LOWER SHUSWAP RIVER

Inventory, Mapping, and Aquatic Habitat Index

City Of ENDERBY

REGIONAL DISTRICT NORTH OKANAGAN

Prepared For:

Regional District North Okanagan, City of Enderby, and Department of Fisheries and Oceans Canada

July 2011

Fisheries and Oceans Canada
Pêches et Océans Canada

LOWER SHUSWAP RIVER
Inventory, Mapping, and Aquatic Habitat Index

A Living Document – Version 1.1

Prepared For:

REGIONAL DISTRICT NORTH OKANAGAN
CITY OF ENDERBY
DEPARTMENT OF FISHERIES AND
OCEANS CANADA

Prepared By:

ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.
102 - 450 Neave Court
Kelowna, BC
V1V 2M2

July 2011

Ecoscape File No. 10-642

ECOSCAPE
Environmental Consultants Ltd.

Fisheries and Oceans Canada   Pêches et Océans Canada

ACKNOWLEDGEMENTS

This project would not have been realized without the assistance and contribution from the following individuals and organizations:

- Bob Harding, Department of Fisheries and Oceans Canada – for coordinating this initiative and providing technical support during field inventory.
- Darryl Hussey, Department of Fisheries and Oceans Canada – for providing technical support during field inventory.
- Lisa Tedesco, Ministry of Environment – for providing technical support during field inventory.
- Bruce Runciman, Department of Fisheries and Oceans Canada – for providing technical support and review through development of the Index Matrices, relative habitat values, and Index Logic.
- Sheldon Romain, Department of Fisheries and Oceans Canada – for safe boat navigation of the Lower Shuswap River and for technical support during field inventories.
- Salmon spawning information was contributed by Nicole Trouton – Stock Assessment (chinook) and Rob Bemister – Stock Assessment (sockeye), both with the Department of Fisheries and Oceans Canada as well as by Mr. Neil Brookes.

Funding for this project was provided by:

Step 1 (River Inventory and Mapping):

- Department of Fisheries and Oceans Canada
- City of Enderby
- Regional District of North Okanagan

Step 2 (Aquatic habitat Inventory):

- Regional District of North Okanagan

The following parties contributed to the development of the Aquatic Habitat Index:

Kyle Hawes, Ecoscape Environmental Consultants Ltd
Jason Schleppe, Ecoscape Environmental Consultants Ltd
Brian Jantz, Lakestream Environmental Services
Bruce Runciman, Fisheries and Oceans Canada

The authors of this report were:

Kyle Hawes, R.P.Bio. (Ecoscape)
Jason Schleppe, M.Sc., R.P.Bio. (Ecoscape)
Brian Jantz, R.P.Bio. (Lakestream)

Geographical Information Systems (GIS) mapping and analysis was prepared by:

Robert Wagner, B.Sc. (Ecoscape)

Recommended Citation:

Hawes, K., J. Schleppe, and B. Jantz, 2011. Lower Shuswap River Inventory, Mapping, and Aquatic Habitat Index. Ecoscape Environmental Consultants Ltd.. Project File: 10-642. 72pp + appendices.

INFORMATION DISCLAIMER

The results contained in this report are based upon data collected during a single season inventory. Biological systems respond differently both in space and time. For this reason, the assumptions contained within the text are based upon field results, previously published material on the subject, and airphoto interpretation. The material in this report attempts to account for some of the variability between years and in space by using safe assumptions and a conservative approach. Data in this assessment was not analyzed statistically and no inferences about statistical significance are made if the word significant is used. Use of or reliance upon biological conclusions made in this report is the responsibility of the party using the information. Neither Ecoscape Environmental Consultants Ltd., nor the authors of this report or the Department of Fisheries and Oceans, the Regional District North Okanagan, or City of Enderby is liable for accidental mistakes, omissions, or errors made in preparation of this report because best attempts were made to verify the accuracy and completeness of data collected, analyzed, and presented.

This is intended as a "*Living Document*". In so being, it may be continually edited and updated and may evolve and be expanded as needed, and serve a different purpose over time.

EXECUTIVE SUMMARY

Background

Mapping of the Lower Shuswap River (LSHU) was conducted following the current three-step Lake Management Process being standardized across British Columbia. Sensitive Habitat Inventory and Mapping (SHIM) and Foreshore Inventory and Mapping (FIM) are protocols used to collect baseline information regarding the current condition of watercourses, shorelines, and associated riparian habitats. These inventories provide information on channel character, shore/bank types and condition, substrates, land use, and habitat modifications. Currently there is no protocol for completing a similar inventory on large rivers. However, using existing SHIM (for wadeable streams) and FIM protocols, inventory methods were adapted, to be both practical and applicable to middle to large-sized river such as the Lower Shuswap.

Project Objectives

The objective of this project was to inventory and map the current instream and riparian habitats and conditions/impairments and catalogue all anthropogenic features and activities occurring along the river and to subsequently complete an Aquatic Habitat Index (AHI). This report summarizes the key findings of the inventory and relative value (index) of habitats occurring both within the river and along its banks. In accordance with the current three-step Lake Management Process, being standardized across British Columbia, Step 3 (Guidance Document) is recommended to be subsequently undertaken to identify the Shoreline Vulnerability or sensitivity to changes in land use or habitat modification. Shoreline Vulnerability zones are based upon the Aquatic Habitat Index. The Shoreline Vulnerability uses a risk based approach to shoreline management, assessing the potential risks of different activities (e.g., agriculture, recreation) in the different shore segments and river reaches.

The goal of this project was to adapt existing and accepted protocols for completing biophysical inventories of aquatic and riparian ecosystems to augment ecological landuse planning. This inventory and data collection design was intended to provide a robust baseline inventory (cataloguing the river and all natural and anthropogenic features occurring within and along it) for improving integrated resource management and planning within the Shuswap River watershed.

The inventory mapped the spatial extents of the main stem of the LSHU and associated flood plain areas within 100-m of the active floodplain limit including but not limited to back channels, islands and wetlands with year round and seasonal connectivity and associated riparian habitats, and important watercourse and fisheries habitat features.

Relative habitat values were assigned to subareas within the river channel and 100-m riparian band. An Aquatic Habitat Index (AHI) was subsequently developed that summated the score of habitat subareas relative to the total area of respective channel reaches and 100-m wide bank segments. The goal was to assign index ranks (*Very Low – Very High*) to the river and left and right banks.

Summary of Results and Discussion

The Lower Shuswap River flows about 72.7 km from Mabel Lake to Mara Lake. The River was broken into a total of 24 reaches. The left bank (looking downstream) was divided into 50 Segments and the right bank was broken into 56 Segments. The total length of the left and right river banks was 81 km and 77 km respectively.

Combined, rural and agricultural landuse predominate the banks of the Lower Shuswap. In terms of segment landuse, only 14% of the right bank was classified as natural (not having recent anthropogenic disturbance) while about 41% of the left bank was classified as natural. The more natural left bank was associated with more restricted access upstream of Enderby. Anthropogenic impacts to the river occurred in highest density from Enderby downstream. During the field inventory, it was estimated that about 35 km (43%) of the left bank was modified and about 47 km (60%) of the right river bank was modified.

Over the lower 33 km of the river from Enderby to Mara Lake (Reaches 1-4), cover is limited to instream vegetation and infrequent deep holding pools. Over this distance, just seven deep holding areas were identified. In total, deep holding areas are estimated to account for less than 2% of the entire Lower Shuswap River. Suitable spawning habitat for salmonids was not identified or encountered until Reach 7, just under 41 km upstream of Mara Lake (about 6 km upstream of Enderby). In terms of aerial coverage, about 146 hectares of the Lower Shuswap is suitable fish spawning habitat, which accounts for about 18% of the total river channel area (829 ha).

Over 80% of the left bank and greater than 90% of right bank are characterized as flood bench associations. These are lush habitats with structural elements often not found in adjacent uplands. Low and middle bench site associations combined accounted for about 57% of the right bank and about 39% of the left bank. Key rearing areas for Chinook are flooded pastures, backwaters and sloughs adjacent to spawning areas (Federenko and Pierce 1982). In terms of potential rearing and nursery habitat, low flood bench sites and riverine wetlands occurring adjacent to the river channel and in backwater areas, cover over 100 hectares. Human-induced isolation of middle or low bench ecosystems from the regular flooding, through sediment accumulation or stream channel changes, hastens the natural succession and can lead to the formation of seral ecosystems that progress towards high bench or upland ecosystems (Mackenzie and Moran 2004). This can in-turn lead to a reduction in suitable rearing and nursery sites for juvenile salmonids.

Bank erosion (moderate to extreme severity) was documented on over 16% of the left bank and 21% of the right bank. High to extreme erosion accounted for about 10% of the left bank and about 13% of the bank. The recorded maximum exposure for a single continuous incident was about 3264 m^2 on the left bank and 2961 m^2 on the right bank. Bank instability appeared to be largely attributed to the lack of riparian vegetation and encroachment associated with agricultural land use, and rural, and residential development. Some of the more severe incidents also appear to be a result of riparian clearing along power transmission corridors. Adding to this, it is generally accepted that increased recreational boating along the Lower Shuswap may be further exacerbating erosion of these un-vegetated and destabilized banks. In other instances, the marked increase (compared with historic aerial photos) in size of some tributary fans (perhaps associated with logging practices and slope destabilization in the upper watersheds) are deflecting river flows to the opposing bank with greater force and, in conjunction with impacts to riparian communities and bank integrity, erosion (on the opposing banks) was considerable.

Based on the results of the field inventory, the Lower Shuswap River was assigned a stream grade of 34%, which is based on a condition score of 2.04/6.00. About 30% of the river (by length) had a high level of impact with poor riparian condition. Reaches 1-4 were in poorest condition (0-1 Scores), combined accounting for about 45% of the Lower Shuswap River. About 29% of the river is in fair condition, and about 26% is in good condition.

The centerline AHI analysis resulted in about 53% of the river being ranked as *Low* represented by the 6 consecutive reaches (1-6) from Mara Lake to about 38.5 km upstream. AHI scores increased markedly in Reach 7 with changing river morphology and a general increase in habitat complexity transitioning from Moderate to continuous High and *Very High* rankings being assigned to Reaches 11-21. Of these, the highest scores occurred through Reach 13 (the Islands) and Reach 19 adjacent to and downstream of the Cooke Creek confluence.

About 43% of the Left Bank of the lower Shuswap River is ranked *Very High.* Conversely, about 45% of the Right Bank of the river is ranked *Low* to *Very Low*. These scores corroborate the field inventory data; where about 41% left bank was classified as natural while only about 14% of the right bank was classified as natural.

Others studies have examined the impact of boat wakes on the hydrodynamics of river channels. With 81% of the docks recorded on the Lower Shuswap River occurring in Reaches 1 – 5 (Mara Lake to Enderby), it is plausible that more intensive watercraft use and operation is a factor in decreased bank stability and increased erosion. The hydraulic character of the lower reaches is a low gradient, low velocity, straight to sinuous glide, with generally low erosive forces. However when combined, the lack of riparian vegetation and boat wakes may be a key causal factor of observed erosion along the river bank in lower reaches. Other agencies and studies have noted that it is difficult to apply a universal rule for all boats because of their variable configuration and behaviour in the water. For instance, a single recommended speed limit may mitigate wave-related impacts from some vessels; while for others, such as sport boats with ballast tanks (to increase wake size), a reduced speed may actually increase the vessel`s draught – effectively increasing the wave height and subsequent impact to the shoreline. As such, the surest approach is to observe the wake produced by individual boats and establish No Wake Zones.

Based on the inventory results, there is a lack of deep water holding pools/thermal refuge areas downstream of Enderby to Mara Lake. This, in conjunction with more intensive landuse and recreational pursuits (namely boating), presents concerns for Fisheries staff relating to the potential stress on migrating adult salmon. In consideration of this it is important to better protect tributaries and groundwater discharge zones not only for the productive habitats but also for the thermal refuge these features provide.

Opportunities for riparian and channel-bank restoration using bioengineering techniques occur along much of the Lower Shuswap River. Benefits of these activities will include bank stabilization and habitat restoration. For instance, spawning was found to be associated with channel complexity, large woody debris, gravel sources, and more intact stream banks. Recognizing the overall lack of large woody debris (LWD) cover through the lower reaches, the inclusion of such in bioengineering projects will help restore instream habitat complexity, especially recognizing that woody debris recruitment from intact riparian forests is lacking.

To fully realize the benefit of such biophysical inventories, actions need to be taken to begin to address concerns or issues identified. In doing so, this information must be presented to pertinent groups and stakeholders to direct appropriate action and management decisions. The inventory and AHI identified areas of concern along the river and, through a restoration analysis, extracted 18 bank segments of priority for more immediate action. For instance, severe bank erosion was indentified along BC Hydro power corridors (Right Bank Segments 23, and 25). Accordingly, this information should be provided to BC Hydro for consideration of streambank restoration initiatives and for the protection of existing infrastructure.

While prioritizing segments for bank restoration and riparian enhancement, the fundamental objective of future management of the river and activities occurring or proposed along it should adhere to the guiding principle of No Net Loss. Therefore, regardless of the current relative instream and bank habitat values identified by the AHI, no activities should be permitted that would result in degradation of these existing scores. Rather, through adherence to Best Management Practices, a net gain in relative habitat value (i.e., increased AHI scores/ranking) should be a fundamental objective of current or proposed activities/developments along segments that have been historically degraded from their natural state. Furthermore, development should be directed away from segments with *High* and *Very High* AHI rankings to avoid a loss in relative habitat value.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

MAPS

APPENDICES

1.0 INTRODUCTION

Mapping of the Shuswap Watershed is being conducted following the current three step Lake Management process being standardized across British Columbia and described below:

1. Sensitive Habitat Inventory and Mapping (SHIM) and Foreshore Inventory and Mapping (FIM) are protocols used to collect baseline information regarding the current condition of watercourses, shorelines, and associated riparian habitats. These inventories provide information on, channel character, shore/bank types and condition, substrates, land use, and habitat modifications. This information is combined where possible, with other mapping information such as previous fisheries inventories, recent orthophotos, and other information. Prior to this project, there is no protocol for completing a similar inventory for large rivers such as the Shuswap.

2. An Aquatic Habitat Index (AHI) is generated using the processed field data to determine the relative habitat value of the aquatic habitats and shoreline areas. This index follows similar methods that were developed for Okanagan Lake and Windermere Lake and is similar to other ongoing assessments along Wasa, and Moyie and Monroe Lakes. The Aquatic Habitat Index uses many different criteria, such as biophysical, fisheries values, and anthropogenic characteristics to estimate the habitat value of a shoreline segment. The Habitat Index classifies this information in a 5-Class system from Very High to Very Low.

3. Shore Line Management Guidelines are prepared to identify the Shore Line Vulnerability or Sensitivity to changes in landuse or habitat modification. Shoreline Vulnerability Zones are based upon the Aquatic Habitat Index described above. The Shoreline Vulnerability uses a risk-based approach to shoreline management, assessing the potential risks of different activities (e.g., construction of docks, groins, marines, etc.) in the different shore segments. The Shore Line Management Guidelines document is intended to provide background information to stakeholders, proponents, and governmental agencies when land use changes or activities are proposed that could alter the shoreline thereby affecting fish or wildlife habitat.

In 2009 Ecoscape Environmental Consultants Ltd. (Ecoscape) was contracted by the Regional District North Okanagan (NORD), the City of Enderby, and Department of Fisheries and Oceans Canada (DFO) to complete a comprehensive inventory of the lower Shuswap River between Mabel Lake and Mara Lake. Subsequently, Ecoscape was contract by NORD in 2010 to develop an aquatic habitat index (AHI) for the lower Shuswap River, which incorporates information gathered and synthesized during the 2009 inventory. The following technical report outlines the project approach and presents and analyses the results of the both the Inventory and AHI phases of the project. This report is intended as a "Living Document". In so being, it may be continually edited and updated and may evolve and be expanded as needed, and serve a different purpose over time.

1.1 Project Background

As resource development and human populations increase in British Columbia, pressures for all resources and services have accelerated. Rapid growth has often overwhelmed the ability of local planners to manage land and preserve sensitive habitats (Mason and Knight, 2001). This has resulted in the loss or degradation of aquatic and riparian habitats that are critical for fish and a diverse wildlife assemblage. More specifically, the rapid population growth and development around our large interior lakes and rivers is one of many factors that is impacting our fish and wildlife resources. This tremendous growth rate has resulted in commercial and residential developments around these large lakes and rivers. This rapid increase in population and development identifies a significant challenge to plan and/or manage future growth around our large interior lakes. Accordingly, there is an urgent need to develop stronger tools and better methods to conserve, protect and reclaim these habitats.

SHIM and FIM are recognized standards for fish and aquatic habitat mapping in urban and rural watersheds in British Columbia. These protocols attempts to ensure the collection and mapping of reliable, high quality, current, and spatially accurate information about local freshwater habitats, watercourses, and associated riparian communities.

These protocols are designed as land-planning, computer-generated, interactive GIS tools that identify sensitive aquatic and terrestrial habitats. They are intended to provide community, stewardship groups, individuals, regional districts and municipalities with an effective, low-cost delivery system for information on these local habitats and associated current land uses.

SHIM and FIM have numerous applications and can:

- Provide current information not previously available to urban planners, to allow more informed planning decisions and provide inventory information for integration into Official Community Plans. In addition, this information can be used to educate the public as to the natural resource values of these systems and the impacts our activities have on them;

- Provide a catalogue of the current condition of the foreshore to aid with permit and compliance monitoring;

- Assist in the design of stormwater/runoff management plans;

- Monitor for changes in habitat resulting from known disturbance;

- Identify and map potential point sources of pollution;
- Help guide management decisions and priorities with respect to habitat restoration and enhancement projects;
- Assist in determining setbacks and fish/wildlife-sensitive zones;
- Identify sensitive habitats for fish and wildlife along watercourses;
- Provide a means of highlighting areas that may have problems with channel stability or water quality that require more detailed study;
- Provide a baseline inventory of existing shoreline developments/modifications such as docks, retaining walls, groynes, stream mouths, and land use activities; and,
- Provide baseline mapping data for future monitoring activities and development of a shoreline management plan.
- Map and identify the extent of riparian vegetation available and used by wildlife and fisheries resources.

2.0 METHODOLOGY – RIVER INVENTORY

Biophysical surveys of the LSHU adapted the data collection methods and standards of Sensitive Habitat Inventory and Mapping (SHIM) (Mason and Knight, 2001) and Foreshore Inventory and Mapping. Data was recorded using a Trimble Nomad and XH GPS Receiver and Trimble GeoXT GPS/Data Logger and entered into a digital data dictionary. Data collection fields for respective biophysical and anthropogenic attributes are listed in the following sub sections. Data collection methods and processing standards can be reviewed in full at:

http://www.shim.bc.ca/methods/SHIM_Methods.html

Entering data into the Trimble Geo XT (Left) using the data dictionary developed specifically for the LSHU inventory (Appendix D). Marking up large format field maps for subsequent incorporation into GIS mapping and integration into the final data deliverables (Right).

2.1 Pre-Field / Start-up

Ecoscape completed the following tasks for this component of the project:

- Ecoscape met with DFO staff (Bob Harding) to:
    - Finalize the goals and objectives for the project;
    - Review and finalize the methodology and important field coordination;
    - Review opportunities to collaborate with other ongoing valley projects and organizations (e.g., OCCP).

- With the assistance of DFO, Ecoscape collected all relevant background information for the project including:
    - Most recent DFO cadastre base;
    - Any orthophotos;
    - Gray literature (consultant reports) or other reference material applicable to the project.

Ecoscape reviewed all pertinent background information useful to the LSHU project and incorporated this data, where relevant, into respective watercourse features and their attributes.

Prior to initiating field surveys, Ecoscape reviewed high resolution digital imagery (ortho photos). Preliminary reach breaks (segments) were identified and right and left bank shoreline segments were determined. In addition, we identified adjacent natural features of interest (i.e., tributaries, side channels, islands, wetlands etc.) that otherwise may not be picked up during standard centerline surveys. Large format field maps were then produced, on which field staff transcribed various field data.

2.2 GPS Video taken from Mara Lake to the Islands.

Prior to deployment of field inventories, Fisheries and Oceans staff conducted a reconnaissance of the LSHU and collected GPS Video. While not employed in subsequent field inventory and analysis, this video will provide an important baseline reference for future monitoring activities and compliance audits.

2.3 Lower Shuswap River Adapted SHIM/FIM for Large River Systems

The LSHU SHIM data collection, data processing, and data deliverables were based on the mapping standards for SHIM (Mason and Knight, 2001), with consideration that the LSHU is a middle to large-sized river. The Data Dictionary (Version 1.1) is provided in Appendix D. This digital data collection format adapts both SHIM and FIM dictionaries into a common field data collection file, tailored to a spatial biophysical inventory on a large river system like the LSHU. The intent of this approach was to develop a specific mapping protocol that can be used on other large river systems in British Columbia.

2.3.1 Centerline Survey

The centerline of the river channel was mapped along the center of the bankfull (not floodplain) width. While both banks and instream features were digitized using air photo interpretation. Comprehensive data for both the left and right river banks were collected independently of the stream centerline as unique "Right Bank" and "Left Bank" line features (reviewed below in Section 2.3.2).

The river was stratified into a series of successive reaches, each possessing and being characterized by different attributes or biophysical characteristics (i.e., hydraulic class, channel characteristics, substrates composition, and riparian class etc.) (Table 1).

Table 1. Overview of River Centerline data fields collected using the Trimble data dictionary.	
Reach Length	Linear measure along centerline of channel (m)
Primary Character:	Modified; Natural; Other
Channel width	Bankfull level (m)
Gradient	% grade
Salmonid Spawning	Yes/No; Species
Livestock Access	Yes/No; Comment
Hydraulic Character	Beaver Pond; Cascade; Cascade-Pool; Falls; Pool; Run; Riffle; Riffle-Pool; Slough; Standing; Wetland; Other
Channel Pattern	Straight; Sinuous; Irregular; Irregular meandering; Regular meanders; Tortuous meanders
Bars	Side; Diagonal; Mid-channel; Spanning; Braided
Islands	Occasional; Split; Frequent – Irregular; Frequent – Regular; Anastomosing
Substrate Composition	% Organic; % Fines; % Gravel; % Cobble; % Boulder; % Bedrock
Embeddedness/Compaction	Degree of embeddeness of coarse substrates in fines (sand/silt)
% Instream Cover	Boulder; Deep Pool; Instream Vegetation; Large Woody Debris; Overstream Vegetation
Reach Impact Rating	See Table 2.

A Level of Impact rating was included in the data dictionary and applied to the centerline reach information (Appendix D). This rating system was designed with the intent of providing a more measurable parameter in evaluating river condition and monitoring and evaluating habitat changes on local watercourses and associated riparian and floodplain communities. Individual reach scores were assigned based on the criteria outlined in Table 2. Weighted scores for respective impact ratings were obtained by dividing the cumulative length of reaches receiving the same impact rating by the total river length being evaluated to obtain a fractional abundance (% of river length). This value was then multiplied by the respective Score (0-6) equaling the weighted score. The sum of weighted scores was then divided by the maximum attainable score (6)[1] and transformed into a percentage value or river grade. This scoring system precedes the Aquatic Habitat Index and, on its own, is a field measure of river condition.

[1] A combined weighted score of 6 would be attained if all reaches were natural with no discernable human disturbance on either the right or left bank. In other words, the river is pristine.

Table 2. Level of Impact rating criteria for Lower Shuswap River Inventory and Mapping.	
River Bank Impact Criteria[1]	Combined River Reach Score
Nil-Nil (*Nil impacts on both banks*)	6
Nil-Low	5
Nil-Mod	4
Nil-High	3
Low-Low	4
Low-Mod	3
Low-High	2
Mod-Mod	2
Mod-High	1
High-High (*Impact on both banks is high*)	0

1. Numeric Bank Impact Scores: Nil=3;Low=2; Mod=1; High=0

2.3.2 Left and Right Bank Mapping (adapted SHIM-FIM)

Conventional SHIM methods describe the right and left bank character and condition within a single stream centerline feature for respective reaches. To better map and evaluate the larger scale represented in the LSHU, the SHIM approach was modified (Appendix D), which adapts the FIM field attributes into the data dictionary. Through this approach, left and right bank lines were logged in the field independently of one another (similar to FIM shoreline mapping) and data fields were populated separate from the Centerline. Individual segments were determined as relatively homogenous sections of shoreline based on vegetation structure, physical character, and general landuse. Shoreline sections that displayed a consistent pattern or distribution of different biophysical units/features interspersed with anthropogenic units (e.g., clearings and fields) were also considered as a single segment. *An example of this would be through rural areas; where remnant natural pockets along the river bank are interspersed with rural residences and small agricultural clearings.* Shoreline segments were determined and assigned independently of river reaches. However, the adjacent river reach was identified in the data for each shoreline segment (e.g., Left Bank Segment 25, River Reach 11).

Large format laminated posters of the River were marked-up to illustrate river and riparian features, attribute lines (e.g., bank armouring) and points (i.e. docks). These features/illustrations were then digitized in the office using a digitizing tablet. Table 3 summarizes the data fields that were collected for each bank segment.

<table>
<tr><th colspan="6">Table 3. Overview of data collected for right and left bank segments during the field inventory.</th></tr>
<tr><td colspan="2">Segment Number</td><td>Reach Number</td><td colspan="2">Segment Length</td><td>Representative Photo</td></tr>
<tr><th colspan="2">Category</th><th colspan="4">Menu/Data Fields</th></tr>
<tr><td colspan="2">Primary Shore Type</td><td colspan="4">Cliff/Bluff; Rocky Shore; Gravel; Sand; Confluence (alluvial fan); Wetland; Other; Flood Low Bench; Flood Mid Bench; Flood High Bench</td></tr>
<tr><td colspan="2">Shore Modifier</td><td colspan="4">Log Yard; Marina small (6-20); Marina large (20+); Railway; Road; None; Other</td></tr>
<tr><td colspan="2">Slope (general slope of shore landward)</td><td colspan="4">Bench; Low (0-5%); Moderate (5-20%); Steep (20-60%); Very Steep (60%+)</td></tr>
<tr><td colspan="2">Land Use (Observed)</td><td colspan="4">Agriculture; Commercial; Conservation; Forestry; Industrial; Institution; Multi Family; Natural Area; Park; Recreation; Rural; Single Family; Urban Park</td></tr>
<tr><td colspan="2">Level of Impact</td><td colspan="4">None; Low (<10%); Medium (10-40%); High (>40%)</td></tr>
<tr><td colspan="2">Livestock Access</td><td colspan="4">Yes/No</td></tr>
<tr><td colspan="2">Relative Condition</td><td colspan="4">%Disturbed; %Natural</td></tr>
<tr><td colspan="2">% Shore Type Distribution</td><td colspan="4">%Cliff/Bluff; % Rocky; % Gravel; % Sand; % Confluence; % Wetland; % Other; % Flood Low Bench; % Flood Mid Bench; % Flood High Bench</td></tr>
<tr><td colspan="2">% Landuse Distribution</td><td colspan="4">Agriculture; Commercial; Conservation; Forestry; Industrial; Institution; Multi Family; Natural Area; Park; Recreation; Rural; Single Family; Urban Park</td></tr>
<tr><td rowspan="8">First Vegetation Band (B1) : (proximal to river channel and may include low flood benches and wetlands that are permanently or seasonally wetted)</td><td>B1 Class</td><td colspan="4">Row Crops; Broadleaf forest; Bryophytes; Coniferous forest; Planted Tree Farm; Disturbed wetland; Dug out pond; Exposed soil; Flood plain; Herbs/grasses; High Impervious; Medium Impervious; Low Impervious; Mixed forest; Natural wetland; Rock; Shrubs</td></tr>
<tr><td>B1 Stage</td><td colspan="4">Sparse (1); Grass/Herb(2); low shrubs <2m (3a); tall shrubs 2-10m (3b); sapling >10m (4); young forest (5); mature forest (6); old forest (7); Mixed age</td></tr>
<tr><td>B1Shrub Cover</td><td colspan="4">None; Sparse (<10%); Moderate (10-50%); Abundant (>50%)</td></tr>
<tr><td>B1Tree Cover</td><td colspan="4">None; Sparse (<10%); Moderate (10-50%); Abundant (>50%)</td></tr>
<tr><td>B1 Distribution</td><td colspan="4">Patchy; Continuous</td></tr>
<tr><td>B1 Bandwidth</td><td colspan="4">Average width (m) of band</td></tr>
<tr><td>B1 Overhang</td><td colspan="4">% Overhanging vegetation for segment</td></tr>
<tr><td>Aquatic Vegetation</td><td>Relative abundance of aquatic vegetation through B1</td><td>% Submergent vegetation in segment</td><td>% Emergent vegetation</td><td>% Floating vegetation</td></tr>
<tr><td colspan="2">Second Vegetation Band (B2) (subsequent band outward from B1. The same data fields as B1 applied)</td><td colspan="4"></td></tr>
<tr><td colspan="2" rowspan="4">Modifications</td><td colspan="2">% of segment retained/armoured by walls and rip rap</td><td colspan="2">Number of Boat launches per segment</td></tr>
<tr><td colspan="2">Docks per segment</td><td colspan="2">% of segment with railway influence</td></tr>
<tr><td colspan="2">Boat House per segment</td><td colspan="2">% of segment with a road influence</td></tr>
<tr><td colspan="2">Groins per segment</td><td colspan="2">Marinas per segment</td></tr>
<tr><td colspan="2">Bank Stability</td><td colspan="2">High; Medium; Low; Eroding</td><td colspan="2">% Eroding</td></tr>
<tr><td colspan="2">Bank Material</td><td colspan="4">Clay; Silt; Sand; Gravel; Cobble; Boulder; Bedrock</td></tr>
<tr><td colspan="2">Comments</td><td colspan="4">Provided with various categories listed above</td></tr>
</table>

2.3.3 Feature Mapping

Morphological, habitat, and anthropogenic features were marked with both the GPS and described on field maps and later digitized as point and polygons into the modified LSHU data dictionary. These features, summarized in Table 4, provide a more quantitative measure of relative disturbance/modification, and aquatic habitat quality/complexity (e.g., aerial abundance of spawning substrates/coarse woody debris measure etc.).

Table 4. Overview of watercourse and habitat attributes that were collected using the Data Dictionary developed for this project (Adapted from Module 3, Mason and Knight, 2001). The complete data dictionary can be found in Appendix D.

Main Attribute	Detailed Feature Collected
Modifications	Type (retaining wall/water withdrawal/bridge/dock etc.) material; length; photo
Culvert Attributes	Type-Material; Condition; Barrier; Size; Baffles
Obstruction Attributes	Type-Material; Barrier; Size; Photo
Stream Discharge Attributes	Point of Discharge; Type-material; Size
Erosion Feature	Type of Erosion; severity; exposure; material
Fish Habitat Attributes	Type of Habitat (Spawning/rearing/cover); Size; Slope; Photo
Enhancement Areas	Type of Enhancement; Potential or existing enhancement
Wildlife Observations	Type of Observation; Wildlife species; Photo
Wildlife Tree Attributes	Type of Tree; Size; Location
Near Waterbody Attributes	Type of Waterbody (spring/side channel/pond etc.); Size
Wetland Attributes (Polygon feature)	Wetland Type-Class; Photo
Representative Photograph Location	Location; Direction.

2.3.4 Key Fisheries Zones

Ecoscape incorporated detailed fish habitat use information, contributed by DFO, regarding salmonid spawning locations, known rearing and nursery sites, and key staging and holding areas. GIS shapefiles were digitized, outlining the spatial extents of respective fish habitat use information, and presented in Map Set 2 along with other observed or contributed wildlife information. Spatial analysis of fisheries utilization of the LSHU relative to reaches and habitats follows in Section 4.3.

2.3.5 Stream Channel Polygon Digitizing

We identified and mapped the spatial extents of side channels, backwaters, and associated riverine wetlands and floodplain communities. In addition to providing a critical baseline for analysis and Habitat Index calculations, this will allow for monitoring spatial changes in channel morphology.

Stream channel vegetation polygons were digitized on orthophotos and verified during field inventories. River channel polygons were categorized according to Groups shown in Table 5.

Table 5. Vegetation polygon codes used for classification of fluvial and riparian ecosystems along the Lower Shuswap River from Mara Lake to Mabel Lake (Adapted from Mackenzie and Moran (2004) and Lloyd et al. (1990).

Group / Map Code		Site / Association Code	Vegetation	Assumed Situation
Riverine Marsh Sites (Wm)		Wm01	Water sedge	A marsh is a shallowly flooded mineral wetland dominated by emergent grass-like vegetation. A fluctuating watertable is typical, with early-season high watertables dropping through the growing season. Exposure of the substrate in late season or during dry years is common.
		Wm02	Beaked Sedge	
		Wm04	Spike rush	
		Wm05	Cattail	
		RG	Reed canarygrass	
Riverine Swamp Sites (Ws)		WS	Willow-Sedge	A swamp is a forested, treed, or tall-shrub, mineral wetland dominated by trees and broadleaf shrubs on sites with a flowing or fluctuating, semipermanent, near-surface watertable. Tall-shrub swamps are dense thickets, while forested swamps have large trees occurring on elevated microsites and lower cover of tall deciduous shrubs.
Shallow water/submerged aquatic (Wa)		WaPd	Pondweed-dominated submergent	These communities are always associated with permanent still or slow-moving waterbodies. Most commonly occur where standing water is less than 2 m deep in midsummer.
		WaMi	Milfoil-dominated submergent	
Low Flood Bench (Fl)		Fl02	Mountain alder – Red-osier dogwood – Lady fern	Low bench ecosystems occur on sites that are flooded for moderate periods (< 40 days) of the growing season, conditions that limit the canopy to tall shrubs, especially willows and alders. Annual erosion and deposition of sediment generally limit understorey and humus development.
		Fl03	Pacific willow – Red-osier dogwood – Horsetail	
		Fl04	Sitka Willow - Red-osier dogwood (levees)	
		Fl06	Sandbar willow	
Mid Flood Bench (Fm)		Fm01	Cottonwood – snowberry – Rose	Middle bench ecosystems occur on sites briefly flooded (10–25 days) during freshet, allowing tree growth but limiting tree species to only flood-tolerant broadleaf species such as black cottonwood.
		Fm02:	Cottonwood – Spruce – Red-osier dogwood	
Un-vegetated (Uv)		GB	gravel bar / sand bar	
		ES	exposed soil	
Treed - Upland Sites (IDFmw1 Sites)	01	DF	FdCw - Falsebox - Prince's pine	gentle slope; deep, medium - textured soils
	02	DS	FdPy - Snowberry - Bluebunch wheatgrass	gentle slope; crest position; deep, medium - textured soils
	03	PP	Fd - Penstemon - Pinegrass	significant slope; warm aspect; deep, medium - textured soils
	04	DP	Fd - Pinegrass - Feathermoss	gentle slope; deep, medium - textured soils
	05	RR	CwFd - Dogwood	gentle slope to level, lower slope, receiving sites; deep, medium - textured soils
	06	RD	Cw - Devil's club - Foamflower	toe slope to depression; deep, medium - textured soils, seepage
	01-YC	DF	$CwFd - Feathermoss (seral association)	gentle slope; deep, medium - textured soils

2.3.6 Retrospective Analysis of Lower Shuswap Riparian Communities

Ecoscape was supplied with historic (1928) air photos covering the lower Shuswap River from Mara Lake to upstream of Enderby about 11km to include Reaches 1-9, totaling about 47.9km of the River. This analysis evaluated a 100-m band beginning at the mapped 2007 channel limits extending outward perpendicular to the river 100 m. Vegetation polygons occurring within the 100m band were digitized and classified according to the following:

- Beach (B)
- Cultivated Field (CF)
- Cleared (CL)
- Low Flood Bench (FL)
- Mid Flood Bench (FM)
- Open Water (OW)
- Rural (RU)
- Treed (T)

Subsequently, each polygon was assigned one of the following Qualifier Codes based on relative condition:

- Natural (N)
- Riparian (R)
- Riparian Fringe (F)
- Low Disturbance (LD)
- Moderate Disturbance (MD)
- High Disturbance (HD)

The relative distribution and spatial coverage of respective ecosystems were then compared between the two years (1928 and 2007) enabling the change analysis. We evaluated channel movement (erosion and accretion) by taking the bankfull river level, interpolated (excluding active floodplain areas) from 2007 imagery, and using this as the benchmark. The historic channel limits were subsequently estimated and digitized from the 1928 geo-referenced air photos, which were then compared against the 2007 channel limits. Areas where the historic (1928) channel extended beyond (outward) the 2007 extents represent areas where channel movement and accretion have occurred. Areas where the historic channel limits were confined by the existing channel limits represent locations of erosion.

2.4 Data Processing and Quality Assurance and Control

The Resource Inventory Committee and SHIM Methodology (Mason and Knight, 2001) provide specific requirements for quality assurance and quality control. These standards, such as GPS settings/precision, logging intervals, and data management and deliverables were followed throughout the field inventory stages of the project.

GPS settings and use were in accordance with Resource Inventory Committee Standards to ensure the collection of spatially accurate data. The coordinate system used was UTM Zone 11 North, North American Datum 83.

Field data was differentially corrected using base data provided by the SOPAC, Dominion Radio Astrophysical Observatory, situated south of Penticton (49°19'21.43074"N, 119°37'29.93095"W, 541.97 m) and/or Kettle Falls, Washington (USFS, Colville National Forest).

Data dictionary tools designed for ARC View 3.x were employed to process the data and to export the data into ESRI shapefiles. Subsequent processing and mapping was completed using ArcGIS 9.3 and 10.x. Processed GPS data (shapefiles) were then converted into geodatabases.

To ensure Quality Assurance and Control the following tasks were followed during completion of this project:

- Field data collected was backed up daily onto the local server and field computer at the end of each field day.
- All field data collected during the field inventories was post processed by the field inventory biologist, and data manager, Kyle Hawes, R.P.Bio.
- We reviewed each attribute field collected during the survey as part of a quality control / assurance process. The final database will be provided to DFO and/or DFO staff for further review at the completion of the project. Corrections and adjustments to the database will be made as necessary.
- We integrated this assessment with additional GIS information provided by other parties.

2.5 Photo Log

SHIM/FIM standards require that a detailed photo log accompany and be incorporated into the data base. All photos were entered into a log for location and subject reference. In addition, coordinate locations (UTM 11North, North American datum 83 Canada) were included in the photo data to enable spatial referencing on the ground.

3.0 METHODOLOGY – AQUATIC HABITAT INDEX

AHI scores derived for each reach of the river channel and left and right bank segments are analogous to the current productivity, which is defined as the sum of relative habitat values for all subareas occurring within a defined area (i.e., river channel extents of a respective reach) (Minns 1997). The AHI is a categorical scale of relative habitat value that ranks the river channel and bank segments in a range between *Very High* and *Very Low*. Our approach to development of the index incorporated the following components:

1. Utilization of all existing data that occurs in a spatial GIS format to develop the index.

2. Species Accounts, developed to inform life history scores for discrete instream habitat units/features for respective key species (sockeye salmon, Chinook salmon, coho salmon, kokanee, and rainbow trout).

3. The AHI was developed and calibrated using professional opinion similar to other habitat indices that have been developed for lake systems. Criteria were reviewed for relevancy and weighted appropriately (i.e., representative of the contribution to overall habitat sensitivity), and the index was developed in such a way that new data layers may be added in the future.

The data previously collected for this project involved numerous spatial data layers and is substantially more complicated to develop than an AHI developed for a lake ecosystem. The dynamic nature of riverine ecosystems required that four separate layers of data be collected as part of the inventory phase. One layer of data was attributed to the primary character of the river, one layer was used to describe the right bank, one layer was used to describe the left bank, and one layer was used to describe the mapped extent of salmonid spawning utilization.

3.1 Instream Morphology and Habitat Feature Polygonization

The river channel, extending to the outer limits of the mean annual high water level (to include low bench floodplain areas) was estimated using field inventory data and subsequent further air photo interpretation. The spatial extents of the channel formed the basis for subsequent stratification of habitat units within (Map Series 4). Habitat units were classified based on complex hydraulic and instream habitat feature classes as one of the following:

- Cascade
- Confluence
- Pool
- Riffle
- Run
- Backwater
- Instream Vegetation
- Low bench floodplain
- Riverine Marsh
- Side Channel
- Large Woody Debris

3.2 Instream Polygon Scoring Matrix

Habitat unit classes (Section 3.1) were assigned a relative habitat value for each of five key fish life history stage/habitat quality categories. The relative productivity value was defined for each habitat unit as the sum of all production scores accrued by each of the 5 key fish species during the time they spend any part of their life history in that area (e.g., for spawning, rearing, and feeding) or accrued elsewhere as a result of a strict habitat requirement to use that area of habitat (e.g., for staging, migration, or cover).

Habitat unit : Fish life history and habitat requirement matrices were developed to determine the relative habitat value for each habitat unit. Life history stages considered were:

- Spawning
- Rearing
- General Living/Feeding

Habitat Requirement categories included:

- Substrate composition
- Cover (habitat complexity)

Life history accounts were developed for each of the five key fish species. The information taken from these accounts informed the relative values assigned each habitat unit for each species and life history stage. Life history accounts follow in Section 3.2.1 and the scoring matrices are included in Section 3.2.2.

3.2.1 Life History Accounts

The Lower Shuswap River flows from Mabel Lake to Mara Lake, a distance of approximately 72km. It supports populations of four species of Pacific salmon; pink *(O. gorbuscha)*, coho *(O. kisutch)*, sockeye and kokanee *(O. nerka)*, and Chinook *(O. tshawytscha).* Other salmonid fish species include rainbow trout *(O. mykiss)*, Rocky Mountain whitefish (*Prosopium williamsoni),* and bull trout *(Salvelinus confluentus).* Non-salmonid fish include suckers *(Catastomus spp.),* Peamouth Chub *(mylocheilus caurinus),* sculpins *(Cottus spp.),* and Northern pikeminnows *(Ptychocheilus oregonensis).* Because of their importance to commercial, recreational and ceremonial purposes the following were selected as key species for matrix development in this study: Kokanee, Sockeye salmon, Rainbow trout, Coho salmon and Chinook salmon.

3.2.1.1 Kokanee

LIFE HISTORY

Kokanee (*Oncorhynchus nerka)* are considered a keystone species in many large British Columbia lakes. They are most often the major source of forage for other predators such as burbot, rainbow trout, lake trout and bull trout. Provincially they are third only to rainbow and cutthroat trout in sport fish catch (Ministry of Water, Land and Air Protection 2003).

Kokanee are a non-migratory form of sockeye salmon. They have very similar traits to sockeye with the one major exception that they spend their entire life in freshwater. Both species will normally spend their first year of juvenile rearing in a freshwater lake, in this case Mara Lake, but while sockeye will out-migrate to the ocean after one year, kokanee remain for 2 or 3 years in the lake before returning to spawn. In British Columbia kokanee typically reach maturity at the end of their third (age 2+) or fourth (age 3+) summer (McPhail 2007). Kokanee management in the system, and in general in B.C., is the responsibility of the provincial Ministry of Forests, Lands and Natural Resource Operations, Fish and Wildlife Branch (formerly B.C. Ministry of Environment).

In 2001, a four year investigation into the status of kokanee populations in the Thompson-Shuswap watersheds, which included the Lower Shuswap River, was initiated by the Ministry of Water, Land and Air protection and completed by Redfish

Consulting. The results of this study were particularly helpful in the preparation of this species account.
Traditionally most fishery managers believed that kokanee were quite abundant, requiring little attention. Today, however, that perception has changed and the prevailing view is that this important species appears to be in trouble in many interior lakes. Reasons for this decline are believed to be habitat related and are focused on spawning habitat deficiencies (Redfish Consulting 2005).

Kokanee populations in Mara Lake, and in fact for most of the Shuswap Lake system, are not well understood. There appears to be a critical absence of information on habitat use, angler harvest and escapement numbers over time (Ministry of Forests, Lands and Natural Resource Operations files. 2011). What is known, however, is that kokanee adults originating from Mara Lake ascend waters of the Lower Shuswap River on an annual basis to spawn and die in selected habitats upstream of the town of Enderby, B.C.

REPRODUCTION

Kokanee adult spawners normally migrate into the Lower Shuswap River starting in early October and runs will extend until late October. The spawning peak will usually occur between October 8 and 15 (Ministry of Forests, Lands and Natural Resource Operations files. 2011). Depending on water velocity and female size, gravel diameters utilized range from about 1.0 to 2.5 cm. Water velocities and depths are also variable and range from 0.15 to 0.85 m/s and from 6 to 37 cm, respectively (McPhail 2007). Like other Pacific Salmon, kokanee die after spawning. Fecundity ranges from about 200 to about 1500 eggs in kokanee. Development rate is a function of incubation temperature.

Spawning locations for kokanee in the Lower Shuswap River are well documented. They utilize main and side channel habitats starting at the Enderby Bridge and extending as far upstream as Cooke Creek. The majority of spawning activity occurs between Ashton Creek and the Top of the Islands Park area. The river is heavily braided into smaller channels in this area which tends to provide spawning habitat of optimal gravel sizes.

This behavior, however, can leave them highly vulnerable to a drop in flows through the winter incubation period as these side channels will dry out first causing heavy egg/alevin mortality. In a 1991 study conducted on the Mid Shuswap River it was determined that approximately 50% of the kokanee eggs deposited in side channels perished due to declining flows caused by B.C. Hydro operations at Wilsey Dam (Jantz 1992). This study led to a change in operational regimes by B.C. Hydro where flows are now reduced prior to kokanee spawning and carried for as long as storage supplies last through the incubation period. It is suspected that even without flow controls on the Lower Shuswap River there is some element of over-winter declines in flows based on the natural hydrograph.

Fisheries personnel use various methods to enumerate these spawning runs including helicopter and drift boat surveys. Frequencies of counts and survey dates have varied considerably over the years which have likely contributed in some part to large variations in annual counts. In 1986 and 1987 both helicopter and drift boat counts were undertaken with the drift counts determined to be the most accurate (Jantz 1986 and 1987). On these surveys both sockeye and Chinook numbers and locations were determined as well. There may also be some influence of natural population cycling but it has been determined that kokanee year strengths do not correspond to those of sockeye (Redfish Consulting 2005).

Annual spawning numbers have varied considerably since the earliest recorded counts of 1950. Numbers range from a high of 337,000 in 1962 to lows of 3600 in 2002 (International Pacific Salmon Commission records reported in Redfish Consulting 2005). In the 1960's and 70's the majority of counts ranged from 50,000 to 100,000. By the 1980's spawning numbers were on the decline with totals of 5,675 and 16,103 in 1986 and 1987 respectively (Jantz 1986 and 1987). A record number for recent years occurred in 2004 when 124,000 were counted (Redfish Consulting 2005). Low numbers in 2002 are a key indicator, however, that escapements have declined considerably in recent years.

AGE GROWTH AND MATURITY

Upon emergence, kokanee usually migrate to a nursery lake before starting to feed. This downstream migration occurs at night with peak migration between dusk and midnight (Lorz and Northcote 1965; Webster, J. 2007). The fry are negatively photactic (avoid light) and, if the migration takes more than one night, they shelter during the day under rocks and organic debris (McPhail 2007). It is not known if downstream migrating fry from the Lower Shuswap River require more than one night to reach Mara Lake.

On lake entry the fry of some kokanee populations immediately move offshore and begin vertical migrations in search of zooplankters, their preferred feed. Other populations, however, remain inshore and forage in the littoral zone for variable amounts of time. These differences in fry behavior probably are related to food availability, temperature and predation risk (McPhail 2007). It is not well understood whether these developing kokanee remain in Mara or move downstream to Shuswap Lake. It is suspected, however, that these fish, once attaining maturity, will return back to the Lower Shuswap River to spawn in the same locations where they were born.

HABITAT INDEX MATRIX

The Habitat Index Matrices developed for this study accordingly rates kokanee adult stages as high for spawning gravel requirements but low in requirements for cover and rearing. During the spawning process they show little concern about hiding and cover as they go about the task of building redds and laying and fertilizing eggs. Gravel conditions and flows are very important during the egg to fry incubation stage. The emergent fry may have some limited requirements for cover or habitat complexity as they attempt to swim downstream under cover of darkness as quickly as possible. As McPhail (2007) explains, if the journey takes more than one night they will seek cover of organic debris or boulders along the way then resume their swim after dark.

3.2.1.2 Sockeye Salmon

LIFE HISTORY

Sockeye salmon (*Oncorhynchus nerka*) are the third most abundant of seven species of Pacific salmon (Groot and Margolis1991). In British Columbia sockeye tend to have similar life history traits as kokanee with a few major exceptions. As with kokanee, sockeye fry normally will spend their first year in a fresh water lake – in this case Mara Lake – then will begin the long journey to the Pacific Ocean. This anadromous tendency allows them to become much larger than kokanee as there is more abundance of feed in the north Pacific than in interior lakes. Sockeye spend from one to four years in the ocean before returning to fresh water to spawn. Sockeye management in the province is the responsibility of the Federal Department of Fisheries and Oceans.

REPRODUCTION

Sockeye spawn in the fall, usually when water temperatures drop below 12^{0}C. In the Lower Shuswap River this normally occurs in late September through October (McPhail 2007). As with kokanee, sockeye will form dense aggregations on spawning grounds. They will normally choose larger spawning substrates than kokanee which tends to cause separation in spawning locations. Like other Pacific salmon sockeye will defend their redds until too weak to maintain position and die after spawning.

Even in larger rivers, sockeye tend to spawn in shallow riffle areas (Groot and Margolis 1991). There are exceptions, however, and it is clear that they have the ability to detect and utilize groundwater upwelling areas. Fecundity varies from about 2,000 to 4,000 eggs related to female size (Harris 1986 as discussed in Groot and Margolis 1991). Incubation times vary related to water temperatures and in the Shuswap River they tend to emerge from gravels in early spring (April and May) then immediately begin their downward migration to Mara Lake. It is not clear whether these sockeye fry, along with kokanee, remain in Mara Lake for their first year of rearing or move to Shuswap Lake downstream of Sicamous Narrows (Redfish Consulting 2005). It is known, however, that these fry need to move downstream quickly to lakes where they begin feeding or they will not survive. They move downstream under cover of darkness to avoid predators.

Sockeye in the Lower Shuswap River tend to disperse much wider than do kokanee. Escapement information provided by staff of the Federal Department of Fisheries and Oceans (DFO) show spawning locations distributed from just above the Enderby bridge in the Ashton Creek area all the way upstream to the outlet of Mabel Lake.

There also appears to be differences in spawning locations depending on year class strengths. Sockeye, unlike kokanee, in the Lower Shuswap River, cycle on a four year rotation and can vary considerably in numbers from year to year. In surveys conducted by the B.C. Ministry of Environment in 1986, sockeye spawners outnumbered kokanee in the area of Enderby bridge to Cooke Creek 27,621 to 5,765 (Jantz, memo to file, MOE).

Sockeye tend to spawn in areas above nursery lakes or in some cases just below (McPhail 2007). It is believed that most of the fry generated in the lower to mid portions of the Lower Shuswap River move down to Mara Lake for their first year of rearing. It is possible, however, that the fry from adult sockeye spawners which utilize spawning areas just below Mabel Lake may actually move upstream to rear in Mabel Lake.

AGE, GROWTH AND MATURITY

As with kokanee, sockeye fry once emerged from the gravel normally will migrate downstream under cover of darkness to their nursery lake for a period of rearing, usually lasting one year. J. D. McPhail (2005) suggests that the migrating fry will look for cover areas in organic debris or boulder substrate if the migration cannot occur in one night. They will then resume their downstream travel once darkness returns.

HABITAT INDEX MATRIX

The Habitat Index Matrices developed for this study tend to be very similar for sockeye as they are for kokanee. Spawning gravel attributes score very high for adult spawning and juvenile incubation while rearing and cover attributes score low due to their tendency to spend most of their juvenile stage rearing in Mara or Shuswap Lake and then the remainder of their adult life rearing in the Pacific Ocean.

3.2.1.3 Rainbow Trout

LIFE HISTORY

Rainbow trout *(Oncorhynchus mykiss)* are an important game fish that reside in the Lower Shuswap River. They are considered the number one target for anglers in the British Columbia interior. It is apparent that there are two forms of trout in the system; a resident population that lives its entire life cycle in the river and adjoining tributaries, and an adfluvial form that spends the majority of its life in large lakes but migrates to rivers and streams to spawn or feed (Ministry of Environment files, Okanagan Region). There are many similarities between these two groups as far as spawning requirements, early rearing and adult life forms and accordingly these life forms will be grouped in this discussion.

Rainbow trout management in B.C. is the responsibility of the provincial Ministry of Forests, Lands and Natural Resource Operations, Fish and Wildlife Branch. In British

Columbia, rainbow trout occur both as freshwater resident and anadromous (steelhead) populations. Steelhead are not known to occur in the Lower Shuswap River.

Rainbow trout in the system, both in lake forms and resident river populations are heavily sought after by anglers and tend to be easily overfished. For this reason, conservative, 'catch and release' angling regulations were introduced by MOE fisheries managers in the mid to late 1990's (Jantz, memo to file, MOE). According to local opinions these measures appear to have been successful in conserving adult trout in the system and increasing angler catch success (pers. comm. Neil Brooks, Kingfisher Community Hatchery).

REPRODUCTION

Rainbow trout are spring spawners and migrations into spawning streams are triggered by rising water temps (above 5^0C.) and rising water levels (Hartman 1966 in McPhail 2007). The Lower Shuswap River is normally in freshet at this time with high flows and turbid waters. These conditions present a challenge for fisheries managers to monitor their activities and population strengths.

Numerous methods have been employed to monitor trout movements in the system including snorkel floats, angling surveys, tagging studies and stream reconnaissance surveys. In 1984 a tagging study was initiated at the mouth of Kingfisher Creek, located about 0.5 km downstream from Mabel Lake (Jantz 1984). A total of 15 rainbow trout in the 3 to 5 kg. range were angled, tagged with floy type, fluorescent spaghetti tags and released back into the river. The majority of these fish were later recovered in a trap located in Danforth Creek, a tributary to Kingfisher Creek, as they moved upstream to spawn. One tag was also later recovered by an angler in Mara Lake which tends to support the belief that some portion of Mara Lake rainbows move into the Lower Shuswap River and tributaries to spawn.

A search of the Ministry of Environment Habitat Wizard reveals that rainbow trout have been found in almost all tributary streams of the Lower Shuswap River. These streams are critically important for the nursery phase of rainbow trout juvenile rearing. Maturing adults will migrate into these streams during freshet flows (April and May) and will spawn on the receding flows following. Unlike Pacific salmon, rainbow trout adults can survive spawning and it has been determined that about 10% will live on to spawn a second time (McPhail 2007). Studies in Kingfisher Creek and Duteau Creek (a tributary of the Mid Shuswap River), determined that juvenile rainbow trout will spend up to two years in these nursery streams before moving downstream to main-stem rivers or lakes (Griffith 1986). Scale interpretation of larger adult rainbow trout caught by anglers in Mabel Lake confirmed that, indeed, almost all adults showed a pattern of one to two years of stream residence prior to in-lake growth (Jantz 1986).

Rainbow trout juveniles rearing in small streams tend to be highly connected with riffles, runs and large woody debris. These areas provide the best habitat for cover and feed consisting of small aquatic insects. They need to select streams that provide suitable habitat to survive summer and winter extremes for up to three years. Low summer flows, caused by agricultural irrigation diversions can have significant impact on smaller streams. Rainbow trout juveniles can also be displaced by other fish, such as coho, which tend to compete heavily for prime feeding areas as they have similar diets (Griffith 1986).

It is believed that many of these developing juveniles will eventually move from nursery tributary streams down to the Lower Shuswap River or Mara Lake. In rivers, rainbow trout will normally establish territories in shallow water along stream margins (Slaney and Northcote 1974). During their adult phase in streams and rivers they occupy riffles, runs, glides and pools and tend to occur in deeper and faster water than juveniles (McPhail 2007). Snorkel surveys conducted by Ministry of Lands, Parks and Housing staff in the Lower Shuswap River in the late 1980's determined that adult rainbow trout preferred runs, riffles, glides and boulder cover areas (Ministry files 40.3504 Shuswap River). They appeared to be highly adaptive to different types of habitat and positioned themselves where the best feeding areas existed. Adults and juveniles feed heavily on drifting stages of aquatic insects such as stone fly nymphs and caddis fly larvae. As they grow, terrestrial insects are added to their diet and so riparian areas along river margins become increasingly important to them (McPhail 2007).

AGE, GROWTH AND MATURITY

Some rainbow trout will live their entire life cycle in small streams or rivers (resident) while others are of an adfluvial nature and will move down to large lakes. In a more recent tagging study, that took place at the mouth of the Mid Shuswap River, where it enters Mable Lake, one tagged rainbow trout was later recovered in Mara Lake and another travelled all the way to Anstey Arm of Shuswap Lake before it was caught and reported by an angler (pers. comm. Paul Askey, Ministry of Forests, Lands and Natural Resource Operations). Information is limited on downstream migration traits but it is believed that they travel in the freshet and utilize cover habitats along the way to escape their predators (McPhail 2007). Adfluvial trout can live up to 8 years before maturing with the norm being 5 or 6 (MOE Okanagan Region files). Their biggest obstacle in lakes is anglers who target them extensively. Rainbow trout are also highly susceptible to rising water temperatures and summer fish kills have been reported on the Lower Shuswap River (C.Bull, memo to file 40.3404 1986). Rainbows can tolerate temperatures up to 27^{0}C but anything higher can be lethal (Lee and Rinne 1980 in McPhail 2007). In adfluvial populations, rainbow trout rely heavily on kokanee and sockeye forage once they move to large lake habits. In Mara and Mabel Lake they can attain sizes of 5 kg. before maturing (Jantz 1984).

HABITAT INDEX MATRIX

The Habitat Index Matrices developed for this study indicate that rainbow trout depend heavily on pools, runs, riffles, boulder areas and cover afforded by riparian vegetation or in-stream woody debris. Log jams associated with pools are also used extensively for feeding and hiding. Tributary stream confluences are important as are small, stable streams which provide rearing habitat for juveniles and resident populations. Of the five species of fish, discussed in these accounts for the Lower Shuswap River, rainbow trout are likely the most sensitive to habitat changes because they spend so much of their life cycle in these zones.

3.2.1.4 Coho Salmon

LIFE HISTORY

Coho salmon *(Onchorynchus kisutch)* are an important species and range through hundreds of coastal and interior streams in British Columbia. Interior Frazer River coho salmon are genetically unique and can be distinguished from lower Fraser River coho. Studies of the genetic structure of Interior Fraser Coho indicate that there are five distinct populations. Three are within the Thompson (North Thompson, South Thompson, and Lower Thompson regions) and two are within the Fraser (the area between the Fraser Canyon and the Thompson-Fraser confluence and the Fraser River and tributaries above the Thompson-Fraser confluence) (Interior Fraser Coho Recovery Team. 2006). South Thompson populations are further divided into sub-populations which are comprised of: the Adams River; Shuswap Lake and tributaries; and the Middle and Lower Shuswap River. Coho management in the province is the responsibility of the Federal Department of Fisheries and Oceans.

Coho populations in the interior of British Columbia are generally in serious trouble. So much so that in 2002 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed them as endangered. COSEWIC was concerned that if Interior Fraser Coho distribution became too fragmented, genetic exchange within the populations may be insufficient to ensure long-term survival (COSEWIC 2002).

Over the period of record (1975-2003) the 3-year average escapement for Interior Fraser Coho peaked in the mid-1980's at over 70,000 fish, and declined to a running average of less than 18,000 individuals in the late 1990's. Similar trends are observed in total abundance (i.e. catch plus escapement), which declined from over 200,000 in the late 1970's and 1980's to less than 30,000 in recent years (Interior Fraser Coho Recovery Team. 2006).

On average, North and South Thompson coho salmon declined in numbers by approximately 60% during the 10-year period from 1990-2000 There were four years (1991, 1995, 1997, and 1998) when productivity was so low that some of the populations may not have been able to maintain replacement spawner numbers, even with a zero exploitation rate (Irvine et al 1999).

Natural spawning is responsible for producing most of the coho salmon escaping to the interior Fraser River, except for the Lower Thompson population where hatchery fish outnumber those produced from fish spawning in natural stream areas. There is no evidence that the overall distribution of coho salmon within the interior Fraser River watershed has changed, although spawners were observed in fewer streams as spawning abundance declined.

For the period 1998 to 2003 coho adults returning to the Lower Shuswap River averaged 1400. Population trends from 1975 to 2003 for the South Thompson Unit peaked at 25209 with the lowest escapement at 1799 for years 1988 and 1996 respectively.

The Middle and Lower Shuswap coho salmon sub-population is located within the Middle and Lower Shuswap rivers and their tributary streams, including Wap Creek, a tributary to Mabel Lake. As is the case in other sub-populations, in periods of higher water, spawners utilize the upper reaches of tributary streams such as Duteau and Danforth creeks, whereas at lower water levels, significant spawner aggregations are observed in the mainstems of the Middle and Lower Shuswap rivers. According to Neil Brooks of the Kingfisher Community Society, coho can be seen spawning from the high banks of the Lower Shuswap River just below the outlet from Mabel Lake.

Bessette Creek, in the Middle Shuswap, was deemed by DFO to be of special conservation concern and has been enhanced since 1998. Fish culture activities take place at the Shuswap River Hatchery and when numbers of juveniles permit, the releases are marked. Adult returns are assessed annually. Because of their ability to hide under overhanging banks and in debris areas, coho are notoriously difficult to enumerate.

Interior Fraser Coho require adequate freshwater and marine habitats to survive and reproduce. These fish spawn in freshwater and the juveniles normally spend one full year in freshwater before migrating to the sea as smolts. The distribution of spawning habitat for coho salmon is usually clumped within watersheds, often at the heads of riffles in small streams and in side-channels of larger streams. However, Interior Fraser Coho are commonly observed spawning in mainstems of larger rivers during periods of low flow, presumably when tributary and side-channel habitats are less accessible.

The outlook for Interior Fraser Coho is highly uncertain and depends on the magnitude of negative impacts due to fishing, habitat perturbations, and climate related changes in survival. A return to higher survivals, combined with continued low exploitation rates, conservation of existing habitat, and habitat restoration, could produce increases in escapements and subsequently population recovery. However, if survival rates are at low levels, such as those recorded in 1998, spawner numbers will continue to decrease, possibly resulting in the eventual extinction of Interior Fraser Coho. Since there is no predictor of future survival rates, a cautious approach to harvest and habitat management will be required to ensure the long-term viability of Interior Fraser Coho (Interior Fraser Coho Recovery Team. 2006).

REPRODUCTION

The timing of river entry and spawning varies with latitude and distance from the ocean. Lower Shuswap River populations spawn in late October and November and typically, spawning occurs at temperatures ranging from about 1^0C to 8^0C (McPhail 2007). Spawning coho are the most secretive of Pacific salmon and most reproduction behavior occurs at night.

Coho have similar tendencies to rainbow trout in their selection of rearing habitat (Griffith 1986). They prefer sites with sub-gravel flow as is found in tail-outs of pools immediately above riffles or upwelling sites. They prefer smaller tributary and headwater streams often not much more than 1m in width. Eggs incubate over winter and hatch in the spring. Incubation timing is dependent on water temperatures as with all other salmonids in the Shuswap system.

According to the B.C. Ministry of Environment Habitat Wizard, coho are present in nine tributary streams of the Lower Shuswap River including Ashton, Brash, Blurton, Cooke, Danforth, Fortune, Johnston, Kingfisher and Trinity Creeks. Danforth Creek, a tributary to Kingfisher Creek is critically important for coho spawning and rearing and coho eggs have been collected there previously for hatchery outplanting (pers. com. Neil Brooks, Kingfisher Community hatchery). This practice has been discontinued because of the fragile state of their numbers.

AGE, GROWTH AND MATURITY

In British Columbia, coho fry usually reach 80-90mm in their first year (Sandercock 1991 in McPhail 2007). Coho fry in interior streams normally spend 1 to 2 years in nursery streams before out-migrating to the Pacific Ocean. They are primarily drift-feeders and take the drifting stages of aquatic insects from the water column or terrestrial insects from the surface. Coho prefer pools and backwater areas. They will aggregate in backwaters, side-channels and quiet embayments along stream margins. They will eventually emigrate to larger rivers and will search out off-channel overwintering areas such as beaver ponds and flooded wetlands (Peterson 1982 in McPhail 1997). In winter they will seek cover under woody debris, undercut banks, cobbles and move deeply into root wads.

HABITAT INDEX MATRIX

The Habitat Index Matrices indicate that coho adults require cascade areas, confluence areas, pools, riffles, runs, cover and access to small streams in upper watersheds. They will hide under cut banks and root wads and will search for suitable gravel in upwelling areas and tail-outs of pools.

Coho juveniles depend heavily on pools, backwaters, in-stream vegetation areas, low and middle flood benches, marsh areas, side channels, cobble areas and large woody debris. Tributary stream confluences are important as are small, stable streams which provide rearing habitat. These streams will support coho through their incubation period and their first year of rearing. Adequate rear-round flows and cool temperatures afforded by well-developed riparian zones are important. Some fry will move to the main rivers where they will seek back-waters, flood benches and beaver dams.

Coho in south central B.C. will usually rear for 1 year in fresh water and then begin their migration to the ocean. They will spend 18 months at sea before returning as adults to spawn. As with all the other Pacific salmon they die after spawning.

3.2.1.5 Chinook Salmon

In British Columbia Chinook salmon spawn in over 250 rivers and streams (McPhail 2007). Within the Fraser River system, there are seven genetically recognizable geographic groupings: an upper, middle, and lower Fraser group; a northern, southern and lower Thompson group; and the Birkenhead River population (Beacham et al. in McPhail 2007). Chinook in the Lower Shuswap River belong to the lower Thompson group. They are the largest of seven species of Pacific salmon and have the widest distribution. They have sustained First Nations for thousands of years, provide important recreational and commercial harvesting opportunities, and were an important part of the colonization of British Columbia.

REPRODUCTION

In the Lower Shuswap River the majority of Chinook spawn between the outlet of Mabel Lake and Trinity Creek, just above Enderby, in coarse gravel substrate, from late-September to early November (Trouton 2004). Prior to the onset of spawning, some of them arrive in mid-summer, and move through the Lower Shuswap to spawn in the Wap and Middle Shuswap Rivers, which both flow into Mabel Lake. Some will hold in Mabel Lake up to 8 weeks before moving downstream to spawn in the Lower Shuswap River while others hold in Mara Lake or in deep pools in the river close to spawning locations. Peak spawning for this stock occurs typically around October 12 each year. A recreational fishery takes place annually for Chinook adults in the Lower and Mid Shuswap Rivers and within Mabel Lake.

The Lower Shuswap has 8 km of good, 19 km of moderate and 47 km of poor quality Chinook spawning habitat (Parker et. al. 2002). There is no known spawning in tributary streams. According to Department of Fisheries and Oceans records, spawning numbers between 1991 and 2005 ranged from a low of 6,000 in 1997 to a high of 24691 in 1999 (2006 DFO Information Document). Neil Brooks of the Kingfisher Interpretive Center suggests that last year’s spawning numbers are much higher and in general have increased substantially from a total of only 2500 adults in the early 1970’s. Chinook spawners are enumerated annually either from helicopter or drift boats. The Kingfisher Community Hatchery assists with the annual collection of adult Chinook brood stock which are then transported to Shuswap River Hatchery where they are spawned, eggs are incubated and then fry are returned back to the Lower Shuswap for release the following spring.

AGE, GROWTH AND MATURITY

Lower Shuswap adult Chinook are generally 5 year olds (2006 DFO Information Document). Chinook females choose the spawning site and appear to prefer sites with subgravel flow (eg. In the tail-outs of pools immediately above riffles or in upwelling sites) (McPhail 2007). Chinook eggs are the largest of the species of Pacific salmon and require higher rates of flow and oxygen than other species. As with the other species of Pacific salmon, adults will die after spawning.

Egg counts for Chinook vary from less than 2,000 to more than 17,000. In a 2000 to 2002 study (Trouton 2004), it was determined that Lower Shuswap River Chinook preferred spawning gravel sizes ranging from 7.95 to 10.43cm diameter and spawning temperatures ranging from 14.9C to 15.8C.

Chinook eggs incubate through the winter period and fry emerge in the early spring. As with the other species discussed earlier, their incubation period varies with water temperatures. Once emerged the diet of fry includes adult chironomids as well as chironomid larvae and pupae, terrestrial insects taken from the surface, and nymphs of larvae of aquatic insects (McPhail 2007). Upon emergence, Chinook fry are often moved downstream by flows from areas where they incubated (Groot and Margolis 1991). Their habitat range is often keyed to flow velocities rather than habitat types. They range widely in habitat use but generally will occupy bouldery areas in faster waters. Downstream timing is not well understood in the Lower Shuswap but it is believed that most will start to migrate toward the Pacific after about 3 months of emergence although some may remain for the winter. Downstream timing appears to be correlated strongly with size (Groot and Margolis 1991).They will eventually move out to the Pacific and return 5 years later to spawn as adults.

HABITAT INDEX MATRIX

Chinook adults are heavily dependent on deep pools where they may hold for up to 8 weeks before moving out to spawning grounds. Their spawning areas must have larger diameter clean gravels which will afford adequate percolation of flows and oxygen to meet incubation requirements. They are particularly sensitive to movements of silt or reductions in flow during the incubation period. Trouton reported in her thesis of 2004, that the Lower Shuswap River lies mainly in rural agricultural land and Chinook are affected by bank erosion, loss of riparian habitat and other effects of farming.

Chinook juveniles in the Lower Shuswap River are not well understood but there appears to be a range in options for early rearing. They do need to find aquatic food items that will sustain them for at least three months of early rearing so habitat conditions that promote insect growth become important such as riffle areas, cover, riparian zones and stable river banks.

3.2.2 Instream Matrix Scores

The relative habitat unit values are presented in the following matrices (Tables 6-9). A 3-class score was assigned to each matrix cell; where 1 = *low value*, 2 = *moderate value*, and 3 = *High value*. The sum of species scores for each habitat unit were then transformed to a relative habitat value, which was calculated as the habitat unit score / maximum habitat unit score.

Table 6. Rearing - habitat unit : fish life history scoring matrix

Species	Habitat Unit/Sub Area: Cascade	Confluence	Pool	Riffle	Run	Backwater	Aquatic Vegetation	Low bench floodplain	Marsh	Side Channel	Large woody debris
Rainbow (Resident)	1	3	2	3	2	3	3	3	3	3	3
Rainbow (Adfluvial)	1	3	2	3	2	3	3	3	3	3	3
Kokanee	1	1	2	1	1	1	1	1	1	1	1
Chinook	1	2	3	2	1	2	3	3	3	3	3
Coho	1	3	3	3	1	3	3	3	3	3	3
Sockeye	1	1	2	1	1	1	1	1	1	1	1
Habitat Unit Score	6	13	14	13	8	13	14	14	14	14	14
Relative habitat value	0.43	0.93	1.00	0.93	0.57	0.93	1.00	1.00	1.00	1.00	1.00

Table 7. General Living - habitat unit/sub area : fish life history scoring matrix

Species	Life Stage	Habitat Unit/Sub Area: Cascade	Confluence	Pool	Riffle	Run	Backwater	Aquatic Vegetation	Low bench floodplain	Marsh	Side Channel	Large woody debris
Rainbow (Resident)	Juv.	2	3	3	3	2	2	2	2	1	3	3
	Adult	3	2	3	3	2	1	2	2	1	2	3
Rainbow (Adfluvial)	Juv.	2	3	3	3	2	1	2	3	1	2	3
	Adult	3	3	3	3	3	1	2	2	1	2	3
Kokanee	Juv.	1	1	1	1	1	1	1	1	1	1	1
	Adult	1	2	2	2	3	1	1	1	1	3	2
Chinook	Juv.	1	2	3	2	3	2	3	3	3	3	3
	Adult	2	2	3	3	3	1	1	2	1	1	1
Coho	Juv.	1	3	3	2	2	3	3	3	3	3	3
	Adult	2	2	3	2	3	2	1	2	1	2	3
Sockeye	Juv.	1	1	1	1	1	1	1	1	1	1	1
	Adult	1	2	2	3	3	1	2	1	1	2	1
Habitat Unit Score		20	26	30	28	28	17	21	23	16	25	27
Relative Habitat Value		0.67	0.87	1.00	0.93	0.93	0.57	0.70	0.77	0.53	0.83	0.90

Table 8. Substrate relative value scores					
Organic	Silt/Sand	Gravel	Cobble	Boulder	Bedrock
8	7	15	13	12	5

Table 9. Cover habitat unit/sub area : fish life history scoring matrix

		Habitat Unit/Sub Area										
Species	Life Stage	Cascade	Confluence	Pool	Riffle	Run	Backwater	Aquatic Vegetation	Low bench floodplain	Marsh	Side Channel	Large woody debris
Rainbow (Resident)	Juvenile	1	1	3	3	2	2	2	1	1	3	3
	Adult	3	2	3	2	2	2	3	1	1	2	3
Rainbow (Adfluvial)	Juvenile	1	1	3	3	2	2	2	2	1	3	3
	Adult	3	2	3	2	2	1	2	1	1	2	3
Kokanee	Juvenile	1	1	1	1	1	1	1	1	1	1	1
	Adult	1	2	2	2	3	1	1	1	1	3	2
Chinook	Juvenile	1	2	3	2	2	3	3	3	2	2	3
	Adult	2	2	3	1	3	1	1	1	1	1	2
Coho	Juvenile	1	3	3	2	2	3	3	3	3	3	3
	Adult	2	3	3	2	3	2	1	1	1	3	3
Sockeye	Juvenile	1	1	1	1	1	1	1	1	1	1	1
	Adult	1	2	2	3	3	1	1	1	1	2	1
Habitat Unit Score		18	22	30	24	26	20	21	17	15	26	28
Relative Habitat Value		0.60	0.73	1.00	0.80	0.87	0.67	0.70	0.57	0.50	0.87	0.93

3.3 Riparian Polygonization

The river channel boundary was established at the estimated mean annual floodplain level to include riparian marshes and low bench floodplain sites. Thus mid bench floodplain ecosystems (i.e., black cottonwood ecosystems) were included in the 100 riparian band and not factored into the stream channel analysis (Section 3.2).

This analysis evaluated a 100-m band beginning at the mapped 2007 channel limits extending outward perpendicular to the river 100 m (Map Series 4). Vegetation polygons occurring within the 100m band were modified by adapting Table 5. Polygons were re-classified into the groups listed in Table 10. In addition, qualifiers were assigned to each polygon to reflect the estimated level of disturbance and habitat quality and condition.

Table 10. Revised vegetation polygon codes assigned to polygons occurring within the 100-m band along the right and left bank of the lower Shuswap River. Refer to Table 5 for descriptions of vegetation associations.

Group / Map Code	Qualifier	Description
Beach (B)		Groomed beach, un-vegetated predominated by sand and silt.
Cleared (Cl)		Forest clearing associated with rural and woodlot activities. A disturbed shrub layer may still be present.
Cultivated (CF)		Cultivated fields (i.e., hayfields, row crops, orchards)
Mid Flood Bench (Fm) – cottonwood riparian ecosystems	F	Narrow riparian fringe generally less than 5-m wide but occasionally up to 10-m.
	HD	Highly disturbed, fragmented/broken canopy. Analogous to a partly treed rural site
	LD	Low disturbance, not recently disturbed. Containing natural tree canopy and understory vegetation associations.
	MD	Moderately disturbed treed riparian area. The habitat community structure may be fragmented or perforated by some land clearing and rural disturbances.
	N	Natural treed cottonwood predominated riparian ecosystems
	R	Narrow riparian fringe along a tributary.
Wetland	WN-LD	Not recently disturbed or with seasonal disturbances (e.g., light seasonal grazing by livestock). Generally, the wetland is in proper functioning condition, but may be at risk by adjacent landuse practices.
	WN-MD	Moderately disturbed wetland ecosystem, ecologic function at risk.
	WN-N	Natural, proper functioning wetland ecosystem
	WN-HD	Highly disturbed wetland and fragmented by landuse and agricultural practices. The ecological function of this feature is severely impaired by human and associated activities.
Un-vegetated (Uv)		
Treed (T) - Upland forest ecosystems (IDFmw1 Sites)	T-F	Narrow riparian fringe generally less than 5-m wide but occasionally up to 10-m.
	T-HD	Highly disturbed, fragmented/broken canopy. Analogous to a partly treed rural site
	T-LD	Low disturbance, not recently disturbed. Containing natural tree canopy and understory vegetation associations.
	T-MD	Moderately disturbed treed riparian area. The habitat community structure may be fragmented or perforated by some land clearing and rural disturbances.
	T-N	Natural treed communities.
River (Ri)		Tributaries
Rural (Ru)	RU-HD	Rural areas containing houses, outbuildings, driveways, and landscaping. Tree canopy is very limited to absence and natural plant associations sparse to absent.
	RU-MD	Rural areas containing houses, outbuildings, driveways, and landscaping. A native tree canopy may be present but it is perforated by development and the understory plant associations have been partly removed.

3.4 Riparian Polygon Scoring Matrix

Relative habitat values were assigned to riparian polygons (delineated within the 100-m riparian band) based the sum of values of four categories: Wildlife habitat rating; biodiversity rating; nutrient value/leaf and litter fall; and Large woody debris recruitment (Table 11). The sum of relative habitat unit scores were then added to the other parameters of the bank AHI system relating to the current level of impact, degree of bank modifications, and current severity of erosion (caused by human activities).

Table 11. Ecological category : riparian habitat unit rating matrix.

Category	B	CF	CL	FM-F	FM-HD	FM-LD	FM-MD	FM-N	FM-R	RI	RU-HD	RU-MD	T-F	T-HD	T-LD	T-MD	T-N	WN-LD	WN-MD	WN-N	WN-HD
	Polygon ID Scores [1]																				
Wildlife Rating	1	1	2	3	2	4	3	5	5	5	0	1	3	2	4	3	5	5	4	5	4
LWD Recruitment	0	0	1	2	2	5	4	5	5	0	0	1	2	2	4	5	5	5	4	0	0
Biodiversity Rating	0	1	2	2	2	4	3	5	5	5	1	2	2	2	4	3	5	5	4	5	3
Leaf and Litter Fall	0	1	2	3	2	4	3	5	5	0	1	1	3	2	4	3	5	1	1	1	1

1. Polygon/Category Scores: 0=Nil; 1=Very Low; 2=Low; 3=Moderate; 4=High; 5= Very High

3.5 AHI Logic, Calibration, and Ranking

Index development and calibration involved multiple iterations - assigning different weights to each of the parameters within the various habitat unit : life history and ecological matrices. Following each iteration, the resultant sensitivity outputs were reviewed and scrutinized by fisheries biologists both on the project team and from DFO. Calibration of the index was ultimately finalized using professional judgment.

The AHI provides a categorical scale of relative habitat value that ranks the centerline and shoreline segments in a range between *Very High* and *Very Low* sensitivity. The index is relative, because it only assesses the sensitivity of one shoreline area relative to another within the extents of the river being examined. Thus index scores and rankings developed for the lower Shuswap River may not be directly transferable to other river systems without re-calibration. The following provides a definition for each AHI ranking:

- *Very High* – Reaches/Segments ranked as *Very High* are considered integral to the maintenance of fish and wildlife species and generally contain important natural riparian and floodplain areas, complex mosaics of habitat units supporting high biodiversity and productivity values, and high value/use salmonid spawning, rearing, and general living habitats. These areas should be considered the highest priority for conservation and protection.

- *High* - Reaches/Segments ranked as *High* are considered to be very important to the maintenance of fish and wildlife species along and within the river and areas can be ranked as *High* for a variety of reasons. These areas should be considered a priority for maintaining current conditions and a high prioritization for conservation should be given to these areas.

- *Moderate* - Reaches/Segments ranked as *Moderate* are areas that are common along the river, and have likely experienced some habitat alteration. These areas may contain important habitat areas, such as shore holding areas (deep pools), but these areas are generally considered more appropriate for development. Because areas of high habitat value may be present, caution should be taken when considering changes in land use to avoid unnecessary harm or degradation to existing habitat values.

- *Low* – Reaches/Segments that are generally highly modified. These areas have been impaired through land development activities. A common symptom along the river is high bank instability and bank erosion exacerbated by the removal/absence of riparian vegetation. Development within these areas should be carried out in a similar fashion as *Moderate* shoreline areas. However, restoration objectives should be set higher in these areas during redevelopment.

- *Very Low* – Segments that are extremely modified and not adjacent to any known important habitat characteristics.

After reviewing the distribution of the data from the iterations, logical breaks in the scores were used to determine the AHI rankings (discussed above). The breaks created reflect the clustering of scores based upon the output of the results, which somewhat mimic a normal distribution (although an analysis of data distribution was not conducted).

3.5.1 Centerline – Instream Zone AHI Logic

The AHI for each channel reach was calculated as the sum of life history scores for each reach. Table 12 presents the categories, relative category weightings, and logic for the Centerline AHI scoring.

The centerline AHI scores for respective reaches (AHI_{reach}) was calculated using Equation 1; where A_h represents the area of individual habitat unit, A_t represents the total area of the river channel contained with the subject reach, and P_h represents the relative habitat value assigned to respective habitat units for each of the five life history/habitat structure matrices (Tables 6-9). Relative spawning values for each reach were determined by splitting the spawning area polygons (by species) at respective reach breaks (A_{spR}) and then dividing the spawning area within each reach by the total mapped spawning extents (A_{spT}) for the river.

$$\text{(eq. 1)} \quad AHI_{reach} = (\Sigma_{rear}(A_h/A_t*P_h)) + (\Sigma_{genli}(A_h/A_t*P_h)) + (\Sigma_{cover}(A_h/A_t*P_h)) + (\Sigma_{sub}(\%_{sub}*P_{sub}) + (\Sigma_{spawn}(A_{spR}/A_{spT}*P_{sp})) + (A_{stage}/A_t*P_{stage})$$

Table 12. The parameters and logic for the Centerline of the Lower Shuswap River

Category	Criteria	Maximum Point based on Species Habitat Matrix	Category Weighting	Logic
General Living	Instream Habitat unit and Hydraulic Class polygons	30	10	% Area * Category Score
Rearing	Instream Habitat unit and Hydraulic Class polygons	14	25	% Area * Category Score
Chinook Staging/Holding	Known Areas	5	5	% Area * Category Score
Spawning[1]	Sockeye Spawning	15	15	% total spawning area Area * Category Score
	Chinook Spawning	5	5	% total spawning area Area * Category Score
	Kokanee Spawning	10	10	% total spawning area Area * Category Score
Substrates	% composition estimated during 2009 field inventory	36	15	% Area * Category Score
Cover	Instream Habitat unit and Hydraulic Class polygons	30	15	% Area * Category Score

1. Initial analysis summarized the relative abundance on a river scale. For the AHI spawning polygons were split according to identified reach breaks to allow a reach by reach analysis. To accomplish this, the data was transformed and described as a percentage of the total river area available for individual reaches for both sockeye and Chinook and kokanee.

3.5.2 River Bank – Riparian Band AHI Logic

The left and right bank AHI segment scores (AHI_{bank}) were calculated using Equation 2. Table 13 presents the categories, relative category weightings, and logic for the river bank AHI scoring.

The relative abundance of each habitat unit type occurring within the 100-m riparian band of each segment (A_{rh}/A_t) was multiplied by the relative habitat value (P_h) assigned to respective riparian habitat units based on the matrix scores (Table 11).

$$AHI_{bank} = [(\%_{nat}*P_n) + (\Sigma_{wild}(A_{rh}/A_t*P_h)) + (\Sigma_{biodiv}(A_{rh}/A_t*P_h)) + (\Sigma_{nutr}(A_{rh}/A_t*P_h)) + (\Sigma_{LWD}(A_{rh}/A_t*P_h))] - [(\Sigma_{erosion}(L_e/L_{seg}*P_{erosion})) + (\%_{ret}*P_{ret}) + (N_{mod}*P_{mod}) \quad \text{(eq. 2)}$$

Table 13. The parameters and logic for the Centerline of the Lower Shuswap River					
Category	**Criteria**	**Maximum Relative Value**	**Percent of the Category**	**Percent of the Total**	**Logic**
Percent Natural	Percent Natural	5	100	20	% Natural Value (%nat)* Category Score (P_n)
Wildlife [a]	Wildlife	5	100	20	% Area * Category Score
Large Woody Debris Recruitment [a]	Large Woody Debris Recruitment	5	100	20	% Area * Category Score
Biodiversity [a]	Biodiversity	5	100	20	% Area * Category Score
Leaf and Litterfall [a]	Leaf and Litterfall	5	100	20	% Area * Category Score
Impairments – Erosion	Low	-0.5	7		% of Segment Length * Score
	Moderate	-1	13		% of Segment Length * Score
	High	-2	27		% of Segment Length * Score
	Extreme	-4	53		% of Segment Length * Score
Impairments – Bank Armouring	Retaining wall, rip rap	-2	38		% of Segment Length * Score
Impairments – Modifications	Dock	-0.25	5		#/km * Score
	Groyne	-1	19		#/km * Score
	Boat Launch	-1	19		# * Score
	Marina	-1	19		# * Score

a. See Table 11 for rating matrix

3.5.3 Bank Segment Correction Values

Recognizing the river banks are functionally connected to the river itself, a correction factor was applied to the raw Bank AHI scores. The primary purpose of this correction was to apply a greater weighting value to bank segments that occur along reaches with *High* and *Very High* Centerline AHI scores. Therefore additional points, relative to the adjacent Centerline AHI score, were assigned to respective bank segments. The reach correction factor (CF_r) was calculated for each reach (1-24) and added to the raw Bank AHI score. The greater the centerline AHI score, across the spectrum from *Low* to *Very High*, the greater the Correction Factor – or – points added to raw Bank AHI scores.

The Correction Factor for each reach (CF_r) was obtained by first calculating the difference ($Diff_r$) between the subject reach Centerline AHI score (AHI_r) and the minimum reach Centerline AHI score (AHI_{rmin}) (Eq. 3). This differential reach score ($Diff_r$) was then divided by the maximum differential reach score ($Diff_{rmax}$) to yield a relative correction value ranging between 0-1. Bank AHI category breaks (i.e., *Very*

Low – Low – Moderate – High – Very High) were established at numeric increments of five (5) based on the distribution (clustering) of raw Bank AHI scores. Therefore, relative correction values were multiplied by 5 to yield the Correction Factor for each Reach (eq. 4). Thus a bank segment, with a *Moderate* raw AHI rankng, that fronts onto a reach ranked as *High* or *Very High* may have a corrected AHI rating = *High* (after the Correction Factor is applied).

(eq. 3) $$Diff_r = ((AHI_r - AHI_{rmin}))$$

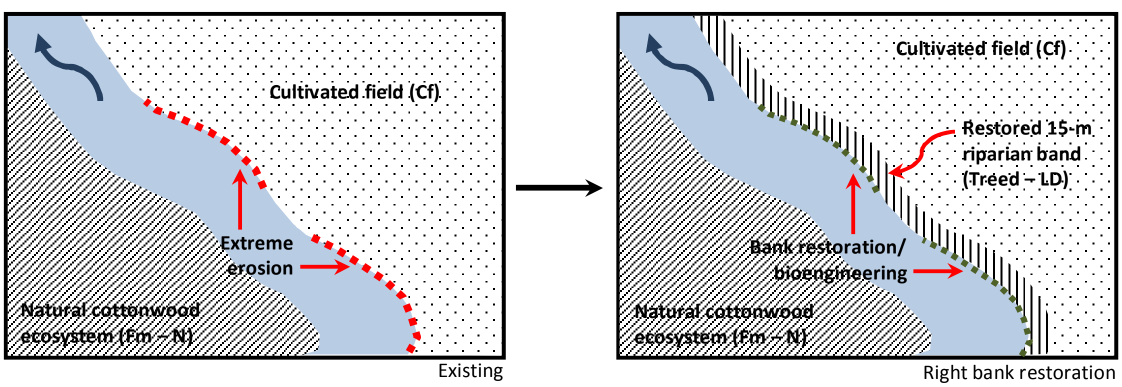
(eq. 4) $$CF_r = (Diff_r - Diff_{rmax}) * 5$$

3.6 Restoration and Segment Prioritization Analysis

To assess the viable restoration potential of a segment, the following changes were made to existing polygons occurring within the 100-m riparian band as well as to the bank inventory data. This involved the following:

1. When the adjacent river polygons were of lesser quality than a treed riparian fringe (i.e., where a cultivated field or cleared area extended to the river's edge) a 15-m treed riparian band with low disturbance qualifier supplanted the existing lesser value condition for that area (implying restoration to the site potential vegetation type).

2. Lengths of "*high*" and "*severe*" bank erosion, inventoried and mapped during the 2009 field inventory, were removed from the bank segment data - representing bank restoration, stabilization, and bioengineering.



3. Once steps 1 and 2 were completed, the AHI was re-run – outputting improved scores for reaches that had higher levels of impact and consequently lower Bank AHI scores and ratings. Bank segments demonstrating the greatest AHI score differential between AHI_{now} and $AHI_{potential}$ were identified as higher priority areas for mitigative action.

Similar analysis completed for lake system AHIs such as Okanagan Lake (Schleppe 2011) also eliminated point modification features (i.e., docks, groins, etc.). However, on the Shuswap River, the primary concern is riparian loss, river encroachment, and bank erosion, whereas modified features were generally limited and had little influence on respective bank AHI scores.

4.0 INVENTORY SUMMARY OF RESULTS

Lower Shuswap River (Watershed Code: 128-835500) flows about 72.7 km from Mabel Lake to Mara Lake.

The River was broken into a total of 24 reaches. The left bank (looking downstream) was divided into 50 Segments and the right bank was broken into 56 Segments. The total length of the left and right river banks was 81 km and 77 km respectively.

4.1 Stream Primary Character

4.1.1 Shore Type Relative Distribution

Over 80% of the left bank and greater than 90% of right bank are characterized and bench flood associations (Figure 1). Flood ecosystems occur on the floodplains of rivers and are inundated during the spring freshet but have well-drained and aerated soils (Mackenzie and Moran 2004). High flood benches were prevalent adjacent lower reaches downstream of Enderby. Middle and low bench sites became more prevalent upstream of Enderby.

Low and Middle Bench site associations combined account for about 57% of the right bank and about 39% of the left bank. Low and Middle Bench Site Associations occur in the geomorphologically dynamic portion of the floodplain and are maintained by a combination of prolonged flooding and site erosion/sedimentation (Mackenzie and Moran 2004). Low bench ecosystems occur on sites that are flooded for moderate periods (< 40 days) of the growing season, conditions that limit the canopy to tall shrubs, especially willows and alders. Annual erosion and deposition of sediment generally limit understorey and humus development (Mackenzie and Moran 2004). Middle bench ecosystems occur on sites briefly flooded (10–25 days) during freshet, allowing tree growth but limiting tree species to only flood-tolerant broadleaf species such as black cottonwood (Mackenzie and Moran 2004).

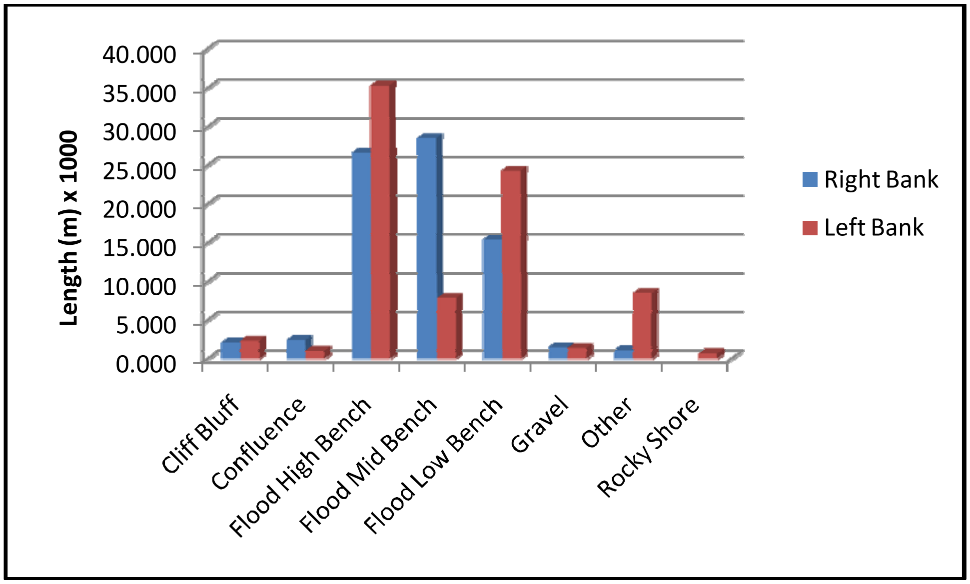


Figure 1. Relative distribution of shoretypes along the left and right bank of the Lower Shuswap River. The total length of the left (LB) and right river banks (RB) was 81 km and 77 km respectively.

Flood Low Bench

Flood Mid Bench

Flood High Bench

Confluence

Rocky Shore

Cliff/Bluff

Other

Gravel

4.1.2 Landuse Relative Distribution

Combined, rural and agricultural landuse predominate the banks of the LSHU (Figure 2). Access to the entire right bank length, which upstream of Enderby is provided by Mabel Lake Road, results in only 14% of the right bank being classified as *Natural*. With more restricted access upstream of Enderby, about 41% of the left bank of the river was classified as *Natural*. The following photo plates illustrate the landuse classes/character described in this inventory.

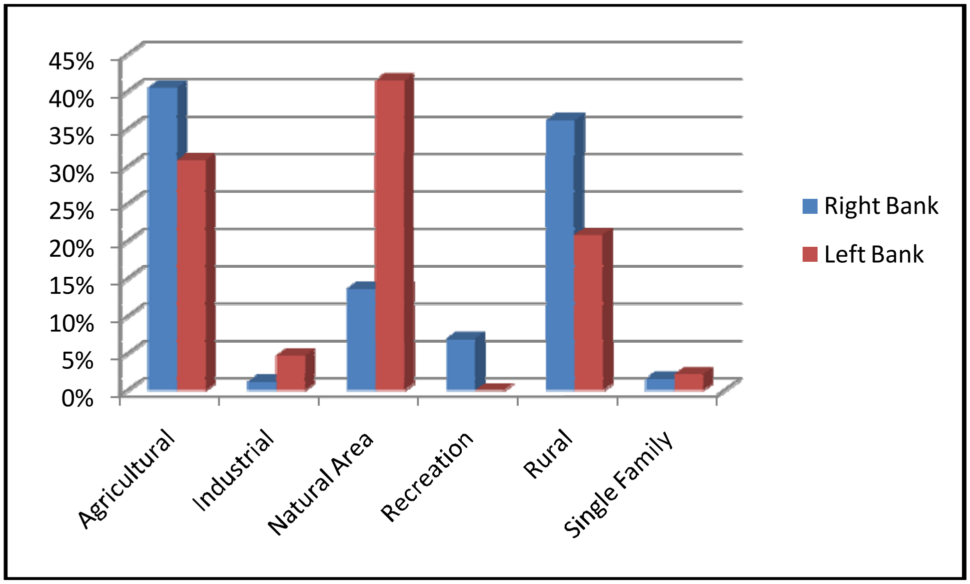


Figure 2. Relative landuse distribution of along the left and right bank of the Lower Shuswap River. The total length of the left (LB) and right river banks (RB) was 81 km and 77 km respectively.

Agricultural

Industrial

Natural Area

Recreation

Single Family

Rural

4.1.3 River Bank Level of Impact

Anthropogenic impacts to the river occurred in highest density from Enderby downstream to Mara Lake. About 35 km (43%) of the left bank has been modified and about 47 km (60%) of the right river bank has been modified. These values were derived from the estimated % disturbed variable within individual segment information. From this data, the estimated percent disturbed value for each bank segment was multiplied by the total segment length to yield a relative length of disturbance along each segment. The sum of relative disturbance length was then obtained separately for the left and right river banks. Figure 3 summarizes the relative distribution of relative impact ratings along both banks of the LSHU.

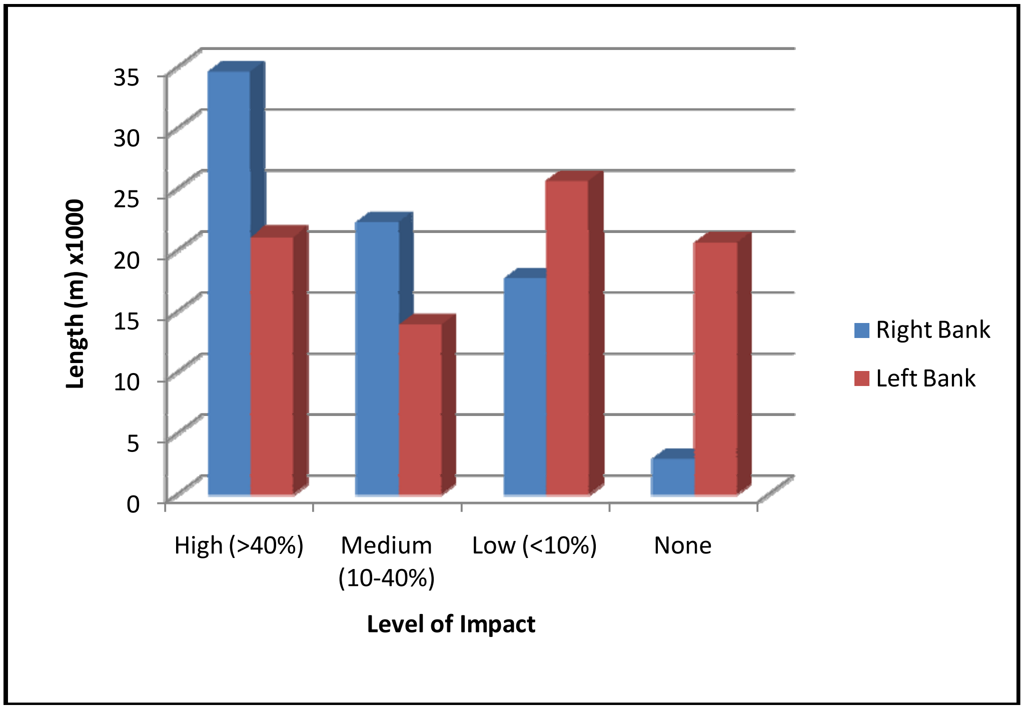


Figure 3. Level of impact ranges on the left and right bank of the Lower Shuswap River. The total length of the left (LB) and right river banks (RB) was 81 km and 77 km respectively.

4.2 Stream Channel and Hydraulic Character

Lower Shuswap River exhibits primarily run/glide morphology for approximately 71% of the 72.7km river length (Figure 4). Higher gradient and subsequent riffle-pool-run morphology do not occur until Reach 7, which begins about 41 km upstream of Mara Lake (Table 14).

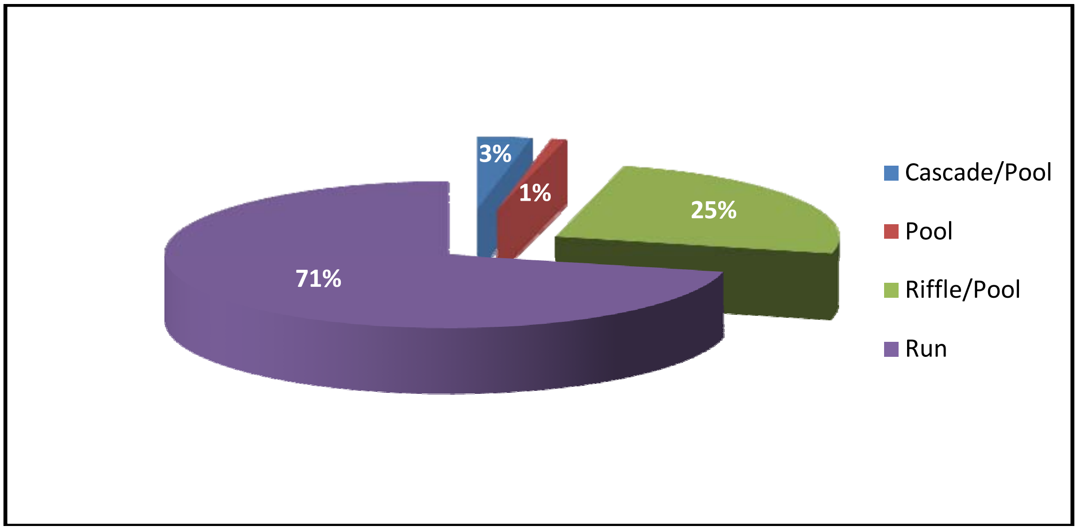


Figure 4. Lower Shuswap River Hydraulic Class Distribution over the 72.7km river length (centerline length).

Table 14. Lower Shuswap River channel character summary.					
Reach	Pattern	Hydraulic Class	Bars	Islands	Length (m)
1	Sinuous	Run	Side	None	8462
2	Irregular	Run	Side	None	4163
3	Straight	Run	Side	None	6834
4	Irregular meandering	Run	Side	None	13100
5	Sinuous	Run	Mid-channel	Frequent - Irregular	2108
6	Irregular	Run	None	None	3832
7	Irregular meandering	Riffle/Pool	Braided	Split	2284
8	Sinuous	Run	Side	Occasional	1652
9	Straight	Run	Side	None	1967
10	Regular meanders	Run	Side	None	3472
11	Irregular	Riffle/Pool	Side	Frequent - Irregular	3799
12	Irregular meandering	Riffle/Pool	Side	Frequent - Regular	2611
13	Irregular meandering	Riffle/Pool	Braided	Anastomosing	1547
14	Straight	Run	None	Split	1495
15	Sinuous	Riffle/Pool	Mid-channel	Occasional	1554
16	Straight	Run	Diagonal	Frequent - Irregular	1461
17	Irregular	Riffle/Pool	Side	Frequent - Irregular	1771
18	Sinuous	Riffle/Pool	Side	None	921
19	Straight	Pool	None	None	593
20	Sinuous	Riffle/Pool	Side	None	420
21	Straight	Riffle/Pool	Side	Frequent - Regular	3146
22	Sinuous	Run	None	None	2011
23	Irregular	Cascade/Pool	Side	None	2254
24	Straight	Run	None	None	1278

4.3 Fish Habitat

Suitable spawning habitat was not identified or encountered until Reach 7, just under 41 km upstream of Mara Lake (about 6 km upstream of Enderby). Downstream of Reach 7, the river channel is composed almost exclusively fine substrates.

Spawning habitat is discontinuous through Reaches 7 to 10. From Reach 11 through to Reach 24 (outflow from Mabel Lake), suitable spawning habitat is nearly continuous over the roughly 22.5 km of river; with Chinook (Table 15) selecting more coarse substrates and sockeye (Table 16) and kokanee utilizing the smaller gravels. In terms of aerial coverage, about 146 hectares of the Lower Shuswap is suitable fish spawning habitat, which accounts for about 18% of the total river channel area (829 ha).

Table 15. Chinook Salmon aerial cover of spawning habitat and holding (deep pool) cover in the Lower Shuswap River between Mara Lake and Mabel Lake.

	Area (m^2)	Percent of LSHU channel [1]
Chinook Holding	259945	3%
Chinook Spawning	1088365	13%

[1] Total River channel = 8290698 m^2

Table 16. Sockeye Salmon aerial cover of spawning in dominant versus non-dominant years in the Lower Shuswap River between Mara Lake and Mabel Lake.

	Area (m^2)	Percent of LSHU channel [1]
Dense Spawning on Dominant Years	1276625	15%
Spawning on Non-Dominant Years	109996	1%

[1] Total River channel = 8290698 m^2

Total and relative instream cover is a field estimate of the type and amount of in-channel cover available to fish. Total cover represents the total percentage of the wetted area of respective reaches occupied by cover. The relative abundance (%) of cover types (e.g., deep pool, large woody debris, etc.) is an estimate of the distribution (of respective cover types) within the total cover estimate for the reach.

Over the lower 33 km of the river from Enderby to Mara Lake (Reaches 1-4), cover is limited to instream vegetation and infrequent deep holding pools. Over this distance, just seven (7) deep holding areas were identified with 25 deep pools identified over the entire Lower Shuswap. In total, deep holding areas are estimated to account for less than 2% of the Lower Shuswap channel (Figure 5). The average residual depth of these deep areas was about 3 m.

Downstream of Enderby, instream large woody debris (LWD) was sparse – likely a function of riparian clearing, which reduces the degree of LWD recruitment. Upstream of Enderby, LWD becomes more prevalent with increasing channel complexity and increased relative length of more intact riparian communities, which are the primary source of LWD.

Instream vegetation, predominated by pondweeds (*Potamogeton* sp.) and milfoils (*Miriophyllum* sp.), accounts for the majority of cover in the lower reaches from Enderby to Mara Lake. Instream vegetation is the predominate instream cover type over the lower four (4) reaches and was estimated to account for just over 3% of the instream area.

Key rearing areas for Chinook were described by Federenko and Pierce (1982) as flooded pastures, backwaters and sloughs adjacent to spawning areas being the preferred areas for rearing. In terms of potential rearing and nursery habitat, low flood bench sites and riverine wetlands occurring adjacent to the river channel and in backwater areas, cover about 100 hectares. These sites are flooded for moderate periods (< 40 days) of the growing season, during which time they provide season nursery and rearing habitat for juvenile salmonids.

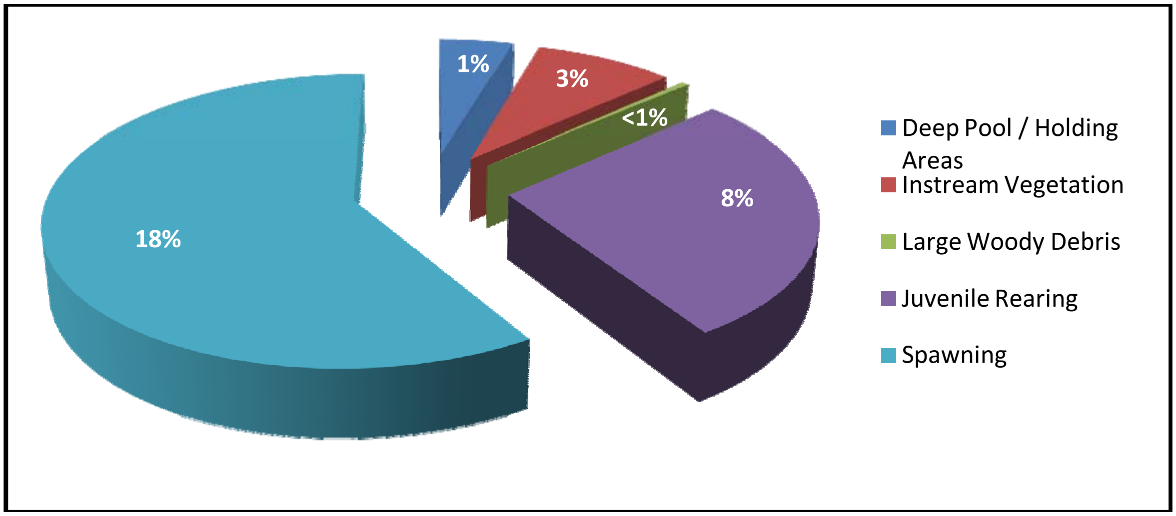


Figure 5. Relative distribution of key habitat elements mapped during the lower Shuswap River inventory. Percentage values shown in the illustration represent the estimated spatial coverage of respective features over the total LSHU instream area (~829 hectares). Juvenile rearing habitat includes low flood sites, backwaters, and riverine marsh. Spawning habitat is a measure of kokanee, dominant year sockeye, and chinook spawning based on field inventory and mapping.


Deep pool/Holding


Instream Vegetation


Large Woody Debris


Juvenile Rearing Habitat


Spawning Habitat (Chinook)

4.4 Modifications

Instream and bank modifications and features were recorded in the field as points and summarized in Table 17. It should be noted that general clearing/removal of riparian vegetation and encroachment by field and urban and rural development was not recorded as individual points and instead were captured within the percent disturbed field for individual shore segments.

In general, greater than ¾ of the recorded features occurred along Reaches 1-5 from Mara Lake to just upstream of Enderby (Table 18). While a total of 89 docks were recorded along the Lower Shuswap, the majority of the structures were small semi permanent floating structures. Only two (2) marinas occur – both of which are at the upstream end of the river at the outlet from Mabel Lake.

The most significant of instream modifications were encountered in Reach 5 just upstream of Enderby. During the survey a diagonal series of pilings were noted stretching over 400m in length. These piles are remnants of a diversion dam that was constructed in 1919. The purpose of this dam was to divert a large volume of water from the river into a narrow channel through which logs were floated to the Okanagan Saw Mill intake. Currently these remnant piles and associated rock aprons are having an influence of the hydrologic character – influencing scour and deposition as well as trapping LWD, which may be providing additional instream cover/structure.

Table 17. Summary of anthropogenic features and modifications catalogued during the Lower Shuswap Inventory Mapping. Features summarized below were documented between Mara Lake and Mabel Lake.

Modification Type	Count/No. Incidents	Left bank	Right Bank	Instream Length	Total Length on LB	% of LB [1]	Total Length on RB	% of RB [1]
Beach grooming	6	4	2	100	80	0.10	20	0.03
Boat Launch	11	5	6					
Bridge	4							
Dock	89	42	47					
Garbage/pollution	8	3	5		135.00	0.17	60.85	0.08
Livestock Access	13	7	6		345.00	0.43	485.00	0.63
Marina	2	0	2				315	0.41
Pilings (Instream)				820.00				
Recreational Access	19	7	12					
Bank stabiliz./armour.					1797.00	2.23	1952.00	2.54
Water Withdrawal	90	31	49					

1. The total length of the left (LB) and right river banks (RB) was 80.7 km and 77.0 km respectively.

Table 18. Percent of modifications occurring within Lower Shuswap River Reaches 1 - 6 from Mara Lake to just upstream of Enderby.	
Modification Type	Percent of total count or extent of features surveyed
Beach grooming	83%
Boat Launch	45%
Bridge	75%
Dock	81%
Garbage/pollution	92%
Livestock Access	89%
Marina	0%
Pilings (Instream)	62%
Recreational Access	47%
Rip rap and bank stabilization	76%
Water Withdrawal	73%

Beach Grooming

Boat Launch

Bridge

Dock

Marina

Livestock Access

Pilings

Recreational Access

Rip rap and Bank Stabilization

Rip rap and Bank Stabilization

Water Withdrawal
Improperly screened intakes, result in impingement or entrainment of fish.

4.5 Discharges/Waterbodies

In total, only six (6) storm drains and one municipal waste water discharge were recorded over the entire 72.7 km length of river. All but one of these features (road runoff drain) occurs along Reach 4 along the left bank (Segments 11, 16, and 18) through the Town of Enderby.

4.6 Bank Stability and Erosion

Bank erosion (moderate to extreme severity) was documented on over approximately 16% of the left bank and 21% of the right bank of LSHU (Table 19).

The average height of bank erosion on the left bank was about 2.7 m, while that on the right bank averaged about 2.3 m. Along the left bank, high to extreme erosion accounts for about 10% of the 80.7 km length. Along the right bank, high to extreme erosion accounted for about 13% of the 77 km length. The maximum recorded eroding bank height was about 12 m on the left bank and about 6 m on the right bank. The recorded maximum exposure for a single continuous incident was about 3264 m^2 on the left bank and 2961 m^2 on the right bank. Table 20 summarizes the distribution of erosion severity along the right and left banks of the LSHU, which is subsequently illustrated in Figure 6.

Table 19. Summary of river bank integrity and erosion.

Bank	Severity	Total Length (m)	Percent of respective river bank[1]
Left	Extreme	2927	4%
	High	4985	6%
	Moderate	4786	6%
	Low	10813	13%
Right	Extreme	4125	5%
	High	6023	8%
	Moderate	6286	8%
	Low	7063	9%

1. The total length of the left and right river banks was 80.7 km and 77.0 km respectively.

Bank instability appeared to be largely attributed to the lack of riparian vegetation and encroachment associated with agricultural land use, rural, and residential sites.

Some of the more severe incidents also appear to be a result of riparian clearing along power transmission corridors. Adding to this, it is generally accepted that increased recreational boating along the Lower Shuswap may be further exacerbating erosion of these un-vegetated and destabilized banks. In other instances, the marked increase (compared with historic aerial photos) in size of some tributary fans (perhaps associated with logging practices and slope destabilization in the upper watersheds) are deflecting river flows to the opposing bank with greater force and, in conjunction with impacts to riparian communities and bank integrity, erosion (on the opposing banks) was considerable.

Table 20. Summary of erosion severity and exposure on the lower Shuswap River from Mabel Lake to Mara Lake.

Bank	Severity	Total Exposure (m^2)	Exposure:Length Ratio	Average Height of Exposure
Left	Extreme	10174.4	3.5	4.06
	High	10132.9	2.0	2.28
	Moderate	8572.5	1.8	1.87
	Low	12886.8	1.2	1.08
Right	Extreme	15413.2	3.7	3.48
	High	11090.2	1.8	1.87
	Moderate	9156.3	1.5	1.58
	Low	6123.75	0.9	0.75

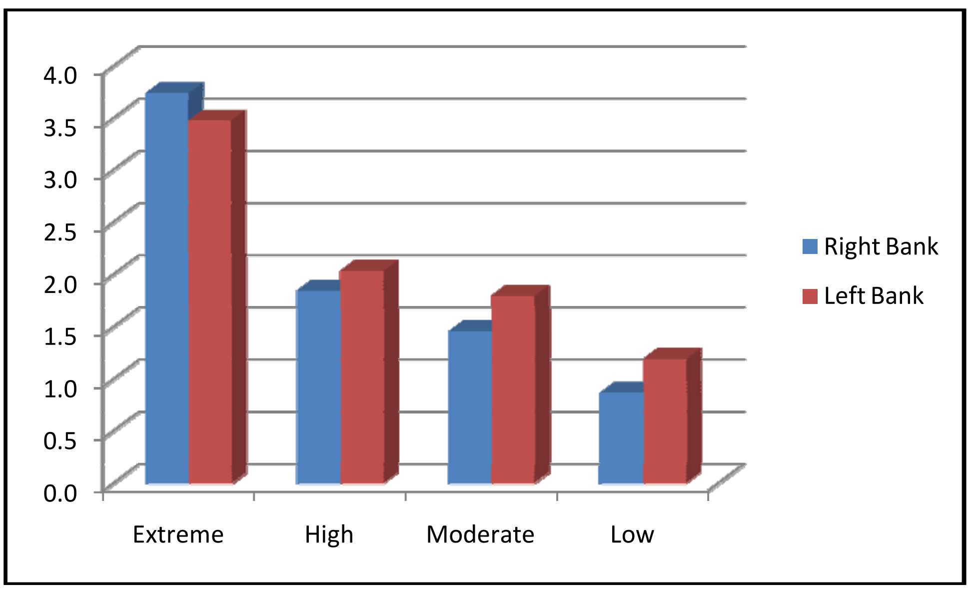


Figure 6. Erosion severity classes exposure: length ratios. The total length of the left (LB) and right river banks (RB) was 81 km and 77 km respectively.

Moderate Severity Erosion

High Severity Erosion

Extreme Severity Erosion

4.7 Lower Shuswap River Condition Score

A condition score was assigned to each river reach. This rating system was designed with the intent of providing a more measurable parameter in evaluating the watercourse condition and monitoring and evaluating habitat changes on local watercourses and associated riparian and floodplain communities.

The sum of weighted scores equaled 2.04 (out of 6), with LSHU receiving a stream grade of 34% (Table 21). About 30% of the river had a high level of impact / poor riparian condition (Figure 7). Reaches 1-4 were in poorest condition (0-1 Scores), combined accounting for about 45% of the LSHU. About 29% is in fair condition, and about 26% is in good condition.

Table 21. Summary of lower Shuswap River Condition.

Reach Condition Score[1]	Condition Value Score	Combined Reach Length by Score (m)	% of LSHU	Weighted Score
high-high	0	21562	30%	0.00
mod-high	1	10997	15%	0.15
high-low	2	6078	8%	0.17
mod-mod	2	5799	8%	0.16
low-mod	3	9379	13%	0.39
low-low	4	4758	7%	0.26
nil-mod	4	4391	6%	0.24
nil-low	5	9771	13%	0.67
			Condition Score	**2.04/6 (34%)**

[1]Reach condition references the condition of both banks. E.g., high-high translates to high level of impact on both banks over the segment.

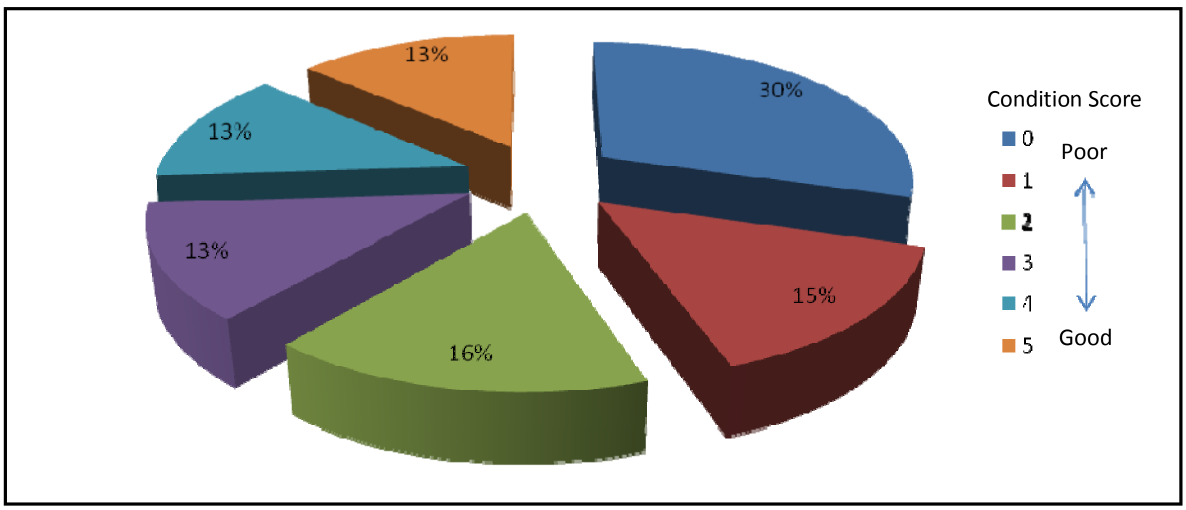


Figure 7. Lower Shuswap River condition distribution based on reach weighted condition scores.

5.0 HISTORIC AIRPHOTO ANALYSIS OF RIVER CHANGE

The historic (1928) air photos covered the Lower Shuswap from Mara Lake to upstream of Enderby about 11km to include Reaches 1-9 totaling about 47.9km of River (Map Set 3). Table 22 summarizes the results of the retrospective spatial analysis of the LSHU and adjacent 100m band, which are illustrated in Figure 8.

Table 22. Retrospective analysis of the aerial coverage of biophysical and anthropogenic units throughout a 100-m band along left and right bank of the Lower Shuswap River from Mara Lake to 47.9 km upstream (Reaches 1-10).

	1928		2007		
Character/Class	Aerial Coverage (m^2)	Relative Abundance (%)	Aerial Coverage (m^2)	Relative Abundance (%)	Net Change (m^2)
Beach	3265	0.04%	29158	0.33%	25893
Cultivated Field	2663734	29.84%	3247767	36.39%	584033
Cleared/Logged	329697	3.69%	424235	4.75%	94538
Natural Clearing	45503	0.51%		0.00%	-45503
Low Bench Floodplain	121759	1.36%	406982	4.56%	285223
Mid bench Floodplain	343804	3.85%	499629	5.60%	155825
Rural	686776	7.69%	1669944	18.71%	983168
Treed Narrow Fringe	99790	1.12%	329702	3.69%	229912
Treed	4725512	52.94%	2254515	25.26%	-2470997
Off Channel water	114124	1.28%	63446	0.71%	-50678

It is interesting to note that by 1928, cultivated fields already comprised about 30% of the 100m band flanking the LSHU. Since that time, another roughly 58 hectares of field were cleared, and in 2007 fields comprised just over 36% of the 100m band. At the same time, rural developments have more than doubled in coverage along the river since 1928. Inversely, tree coverage within the 100m band along the lower 48 km of the LSHU was reduced by over two times from 53% relative coverage down to about 25% relative coverage. This net reduction of riparian forest may be a key factor in the observed destabilization of channel banks and subsequent erosion.

Table 23 summarizes the retrospective analysis of channel migration (erosion-accretion). Based on the spatial analysis, we estimate that there has been accretion of about 6.8 hectares along Reaches 1-9 (Table 23). This result would seem to conflict with the inference that, in general, bank erosion is one of the primary issues/concerns along the LSHU. However, intensified human activities in watersheds can lead to increased sediment loading in tributaries and downstream receiving waterbodies from poor drainage management, logging, landslides, stromwater runoff, and agricultural erosion/runoff. These persistent and cumulative sediment inputs can result in aggradation and accretion. The following photos of the Brash Creek and Ashton Creek alluvial fans at the confluence with the LSHU illustrate this accretion. The marked size increase (compared with historic aerial photos) of these tributary fans (perhaps associated with logging practices and slope destabilization in the upper watersheds) are deflecting river flows to the opposing bank with greater force and, in conjunction with impacts to riparian communities and bank integrity, erosion (on the opposing banks) was notable. Within the limits of coverage of the 1928 imagery, the most notable fans occurred at the confluence of Brash Creek and Ashton Creek (within Reach 9). Combined these two fans have increased in area by over 11,000 m^2. As they have expanded into the Lower Shuswap Channel, flows have consequently been deflected to the opposing (left) bank. As a result, about 9400 m^2 of the left bank was eroded.

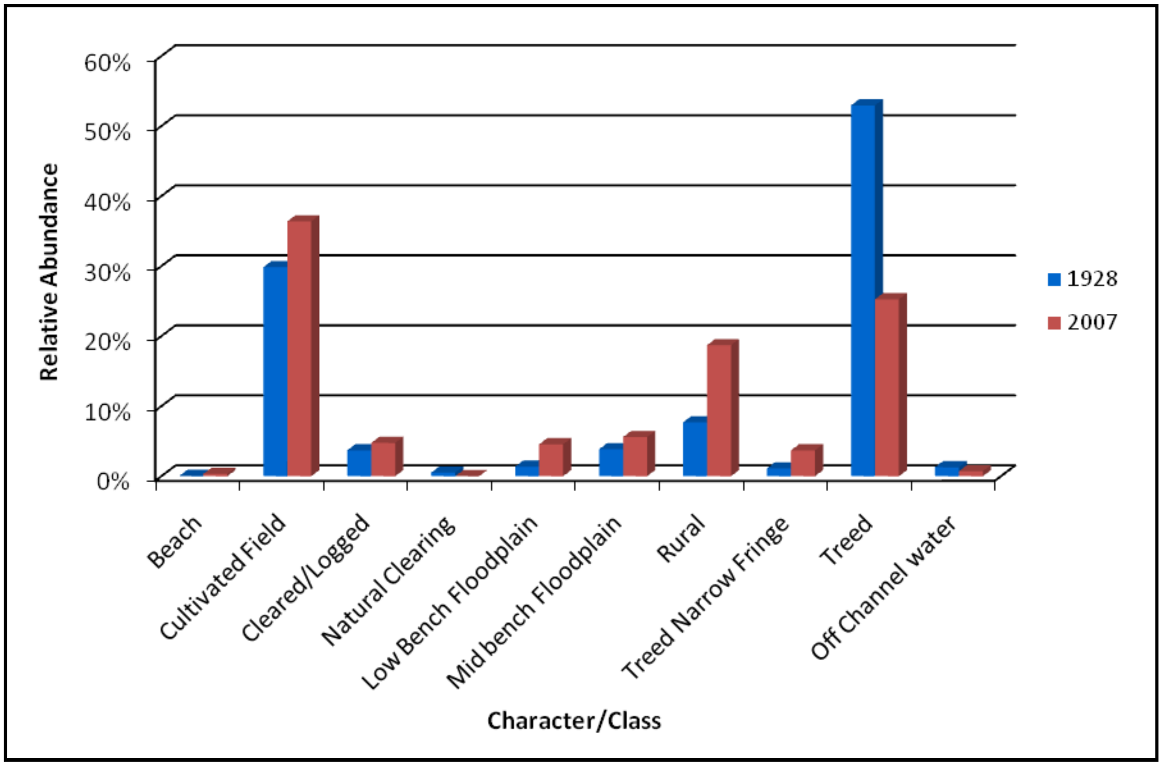
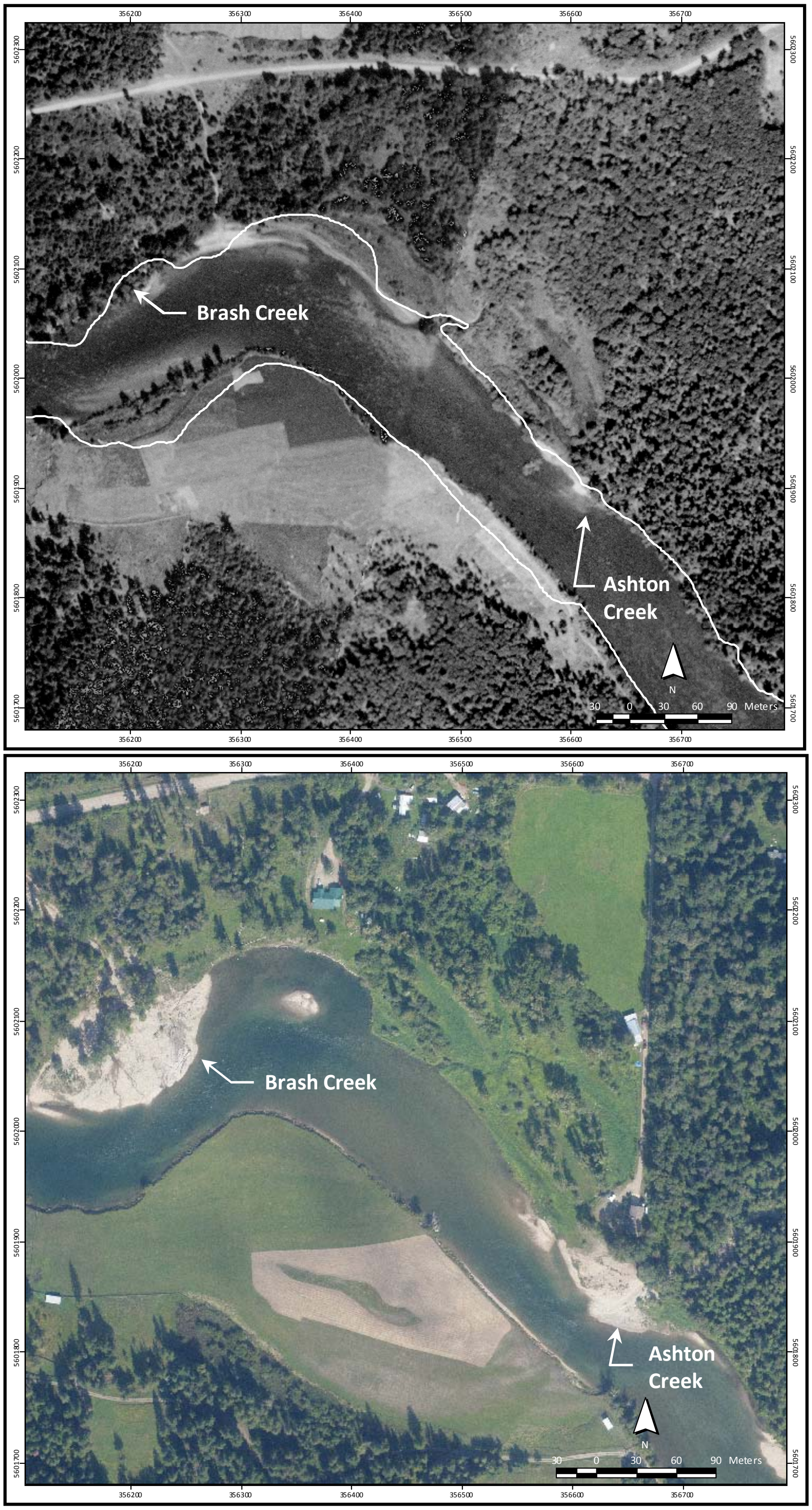


Figure 8. Lower Shuswap River condition change analysis (1928-2007).

Table 23. Retrospective analysis of erosion, accretion and migration of the Lower Shuswap River from Mara Lake to 47.9 km upstream (Reaches 1-10) from 1928 to 2007.

Reach	Reach Length (m)	Character	Area (m^2)	Net Change (m^2)
1	8462	Accretion	21286	
		Erosion	-41348	-20062
2	4163	Accretion	8885	
		Erosion	-27735	-18850
3	6834	Accretion	52345	
		Erosion	-16921	35424
4	13100	Accretion	116655	
		Erosion	-67576	49079
5	2108	Accretion	20535	
		Erosion	-10750	9785
6	3832	Accretion	35457	
		Erosion	-15614	19843
7	2284	Accretion	16258	
		Erosion	-15164	1093
8	1652	Accretion	9206	
		Erosion	-1632	7574
9	1967	Accretion	1880	
		Erosion	-17976	-16095
10	3472	Accretion	539	
		Erosion	-580	-41



1928 georeferenced air photo (top) and 2007 orthophoto (bottom) showing alluvial fans of Brash Creek and Ashton Creek. The white line indicates the channel limits of the Lower Shuswap River in 2007.

6.0 AQUATIC HABIAT INDEX RESULTS

The results summarized in Sections 6.1 and 6.2 below are illustrated in Map Series 5 and the raw AHI analysis scores are included in Appendix C. Section 6.1 summarizes the AHI scores and resultant rankings (i.e., *Very Low – Very High*) for the 24 reaches of the lower Shuswap River, represented in the maps and data analysis as the *centerline*. Section 6.2 summarizes the AHI scores and resultant rankings for the respective left and right bank segments.

6.1 The River

The centerline AHI analysis resulted in about 53% of the river being ranked as *Low*. The relative distribution of centerline AHI rankings are illustrated in Figure 9. Figure 10 illustrates the actual scores and AHI rankings, indicating that the 53% relative length being ranked as *Low* occurs over 6 consecutive reaches (1-6) from Mara Lake to about 38.5 km upstream. AHI scores increased markedly in Reach 7 with changing river morphology and a general increase in habitat complexity and an increased productive value for salmonids. Accordingly, reaches 7-10 received *Moderate* AHI rankings. Instream habitat quality and diversity increases further upstream of Reach 10, with *High* and *Very High* AHI rankings being assigned to Reaches 11-21. Of these, the highest scores occurred through Reach 13 (the Islands) and Reach 19 adjacent to and downstream of the Cooke Creek confluence. Reaches 22-24 were assigned *Moderate* rankings due to reduced habitat diversity thus not receiving high scores for all life history categories (i.e., spawning cover) used in the index. For instance, Reach 23 (Skookumchuck Rapids) received high life history scores for general living, rearing, and cover. However, scores for spawning were relatively low. Thus, the sum of life history scores (AHI score) for the mosaic of habitat units within the river channel was lower on the spectrum of AHI scores (Appendix C). As a result, a *Moderate* AHI ranking was assigned.

Figure 11 profiles the centerline based on respective reach AHI scores and ranks along the lower Shuswap River.

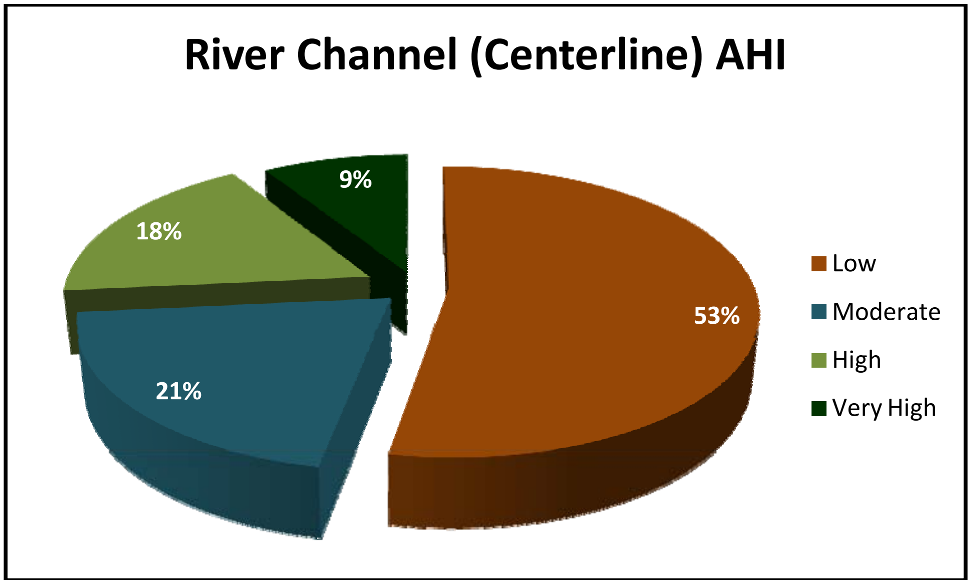


Figure 9. Relative AHI rank distribution (by length) of the Lower Shuswap River channel (centerline) from Mara Lake to Mabel Lake.

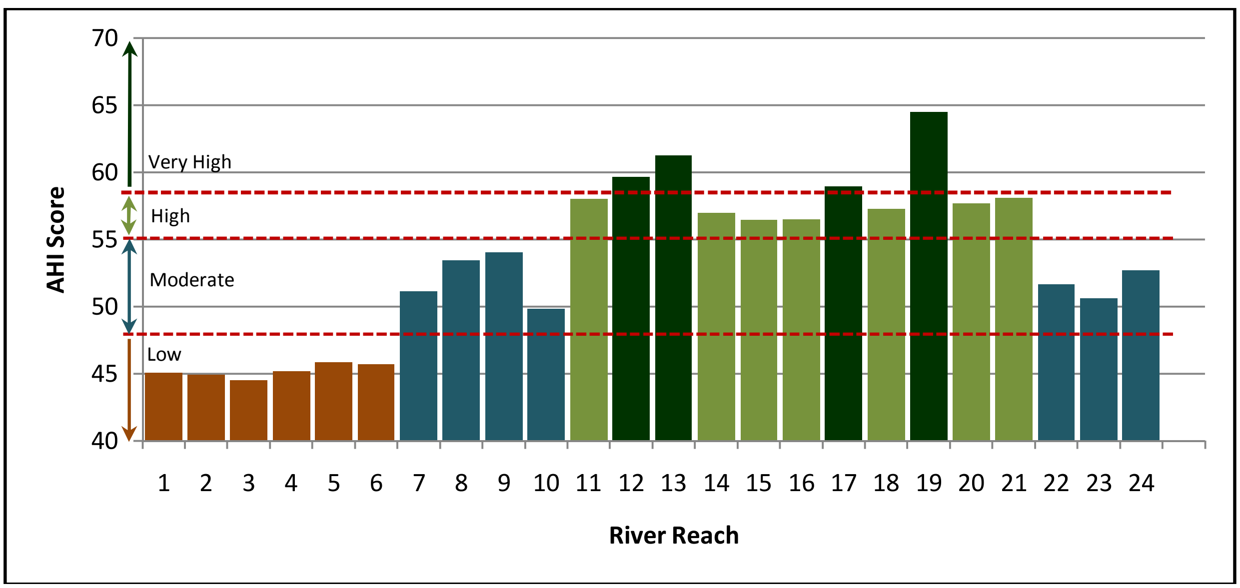


Figure 10. Centerline/reach AHI scores and AHI Rank values (Low/Moderate/High/Very High).

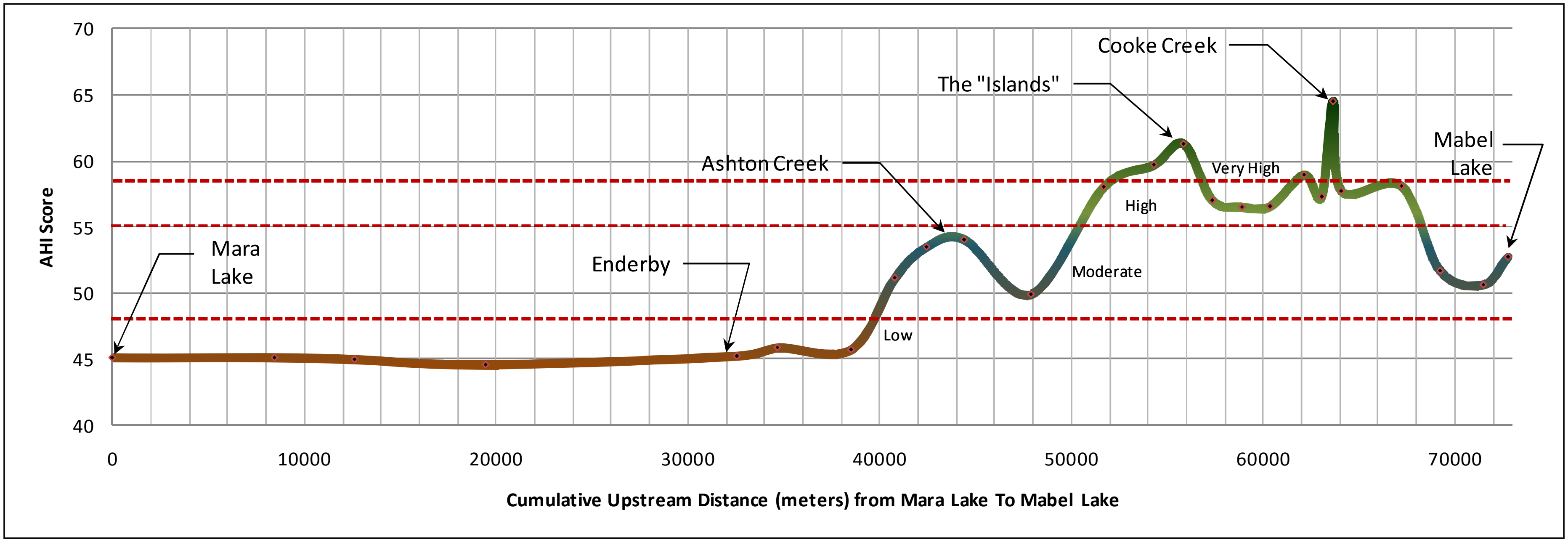


Figure 11. Scaled profile of the lower Shuswap River from Mara Lake to Mabel Lake – illustrating the spectrum of centerline/reach AHI scores.

6.2 The Banks

About 43% of the Left Bank of the lower Shuswap River is ranked *Very High* according to Bank AHI scores (Figure 12). Conversely, about 45% of the Right Bank of the river is ranked *Low* to *Very Low* (Figure 13). Figures 14 and 15 illustrate respective segment scores on the left and right bank and AHI ranks, which were determined by the distribution (clustering) of AHI scores.

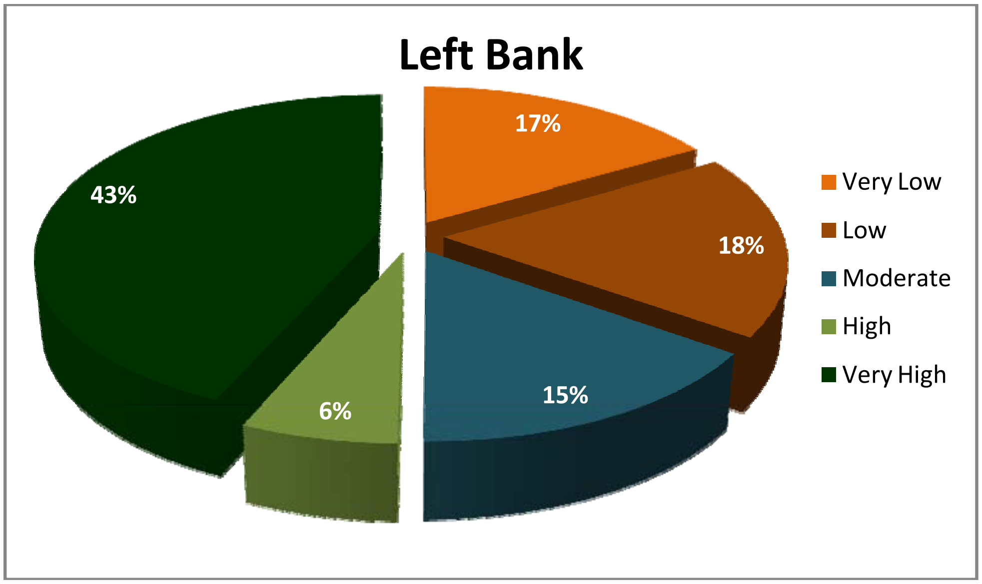


Figure 12. Relative AHI rank distribution (by length) of the left bank (looking downstream) of the lower Shuswap River.

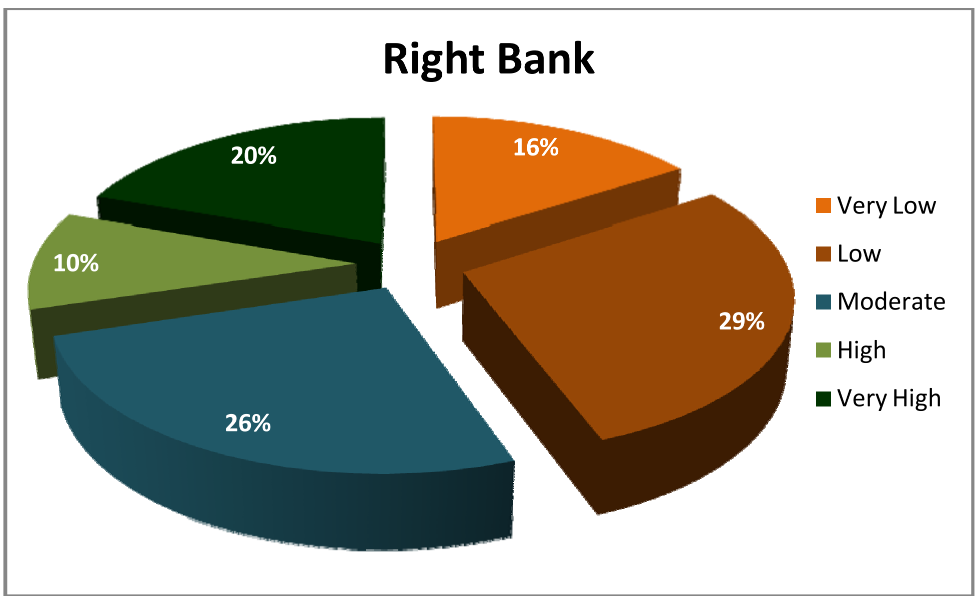


Figure 13. Relative AHI rank distribution (by length) of the right bank (looking downstream) of the lower Shuswap River.

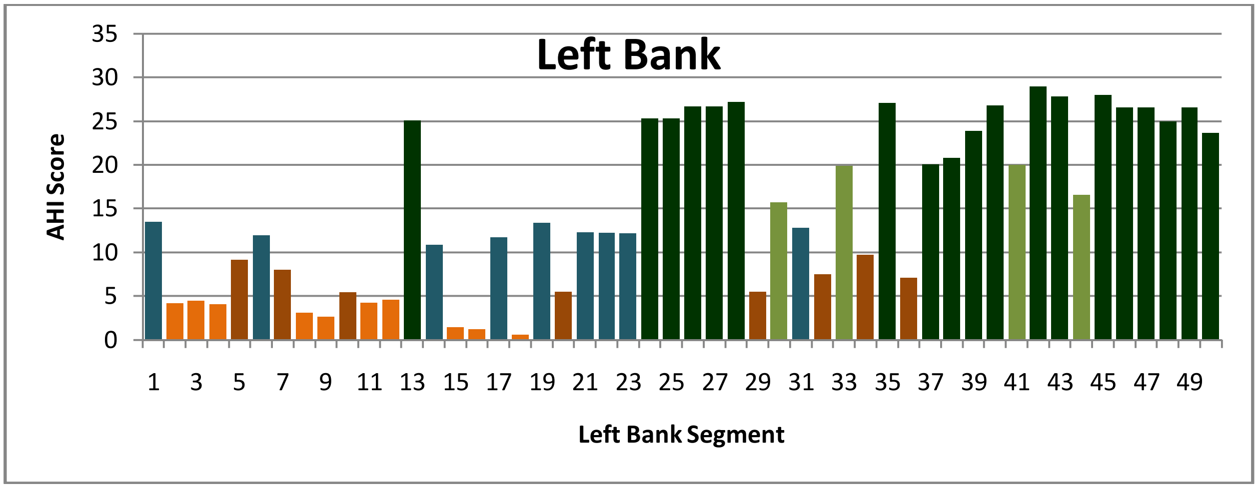


Figure 14. Left bank segment AHI scores. The bars are coloured according to the AHI ranking: orange=*very low*; brown=*low*; teal=*moderate*; light green=*high*; dark green=*very high*.

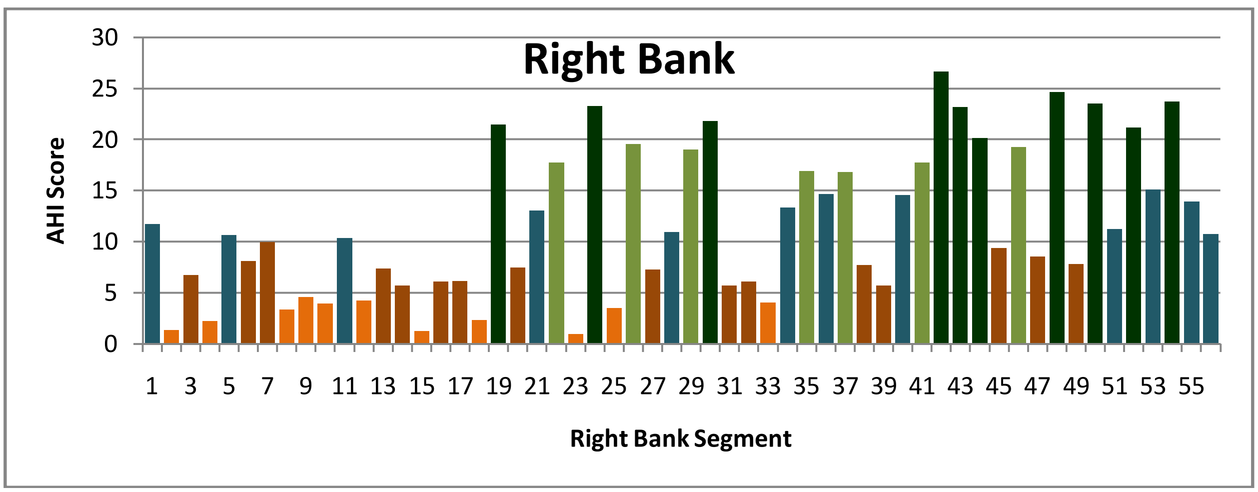


Figure 15. Right bank segment AHI scores. The bars are coloured according to the AHI ranking: orange=*very low*; brown=*low*; teal=*moderate*; light green=*high*; dark green=*very high*.

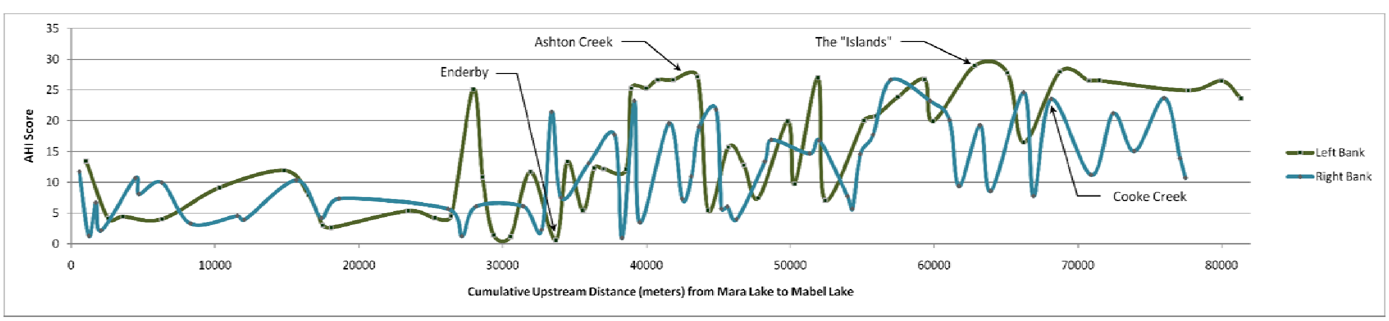


Figure 16. Scaled profile of the lower Shuswap River from Mara Lake to Mabel Lake illustrating the left and right bank AHI score spectrum.

6.3 Restoration Analysis and Priorities

Eleven bank segments were extracted from the restoration analysis as those with the greatest potential AHI score differential between AHI_{now} and $AHI_{potential}$ (Table 24). Figures 17 and 18 illustrate the differences between the AHI_{now} and $AHI_{potential}$ scores and highlight the segments listed in Table 24. These segments represent high priority sites – requiring more immediate attention in regards to bank and riparian restoration. In addition, seven (7) moderate priority sites were extracted. Of these 18 priority segments combined, 13 occur on the right bank. The predominance of right bank priority sites is a result of the lower overall AHI scores achieved for this bank of the river.

Table 24. Summary of priority bank segments extracted from the AHI Restoration analysis. High priority sights are in **bold**.

Bank[1]	Segment	Adjacent Centerline Reach	Existing Bank AHI[2]	Potential Bank AHI	Score Differential
Left	16	4	1.03	2.67	1.64
Left	18	4	0.45	2.17	1.73
Left	**29**	**9**	**3.13**	**5.08**	**1.95**
Left	**32**	**10**	**6.09**	**9.20**	**3.11**
Left	**36**	**11**	**3.69**	**5.74**	**2.05**
Right	2	1	1.16	3.08	1.93
Right	4	1	2.05	3.88	1.83
Right	**9**	**2**	**4.46**	**6.48**	**2.01**
Right	**15**	**4**	**1.08**	**5.10**	**4.02**
Right	16	4	5.94	7.65	1.70
Right	**23**	**6**	**0.67**	**4.92**	**4.26**
Right	**25**	**6**	**3.21**	**8.21**	**5.01**
Right	33	10	2.70	4.37	1.67
Right	**38**	**11**	**4.32**	**6.94**	**2.61**
Right	**39**	**11**	**2.34**	**4.45**	**2.11**
Right	**40**	**11**	**11.20**	**13.57**	**2.38**
Right	**41**	**12**	**13.95**	**15.74**	**1.78**
Right	56	24	8.66	10.53	1.87

[1.] The left and right banks are determined when looking downstream

[2.] AHI scores used in the restoration analysis were not adjusted according to the adjacent centerline AHI scores

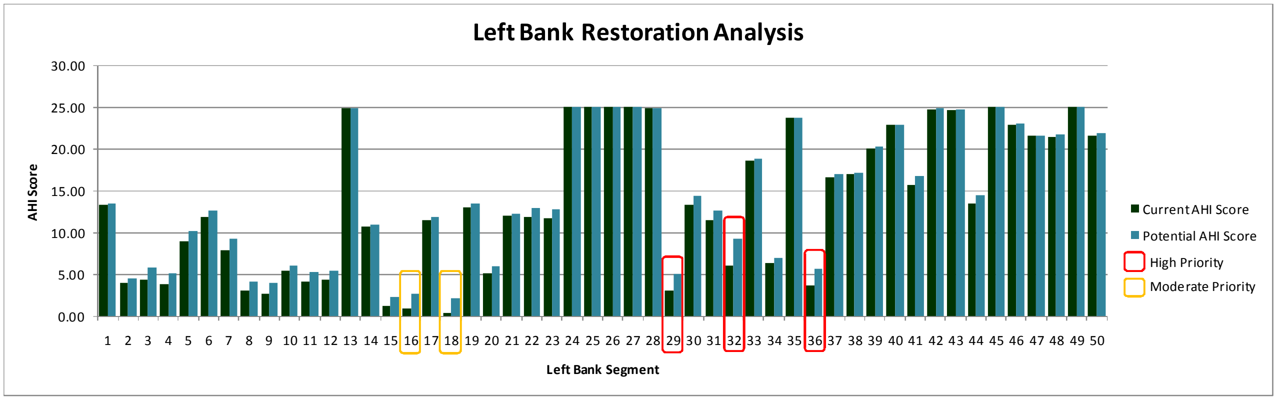


Figure 17. Comparison of current left bank AHI scores and Potential bank AHI scores based on the results of the restoration analysis.

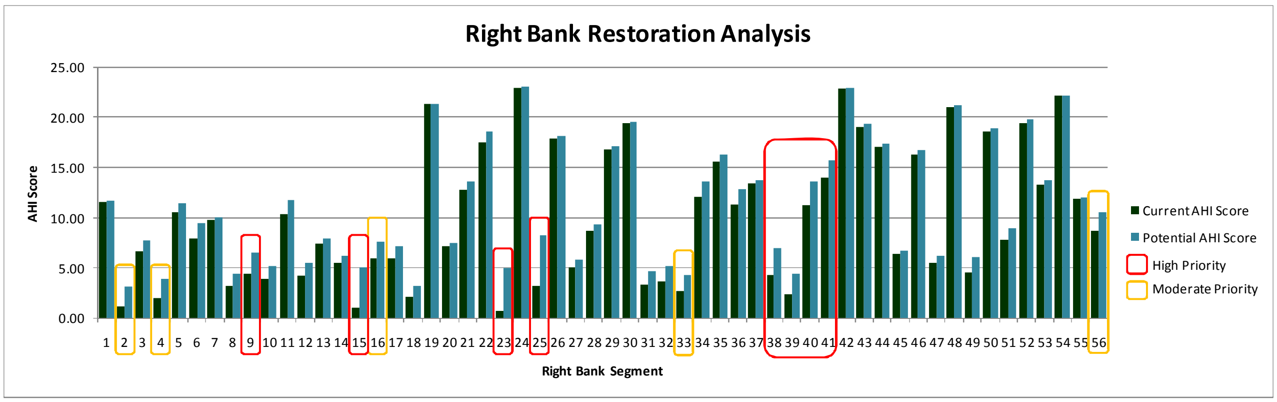


Figure 18. Comparison of current right bank AHI scores and Potential bank AHI scores based on the results of the restoration analysis.

Segment 25 along the right bank.

Segment 18 along the left bank.

7.0 DISCUSSION

Flood ecosystems are intensively used by many wildlife species. These are lush habitats with structural elements often not found in adjacent uplands. In addition, the low flood sites may provide critical rearing habitat for juvenile salmoinds during seasonal inundation periods. The *High* and *Very High* AHI scores/ranks supports this ecological statement; where the mosaic of riparian habitats and complex instream habitat subunits and diverse fish life history utilization occurring in reaches 11-21 combine to represent the highest centerline and bank AHI scores throughout the lower Shuswap River.

The areal extent of flood ecosystems remains constant in a stream reach over time, given no fundamental change in water regime or sediment load, but their location in the floodplain changes in response to stream channel changes (Mackenzie and Moran 2004). Flood ecosystems are maintained by a combination of annual flooding, erosion, channel movement, and deposition, which modify the site conditions on the floodplain regularly. Middle bench ecosystems will succeed low benches as sites accumulate sediments and become raised above the stream. With human influence, continued isolation of middle or low bench ecosystems from the regular flooding, through sediment accumulation or stream channel changes, hastens the natural succession and can lead to the formation of seral ecosystems that progress towards modified high bench ecosystems (Mackenzie and Moran 2004).

Recognizing the above, it is paramount that landuse planning and management of the LSHU focus on conservation and restoration of floodplain ecosystems.

Hard armouring of gravel banks can reduce the supply of gravel through natural stream channel migration processes and the removal of riparian vegetation hastens bank erosion and fine sediment deposits. Moreover, upland activities can impact floodplains as noted in the retrospective analysis. Instead of conventional hard armouring techniques, riparian and channel-bank restoration using bioengineering techniques should be investigated. Benefits of these activities will include bank stabilization and habitat restoration. For instance, spawning was found to be associated with channel complexity, large woody debris, gravel sources, and more intact stream banks. Recognizing the overall lack of large woody debris (LWD) cover through the lower reaches, the inclusion of such in bioengineering projects will help restore instream habitat complexity, especially recognizing that woody debris recruitment from intact riparian forests is lacking.

Live palisade using cottonwood to restore mid flood bench riparian ecosystems and to promote bank stability (Photos by D. Polster).

The restoration analysis extracted 18 priority segments requiring more immediate attention. To fully realize the benefit of such biophysical inventories, actions need to be taken to begin to address concerns or issues identified above. In doing so, this information must be presented to pertinent groups and stakeholders to direct appropriate action and management decisions. For instance, severe bank erosion was indentified along BC Hydro power corridors (Right Bank Segments 23, and 25). Accordingly, this information should be provided to BC Hydro for consideration of streambank restoration initiatives and for the protection of existing infrastructure.

This survey of the LSHU revealed that approximately 35 km (43%) of the left bank and about 47 km (60%) of the right of the river has been modified to some degree. Over much of its length, the Shuswap River only has a narrow band of native vegetation remaining along the river bank. Modifications instream and along the stream banks result in impacts to the watercourse, such as non-point-source pollution, sedimentation and associated degradation to water quality and fish habitat.

Based on the inventory results, there is a lack of deep water holding pools/thermal refuge areas downstream of Enderby to Mara Lake. This, in conjunction with more intensive landuse and recreational pursuits (namely boating), presents concerns for Fisheries staff relating to the potential stress on migrating adult salmon. In consideration of this it is important to better protect tributaries and groundwater discharge zones not only for the productive habitats but also for the thermal refuge these features provide. Considering this, more work should be done to investigate water quality and supply along the river and to identify thermal refuge areas.

Watercraft can impact the biophysical values of waterbodies through fuel and exhaust emissions, noise pollution, direct contact with flora and fauna, and hydrodynamic impacts such as wake-induced shoreline erosion and turbulent prop wash. In terms of the hydrodynamic impacts, recent studies have correlated boat waves to an increase in shoreline erosion and stirring of bottom Sediments (Hill et al. 2002). In other studies it was concluded that the wakes contributed a significant amount of bank erosion and sediment disturbance near the bank was markedly increased for wake heights exceeding 13-14 cm (Dorova and Moore 1997). With 81% of the docks recorded on the Lower Shuswap River occurring in Reaches 1 – 5 (Mara Lake to Enderby), it is plausible that more intensive watercraft use and operation is a factor in decreased bank stability and increased erosion. The hydraulic character of the lower reaches is a low gradient, low velocity, straight to sinuous glide, with generally low erosive forces. However when combined, the lack of riparian vegetation and boat wakes may be a key causal factor of observed erosion along the river bank in lower reaches. Other agencies and studies have noted that it is difficult to apply a universal rule for all boats because of their variable configuration and behaviour in the water. For instance, a single recommended speed limit may mitigate wave-related impacts from some vessels; while for others, such as sport boats with ballast tanks (to increase wake size), a reduced speed may actually increase the vessel`s draught – effectively increasing the wave height and subsequent impact to the shoreline. As such, the surest approach is to observe the wake produced by individual boats and establish No Wake Zones. Research the effects of boat wake on the LSHU and bank erosion. In developing attainable operational and management guidelines for boat use on the river a better understanding of key boating zones, and relative waves heights at the full range of speed and boat size is required.

About 38.5 km (53%) of the lower Shuswap River received a *Low* centerline AHI ranking. This ranking applied to the lower six (6) reaches beginning at the confluence with Mara Lake to upstream of Enderby. The *Low* ranking is a result of limited habitat complexity (i.e., being a slow glide), absence of salmonid spawning habitat, and being generally limited in instream cover. However, these lower reaches are still critical in their migratory status and the submerged aquatic macrophyte beds would support increased food web production benefiting both fish and waterfowl. Thus, regardless of having a low index score and ranking, restoring bank integrity and a functioning riparian band is equally important along these lower reaches.

The *Very High* and *High* river bank areas and those adjacent to *High* and *Very High* ranked reaches are considered the most important areas and mechanisms to protect these key habitat features need to be developed. This analysis highlights the importance of conserving important natural areas that remain and prioritizing habitat improvements where feasible. In review of development applications, the protection of critical and natural areas should be addressed. The data in this report should be utilized to identify shoreline areas that should be protected.

While the restoration analysis extracted 18 priority segments requiring more immediate attention, conservation of existing riparian conditions is paramount to prevent a reduction in Bank AHI scores for respective segments. The scores and corresponding rankings established in this analysis should form the baseline when reviewing current and proposed activities along the River. The review of existing or proposed activities should be measured against these baseline AHI scores using the metrics and relative habitat value scores for riparian band habitat units of the Bank

AHI (net change analysis). In doing so, such activities and the potential impacts and modifications they may cause can be evaluated in accordance with the Canadian Policy for the management of fish habitat; where No Net Loss is the guiding principle.

8.0 CLOSURE

This Document has been prepared for the exclusive use of the Department of Fisheries and Oceans, Regional District North Okanagan, and the City of Enderby. It has been prepared based upon information collected during the comprehensive field inventory and other related documentation.

Questions or comments in reference to this report, and the data presented should be forwarded to the undersigned.

Respectfully Submitted,
ECOSCAPE Environmental Consultants

Kyle Hawes, R.P.Bio.
Senior Aquatic Resources Biologist

Jason Schleppe, M.Sc., R.P.Bio.
Senior Fisheries Biologist

Brian Jantz, R.P.Bio.
Senior Fisheries Biologist

REFERENCES

Dorova, J. and G. Moore, 1997. Effects of boatwakes on streambank erosion, Kenai River, Alaska. Technical Report 97-4105, U.S. Geological Survey, Anchorage, Alaska, prepared in cooperation with the Alaska Department of Fish and Game.

Fedorenko, A.Y. and B.C. Pearce. 1982. Trapping and coded wire tagging of wild juvenile Chinook salmon in the South Thompson/Shuswap River system, 1976, 1979, and 1980. Can. MS. Rep. Fish. Aquat. Sci. 1677. 63pp.

Hill, D.F., M.M. Beachler, and P.A. Johnson. 2002. Hydrodynamic Impacts of Commercial Jet-Boating on the Chilkat River, Alaska. Department of Civil & Environmental Engineering, The Pennsylvania State University. 115pp.

Lloyd, D., K.Angove, G. Hope, and C. Thompson. 1990. A guide to site identification and interpretation for the Kamloops Forest Region. Land Management Handbook No. 23. February, 1990. BC Ministry of Forests.

Mackenzie, W.H., and Jennifer Moran. 2004. Wetlands of British Columbia - A guide to identification. British Columbia Ministry of Forests, Forests Science Program. 287pp.

Mason, B., and R. Knight. 2001. Sensitive Habitat Inventory and Mapping. Community Mapping Network, Vancouver, British Columbia. 315pp + viii. M. Johannes, Editor.

Resource Inventory Committee. 2001. Reconnaissance (1:20000) fish and fish habitat inventory: Standards and procedures. Version 2. 170pp.

Resource Inventory Committee. 2001. Standards for Fish and Fish Habitat Maps. Version 3.0. Province of British Columbia. 66pp.

Griffith, R. P. 1986. Rainbow trout production and Implications of Coho Salmon Enhancement in the Bessette Creek Drainage, Tributary to the Middle Shuswap River. Fisheries Improvement Unit. BC Fisheries Branch.

Groot, C. and L. Margolis (eds). 1991. Pacific Salmon Life Histories. University of British Columbia Press, Vancouver, B.C.

International Pacific Salmon Commission records. Department of Fisheries and Oceans, Vancouver, BC.

Jantz, B. Creel Survey and Life History Characteristics of Rainbow Trout and Kokanee in Mabel Lake. 1984.

Jantz, B. Memo to file: Kingfisher Creek Rainbow Trout Tagging Project 1984. Ministry of Lands, Parks and Housing. Okanagan Region. Penticton.

Jantz, B. Memo to file 40.3403 Shuswap River. Ministry of Lands, Parks and Housing 1986 and 1987. Okanagan Region. Penticton.

Jantz, B. Effects of Winter Flow Reductions on Kokanee Salmon Spawning Habitat in the Middle Shuswap River. 1992. Province of B.C. Ministry of Environment, Lands and Parks. Penticton, B.C.

Lorz, H. W., and T. G. Northcote. 1965. Factors affecting stream location, timing and intensity of entry by spawning kokanee (*Oncorhynchus nerka)* into an inlet of Nicola Lake, British Columbia. J. Fish. Res. Board Can. 22; 665-687.

McPhail, J.D. 2007. The Freshwater Fishes of British Columbia. University of Alberta Press.

Ministry of Forests, Lands and Natural Resource Operations Lake and River Files. Fish and Wildlife Branch, Penticton, B.C. 2011.

Ministry of Water, Land and Air Protection. 2003. 2000 Survey of Sport Fishing in British Columbia with summary information from the 1985, 1990 and 1995 surveys. Province of BC, Victoria, BC.

Minns, C. 1997. Quantifying “no net loss” of productivity of fish habitats. Can. J. Fish. Aquat. Sci. 54: 2463-2473 (1997).

Redfish Consulting. 2005. Final Survey Results of Select Lakes in the Kamloops Area Inhabited by Kokanee – Year 4. 2004.

Schleppe, J., 2010. Okanagan Lake Foreshore Inventory and Mapping. Ecoscape Environmental Consultants Ltd.. Project File: 10-596. 2011. Prepared for: Okanagan Collaborative Conservation Program

Slaney, P.A., and T.G. Northcote. 1974. Effects of prey abundance on density and territorial behavior of young rainbow trout *(Salmo gairdneri)* in laboratory stream channels. J. Fish. Res. Board Can. 31:1201-1209.

Webster, J. 2007. 2007 Kokanee Fry Out-migration, Mission Creek Spawning Channel - 2006 Brood Year.

MAP KEY

Map Series 1 - 2009 Inventory Mapping Deliverables

Set 1 – Landuse, Bank Erosion, Bank and Channel Modifications

Set 2 – Significant Habitat areas/features for Fish and Wildlife

Set 3 – Retrospective Analysis of Riparian Communities (1928-2007)

Map Series 2 - 2010/11 Aquatic Habitat Index

Set 4 – Riparian Habitat, Hydraulic, and Instream habitat feature classification

Set 5 – Lower Shuswap River Aquatic Habitat Index - River Channel and Bank Sensitivity Classes