Specifications

Juvenile stock status of steelhead in the Squamish River watershed are ongoing with Level 4 studies focused on: steelhead fry habitat and fry abundance using triple pass removal (electrofishing) in enclosed areas; and steelhead smolt using RSTs. These studies should continue, particularly in locations in and around the Cheakamus River given the August 2005 spill of caustic soda that resulted in approximately 90% mortality in four age classes of rearing juvenile steelhead/rainbow trout (McCubbing et al., 2005).

Ongoing adult escapement studies using snorkel surveys (Level 2-3) in these systems will likely continue, however, increased resolution and a move to true abundance measures (Level 4) is recommended given this species conservation status. These may include options put forth in Table 3:

- Mark-recapture
- Resistivity counters
- Hydroacoustic counters

A high priority should be given to finding a suitable location for a resistivity counter for steelhead (R. Bocking, pers. comm. March 2006). Options of assessment for Squamish steelhead are summarized in Table 11.

Table 11. Summary Table of Assessment Options for Squamish Steelhead Stocks

Stage	Current	Suggested	Examples
Juvenile	Level 4	Continue Level 4	Electrofishing
Adult	Level 2	Level 2 (continue)	Snorkel surveys
		Level 5	Resistivity or hydroacoustic counters

5.6.6 Operational Assessment Plan

Cheakamus River steelhead smolt outmigration studies

Location: Cheakamus River

Groups: BC Hydro; Instream Fisheries Research Ltd.

Contact Persons: Don McCubbing and Caroline Melville (Instream)

Description: Monitor steelhead smolt densities and migration using RST trapping methods established as time series.

Data: Data includes annual steelhead smolt counts. Data will be provided to BC Hydro under their Water Use Plan program.

Links to other projects: The studies are primarily focused on juvenile steelhead; however, incidental coho and chinook captures are also reported.

6.0 DATA MANAGEMENT PROTOCOLS

Standardization of methods and establishing effective data management protocols are key in establishing long term trends in salmonid escapement and abundance. Standardization of field methods, survey frequencies, data collection and storage, as well as improving communications and establishing methods to input results into Regional databases are required to link studies conducted my multiple players within the watershed. Ownership, storage and dissemination of data are, therefore, crucial and are addressed below extracting certain key tools from DFO's "Management Policy for Scientific Data". The establishment of specific framework will ensure that data flows effectively and efficiently from the field to in-season dissemination to post season analysis to incorporation into broader assessments.

6.1 Data Archiving

All Squamish River watershed scientific data related to stock assessment must be managed as part of an integrated system accessible through a central data centre. Given the need to integrate all watershed data in one place and to have a single point of access for all stakeholders, it is recommended that data be stored and managed in the Squamish area in association with the SRWS. Specific managers and support staff will need to be designated and key data management responsibilities outlined. Contact names and numbers will be provided to all participants of Squamish River watershed stock assessment programs and information will be available to all participants.

The responsibilities of the integrated system of data centres will be to:

- Respond to internal and external data requests.
- Maintain inventories and documentation for all data holdings.
- Provide basic data retrieval, integration and summarization capabilities to satisfy common requests.
- Ensure long term accessibility and documentation in the event of organizational changes, retirements, etc.
- Protect data against loss resulting from error, accident, technological change, degradation of media, etc.

6.2 Data Submission

It will be the responsibility of the designated managers to ensure that data collectors under their management submit their data as well as data collected under contract to or partnership with other agencies, to the data centre in a timely fashion. This is important to ensure that data are quickly migrated into a 'managed' environment where they are properly backed up and secured from accidental or circumstantial loss.

Timely fashion will be taken to mean that: (a) data sets will be submitted immediately after the data are processed (b) submission will not be delayed while data analysis, statistical treatment, interpretation and publication occur, and (c) submission will include metadata prepared by the data collector to accompany the data set and document the methodologies and other details needed so that others are aware of the potential limitations of the data.

Exceptions to this policy are possible if: (a) the responsible manager and the responsible data centre have agreed that the data in question are not appropriate for submission, or (b) it can be demonstrated that there is a legal imperative (e.g. legal chain of custody requirements) that categorically prohibits submission of the excluded data, or (c) an extension or exemption from the policy is sought for other reasons and granted in writing by the senior manager.

Data submission to the responsible data centre does not mean that the data will be openly accessible. Thus concerns about access shall not be seen as a valid reason for not submitting data. It is the responsibility of the senior manager to designate data as classified for the purpose of preventing access to data which may not and must not be openly accessible.

6.3 Availability of Data

All scientific data are to be public resource and subject to full and open access. In cases where danger of improper or incorrect interpretation of the data are present, steps shall be taken to ensure that potential users are fully apprised of this possibility and a contact person should be identified who can provide assistance in proper use and interpretation.

6.4 Inclusion of a Data Management Component in Science Project Plans

All science project proposals and plans should demonstrate the existence of a comprehensive data management plan, or must develop one if the existing infrastructure cannot adequately respond to the requirements of the project. This plan should include strategies and schedules for the transfer of the data to the responsible data centre. The project budget must clearly indicate the allocation of resources for data management and how these resources will be used. The designate will be responsible for conducting periodic reviews of data management activities to ensure that they are consistent with the plan.

6.5 Data Submitted under Regulations or Having Legal Aspects

Scientific data that have legal aspects constraining their distribution, whether collected by DFO or submitted by third parties, should be kept in their original form, and appropriately secured. If confidential data are submitted by third parties, a letter from the third party will be obtained indicating that the data are confidential. As well, the data manager responsible for that data set should designate the data as "Protected - Third Party Information".

7.0 CLOSURE

We trust the information contained in this interim report is sufficient for your review and invoicing requirements. Please do not hesitate to contact the undersigned should you have any questions or comments in regard to this study.

Yours very truly,

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