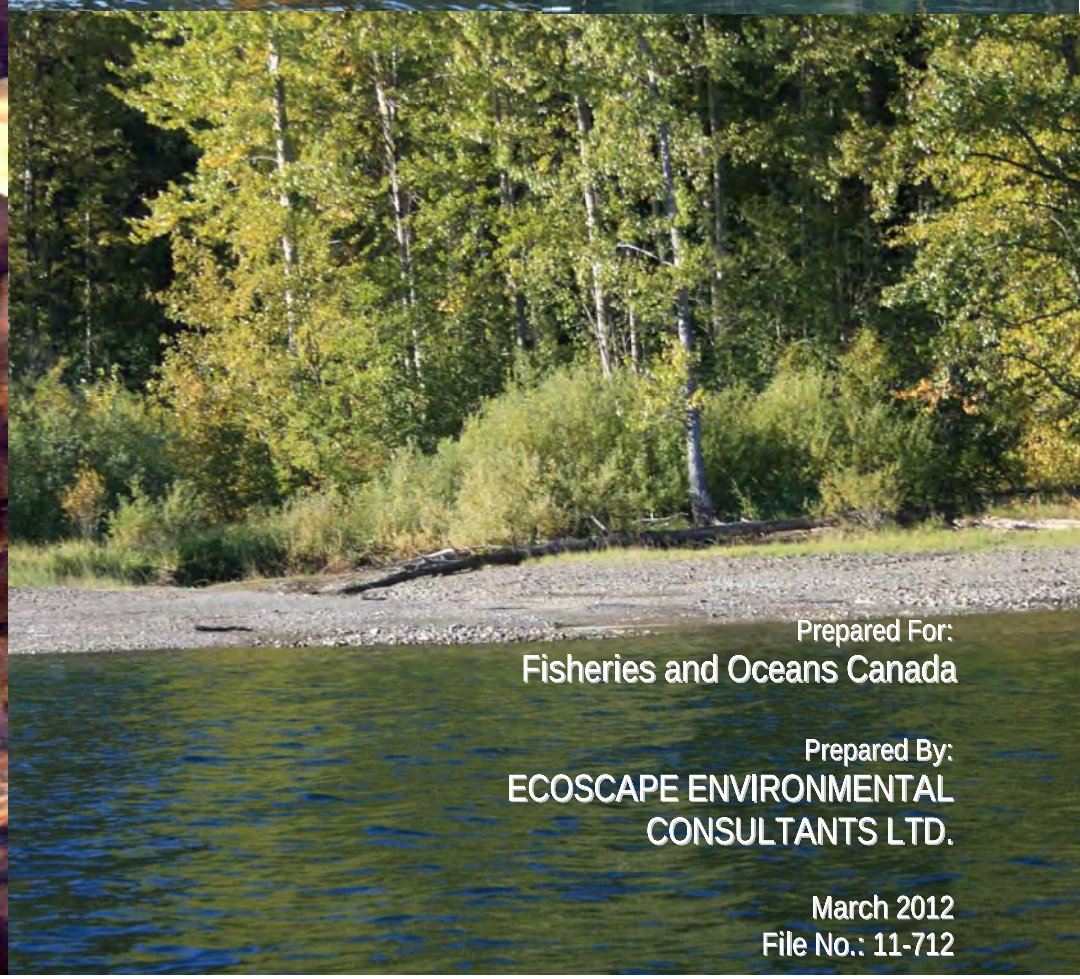
Foreshore Inventory and Mapping and Aquatic Habitat Index

West Arm of Quesnel Lake



Prepared For:
Fisheries and Oceans Canada

Prepared By:
ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.

March 2012
File No.: 11-712

FORESHORE INVENTORY AND MAPPING AND AQUATIC HABITAT INDEX

West Arm of Quesnel Lake

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EXECUTIVE SUMMARY

The West Arm of Quesnel Lake and the Quesnel River watershed as a whole supports a prolific sockeye salmon stock and rainbow trout fishery, as well as providing habitat for Interior Fraser coho, Chinook, kokanee, and bull trout, making these waterbodies a key area of interest for resource managers and public stakeholders (MoE, 2011a; Lawrence, 2004; Holmes, 2009; Sebastian et al, 2003). While residential development is not currently widespread along the foreshore of the West Arm of Quesnel Lake, landuses such as forestry, mining, agriculture and recreation are active in the watershed and an integrated resource management approach is necessary to ensure sustainable natural resource management.

Currently, lake management projects in the province of BC adhere to the following three-step process:

1. Foreshore Inventory and Mapping (FIM) – FIM is a broad scale inventory process that attempts to define and describe the shoreline of our large and small lake systems.

2. Aquatic Habitat Index or Ecological Sensitivity Index (AHI) – The AHI utilizes data collected during the FIM, field reviews, and other data sources (e.g., Land and Data Warehouse, previously published works, etc.) to develop and rank the sensitivity of the shoreline using an index.

3. Development of Shoreline Management Guidance Documents - Guidance documents are the final step in the process. By implementing this work, in conjunction with existing lake and watershed information, into a guidance document, it will facilitate informed decision making and prioritization of management issues and key areas of concern.

This report presents Step 1 and Step 2 for the West Arm of Quesnel Lake.

Foreshore Inventory and Mapping results (FIM) for this project provides valuable information regarding features, habitats, and other information for the shoreline of the West Arm of Quesnel Lake. A summary of the data collected indicates the following:

- The total length of disturbed shoreline was 9.2 km, while the remaining 61 km, or 87%, were described as being natural.

- Natural area was the primary landuse, representing 72% of the shore length. Rural land use was the next most common, accounting for nearly 17% of the shore length. Approximately 81% of the rural land parcels remain in a relatively natural state. However, these large, privately-owned parcels represent areas of potential future build-out, as development pressures increase, including subdivision and subsequent anthropogenic impacts.

- The most predominant shore type observed around the West Arm of Quesnel Lake was gravel beach, which accounted for 49% or 34 km.

- There is approximately 25 km of shoreline that has aquatic vegetation, which represents approximately 36% of the total shoreline length. Most of the vegetation observed was emergent, including grasses and herbaceous vegetation below the high water level, which occurred along 33% of the shoreline or 23 km.

- Docks were the most commonly observed type of shoreline modification, occurring within both rural and single family residential areas. There were a total of 129 docks counted during the assessment, which equates to 1.8 docks per km.

- Approximately 54 km, or 77%, of the shoreline was described as having less than 10% impact. Approximately 11% (7.6 km) of the West Arm of Quesnel Lake exhibited high levels of impact where greater than 40% of the shoreline was impacted.

- High juvenile rearing value occurs along 14 km, with disturbance noted along 2% or 322 m.

The Aquatic Habitat Index (AHI) for the West Arm of Quesnel Lake provides valuable information regarding the estimated habitat values of different shoreline areas. The AHI is a categorical scale of relative habitat value that ranks shoreline segments from Very High to Very Low (Very High, High, Moderate, Low, and Very Low). The following summarizes the results of the AHI analysis:

- Approximately 51% of the shoreline is ranked as Very High and High. Around 48% of the shoreline length is moderate, and the remaining 2% is ranked Low and Very Low.

- The analysis indicated that very high value shorelines occurred primarily adjacent to stream mouths and gravel shores, with a reduced representation of very high value habitat occurring along rocky, cliff/bluff and sand shores. The West Arm of Quesnel Lake exhibited limited very low AHI ratings.

- Within areas ranked as Very High, the shoreline was 96% natural. In High value areas, the shoreline was 95% natural and within Moderate value areas the shoreline was 80% natural. Areas of Low Value were around 48% natural, while areas with Very Low value had 5% of the shoreline remaining natural.

The inventories and analysis completed as part of this study should help effectively manage and protect important aquatic resources along the West Arm of Quesnel Lake. The entire shoreline of the West Arm of Quesnel Lake was not inventoried due to financial and staff constraints, although completion of the remainder is intended as a priority. The West Arm of Quesnel Lake has areas of importance for salmonid habitat which have experienced anthropogenic impacts, particularly near the Quesnel River confluence. However, 87% of the shoreline remains in a relatively natural condition and 51% of the shore length surveyed received an AHI ranking of high or very high value. Information collected with the FIM and AHI steps should be integrated with existing initiatives, such as watershed-based fish-sustainability planning. Recommendations have been presented that are intended to aid foreshore protection, guide future data management, and for future biophysical inventory works.

ACKNOWLEDGEMENTS

The following parties carried out fieldwork for this assessment:

Don Lawrence, Senior Habitat Biologist, Fisheries and Oceans Canada
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Brad Mason, Inventory Biologist, Fisheries and Oceans Canada

GPS Video
Brad Mason, Inventory Biologist, Fisheries and Oceans Canada

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Fisheries and Oceans Canada
Ministry of Natural Resource Operations (formerly Ministry of Environment)
Cariboo Regional District
Community Mapping Network

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

The results contained in this report are based upon data collected during surveys occurring over a one week period. Biological systems respond differently both in space and time and exhibit extreme variability. For this reason, conservative assumptions have been used and these assumptions are based upon field results, previously published material on the subject, and air photo interpretation. Due to the inherent problems of brief inventories (e.g., property access, GPS/GIS accuracies, air-photo interpretation concerns, etc.), professionals should complete their own detailed assessments of shore zone areas to understand, evaluate, classify, and reach their own conclusions regarding them. Data in this assessment was not analyzed statistically and no inferences about statistical significance should be made if the word significant is used. Use of or reliance upon conclusions made in this report is the responsibility of the party using the information. Neither Ecoscape Environmental Consultants Ltd., Fisheries and Oceans Canada, Cariboo Regional District, project partners, nor the authors of this report, are liable for accidental mistakes, omissions, or errors made in preparation of this report as best attempts were made to verify the accuracy and completeness of data collected and presented.

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1.0 INTRODUCTION

The West Arm of Quesnel Lake and the Quesnel River watershed as a whole supports a prolific sockeye salmon stock and rainbow trout fishery, as well as providing habitat for Interior Fraser coho, Chinook, kokanee, and bull trout, making these waterbodies a key area of interest for resource managers and public stakeholders (MoE, 2011a; Lawrence, 2004; Holmes, 2009; Sebastian et al, 2003). While residential development is not currently widespread along the foreshore of the West Arm of Quesnel Lake, landuses such as forestry, mining, agriculture and recreation are active in the watershed and an integrated resource management approach is necessary to ensure sustainable natural resource management.

It is a complex relationship between development pressure, the natural environment, and social, economic and cultural values. To balance these various community values, a solid understanding of aquatic and riparian resource values, land use interests, and concerns of local residents is needed to develop long-term planning and policy objectives. Development of long term planning objectives at the local, provincial and federal levels is also required so that our aquatic resources are effectively managed. Detailed shoreline inventories increase the knowledge base regarding the environmental resources present, allowing all stakeholders to understand how development may affect these habitat features and their current level of impairment. With this information, more informed land use planning decisions can be made, with effort to balance land use management with natural resource values.

Managers at all levels of government and the general public recognize the importance of managing our watersheds in a sustainable manner. Current management practices being implemented throughout British Columbia are utilizing a three step process to help integrate environmental data with land use planning information to provide a baseline of waterbody condition, and facilitate review and decision making processes. For this project, steps 1 and 2 below were completed. The three step process involves the following steps:

1. Foreshore Inventory and Mapping (FIM) – FIM is a broad scale inventory process that attempts to define and describe the shoreline of our large and small lake systems. The inventory provides baseline information regarding the current condition, natural features of the shoreline, and its level of development (e.g., number of docks, groynes, etc.). Sufficient data is collected that will allow managers and the public to monitor shoreline changes over time and to measure whether proposed land use decisions are meeting their intended objectives. This baseline inventory provides sufficient information to facilitate identification of sensitive shoreline segments as part of step 2 below.

2. Aquatic Habitat Index or Ecological Sensitivity Index (AHI) – The AHI utilizes data collected during the FIM, field reviews, and other data sources (e.g., Land and Data Warehouse, previously published works, etc.) to develop and rank the sensitivity of the shoreline using an index. An index is defined

as a numerical or categorical scale used to compare variables with one another or with some reference point. In this case, the index is used to compare the sensitivity of the different shoreline areas around the lake to other shoreline areas within the lake (i.e., the index compares the ecological or aquatic sensitivity of different shoreline areas within the lake system to each other rather than to other lake shorelines). The index provides an indication of the relative value of one shoreline area to another.

3. Development of Shoreline Management Guidance Documents - Guidance documents are the final step in the process. Guidance documents are intended to help land managers at all levels of government quickly assess applications and is intended to be the first step for review, planning, and prescribing shoreline alterations (i.e., land development) by applicants and review agencies. By implementing this work, in conjunction with existing lake and watershed information, into a guidance document, it will facilitate informed decision making and prioritization of management issues and key areas of concern.

This report presents Step 1 and Step 2 for the West Arm of Quesnel Lake.

2.0 PROJECT OVERVIEW

The FIM and AHI project for the West Arm of Quesnel Lake provides an opportunity for the project partners to support an initiative that will act as a tool for future policy development and allow for improved management of these resources. The information generated from this project and future steps, including the development of shoreline management guidelines, should help to facilitate policy development and informed review of land use applications. The intent of this project is to provide a baseline overview of the shoreline condition of the West Arm of Quesnel Lake. The methodology employed for this assessment is discussed in detail below and is a provincial standard that is being used to map shorelines around the province. The mapping protocol will allow stakeholders to understand what the current condition of the shoreline is, to set objectives for improved shore management in Official Community Plans or other policy documents, and measure and monitor changes in the shoreline over time.

Due to financial and staffing constraints, the entire shoreline of the West Arm of Quesnel Lake was not inventoried. However, completion of the remaining length of shoreline is a priority and the intent is to initiate this next phase as soon as possible. Completion of FIM and AHI on the entire Quesnel Lake shoreline is also planned for the future.

2.1 Project Partners

Numerous different parties have contributed to the success of this project. Foreshore Inventory and Mapping (FIM) protocols have been developed over the last several years and have become a standardized approach to shoreline inventory. Numerous different local governments, non-profit organizations, biological professionals, and provincial and federal agencies have contributed to the development of the FIM protocol and Appendix A (Detailed methods) provides a more accurate list of contributing parties.

This specific project was funded by the following agencies and organizations:

1. Fisheries and Oceans Canada
2. Cariboo Regional District
3. Ministry of Natural Resource Operations (formerly Ministry of Environment)
4. Community Mapping Network

2.2 Objectives

The following are the objectives of this project:

1. Compile existing map base resource information for the West Arm of Quesnel Lake;

2. Foster collaboration between the local government, Fisheries and Oceans, Ministry of Natural Resource Operations, First Nations, and the local communities;

3. Provide an overview of foreshore habitat condition on the lake;

4. Inventory foreshore morphology, land use, riparian condition and anthropogenic alterations;

5. Obtain spatially accurate digital video of the shoreline of the lake;

6. Prepare the video and GIS geo-database for loading onto the Community Mapping Network at www.cmnbc.ca.

7. Collect information that will aid in prioritizing critical areas for conservation and or protection, and lakeshore development;

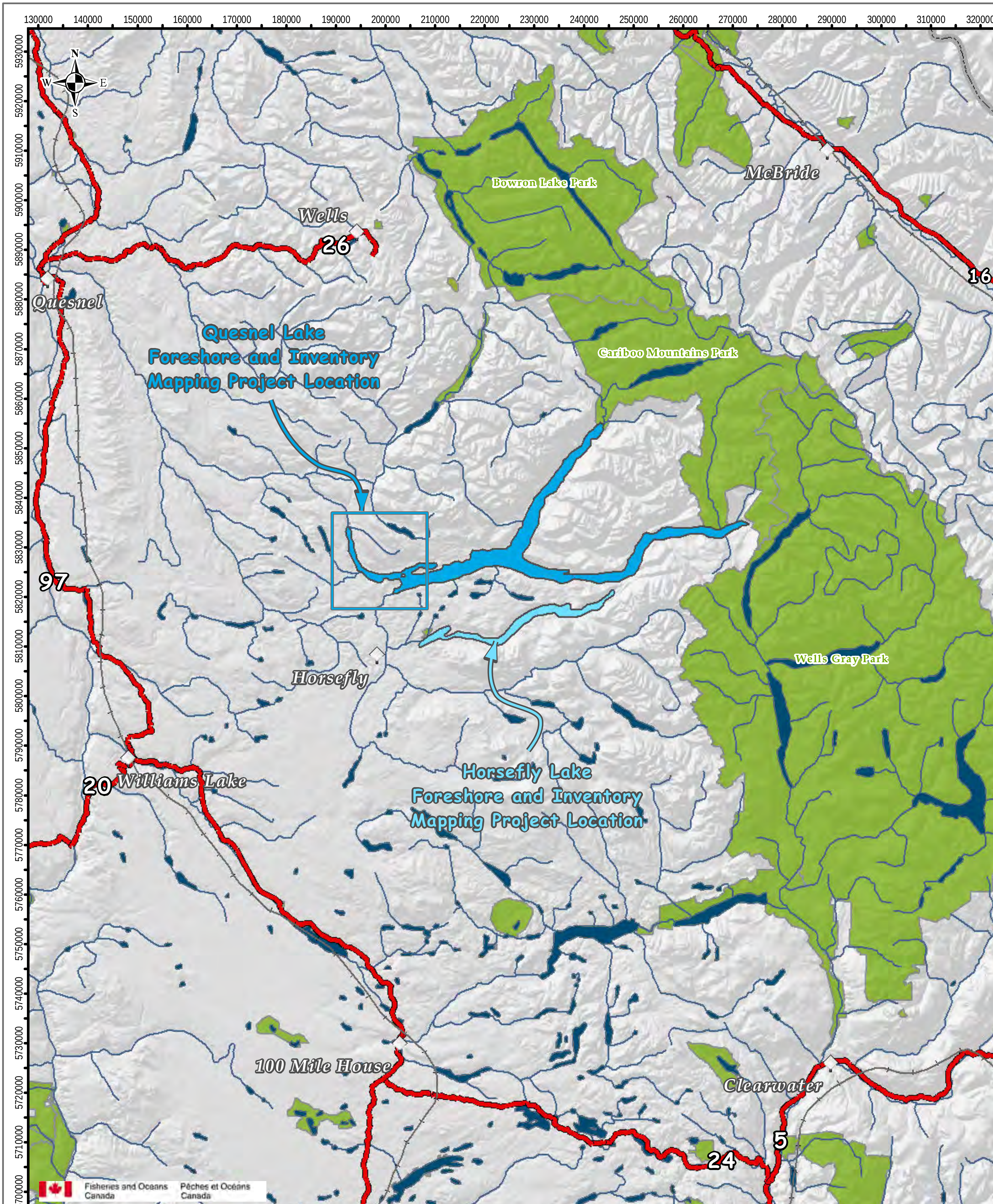
8. Make the information available to planners, politicians and other key referral agencies that review applications for land development approval; and,

9. Integrate information with upland development planning, to ensure protection of sensitive foreshore areas, connectivity with sensitive terrestrial ecosystems and watershed based land use planning.

The FIM and AHI completed as part of this assessment will begin to address many of these objectives. Completion of Step 3, Shoreline Management Guidelines, is required to address the more detailed planning aspects to meet long term objectives.

2.3 Study Location

The general location of the study area is found in Figure 1.



Quesnel Lake and Horsefly Lake

Foreshore Inventory and Mapping

Figure 1 - Project Location

2.4 Important Fisheries and Wildlife Resource Information

The West Arm of Quesnel Lake provides an important migration corridor for salmonid species, including sockeye (*Oncorhynchus nerka*), chinook *(Oncorhynchus tshawytscha)*, Interior Fraser coho (*Oncorhynchus kisutch)*, kokanee (*Oncorhynchus nerka*), bull trout (*Salvelinus confluentus*) and rainbow trout (*Oncorhynchus mykiss*), in addition to providing staging, rearing and spawning value (Morton and Williams, 1990; DFO, 2001; Sebastian et al, 2003; Lawrence, 2004; Holmes, 2009). Anadromous species migrate approximately 80 km along the Quesnel River between the West Arm of Quesnel Lake and the Fraser River, with the confluence of the two rivers located within the community of Quesnel, British Columbia (Morton and Williams, 1990; Holmes, 2009). The major tributary occurring along the shoreline of the West Arm of Quesnel Lake is the Horsefly River (Watershed Code: 160-635400), which is one of the most prominent salmonid producers within the Fraser River Basin (Lawrence, 2004; Holmes, 2009). To a lesser magnitude, Hazeltine Creek (Watershed Code: 160-585700), Cedar Creek (Watershed Code: 160-544100), Winkley Creek (Watershed Code: 160-620700) and Poquette Creek (160-525700) provide salmonid spawning habitat, and have various fish assemblages (MoE, 2011a; DFO, 2001; Holmes and Holmes, 2008/2009). Several un-named tributaries occurring along the shoreline also provide fish and wildlife habitat value. Shore spawning kokanee and sockeye occur in Quesnel Lake along the North and East Arms (DFO, 2001; Sebastian et al, 2003), although locations along the West Arm of Quesnel Lake were not spatially identified during the 2009 FIM field inventory.

Sockeye returns are estimated to have increased by 32 times since the early 1950s, and the Quesnel Lake sockeye are a major contributor to the Fraser River sockeye catch (Sebastian et al, 2003; Holmes, 2009). While sockeye numbers have increased, stream spawning kokanee numbers have declined concurrently (Sebastian et al, 2003). Juvenile sockeye have been documented to disperse along well-defined migration routes within 5 m of the shore up to 25 km from the Horsefly River/Quesnel Lake confluence along the east and south shorelines of the West Arm of Quesnel Lake before moving offshore (Morton and Williams, 1990). Outmigration timing is consistent with stream spawning kokanee and intraspecific competition for food between juvenile kokanee and sockeye has been cited as a potential reason for the decline in stream spawning kokanee within the Quesnel Lake system (Sebastian et al, 2003; Holmes, 2009). Kokanee are the primary food source for the large, piscivorous rainbow trout occurring within Quesnel Lake, which grow to 7-10 kg, reaching maturity at age 6 or 7 (Sebastian et al, 2003; Lawrence, 2004; Holmes, 2009). Fishing (prior to increased fishing restrictions) and reduction in kokanee numbers are potential factors in reduced size and growth rates that have been observed of the Quesnel Lake rainbow trout (Sebastian et al, 2003).

Interior Fraser coho occur in several tributaries within the Quesnel Lake watershed (Holmes and Holmes, 2008 and 2009; Holmes, 2009). The Interior Fraser coho are genetically distinct from coho within the lower Fraser River and, as of 2002, were designated as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2002). They are considered to be at serious risk of extinction, due to population declines in excess of 60% of individuals attributed to modifications to freshwater and marine habitats and overexploitation (COSEWIC, 2002; Holmes and Holmes, 2009).

Chinook salmon are also present within the West Arm of Quesnel Lake, although numbers in the Horsefly River between 1991 and 2008 indicated a decline (Holmes, 2009).

The expanse of undeveloped terrain surrounding the West Arm of Quesnel Lake also provides habitat for a diversity of wildlife species, including the Provincially Blue-listed (special concern, formerly vulnerable) grizzly bear (*Ursus arctos*) (BC CDC, 2011). Maintaining connectivity and movement corridors along riparian areas, particularly those with salmon spawning populations, is a key management consideration for this species (Lawrence, 2004). Being cognizant of avoiding bear-human conflict in developed areas of the shoreline is also important, including management of attractants and reducing human access during peak salmon spawning and subsequent bear feeding activity. The southern mountain population of the Red-listed (extirpated, endangered or threatened) Mountain caribou (*Rangifer tarandus*) occurs to the north of the West Arm of Quesnel Lake in higher elevations (BC CDC, 2011). While not a wildlife species, the Blue-listed tender sedge (*Carex tenera*) has been documented to occur within the wetland community associated with the confluence of the Horsefly River and the West Arm of Quesnel Lake (BC CDC, 2011).

The above information only briefly touches on the fish and wildlife habitat values of the West Arm of Quesnel Lake. Fish, wildlife, recreation and water quality considerations make it essential to identify, manage and protect the shoreline area. The data collected during this assessment provides a baseline upon which goals and objectives can be created and monitored, in order to effectively manage this valuable resource.

2.5 Foreshore Management Overview

The importance of fisheries and wildlife resources along The West Arm of Quesnel Lake and the sensitive ecosystems associated with the lake and foreshore, provide a clear rationale for completion of a detailed shoreline inventory and mapping project. A three step process is currently being used as a shoreline management template in the province. This three step process has been previously described in other sections of this document, but generally involves the following three components: inventory using the FIM, an analysis of relative habitat value using an AHI, and development of shoreline management guidelines.

3.0 FORESHORE INVENTORY & MAPPING METHODOLOGY

The FIM detailed methodology is found in Appendix A. This inventory is based upon mapping standards developed for Sensitive Habitat Inventory and Mapping (SHIM) (Mason and Knight, 2001) and Coastal Shoreline Inventory and Mapping (CSIM) (Mason and Booth, 2004). The development of mapping initiatives such as SHIM, FIM, and CSIM is an integral part of ecologically sensitive community planning. The following sections summarize specific information for the West Arm of Quesnel Lake FIM.

3.1 Field Surveys

Field surveys for this project occurred on October 6 and October 7, 2009. A three to four person crew completed the field inventory. Field surveyors were each assigned data to collect during the surveys. Field assessors used 2 ft by 3 ft, scaled colour air photos with cadastre and topographic information to assist with field data collection. Two TRIMBLE GPS units with SHIM Lake v. 2.6 (FIM Data dictionary name) were carried and a hurricane antennae was also used. Digital photographs and GPS digital video were collected. The specifics of the GPS digital video are discussed in the FIM methodology.

The principle objectives of these video and photographic surveys were to:

- Provide a photographic documentation of the entire shoreline
- Record data relating to the presence or absence of development such as retaining walls and boat launches

Weather during the surveys varied from clear to overcast with light rain, and no significant storm events were noted. Weather is an important consideration, particularly during the photo and video documentation portions of the assessment. Good photo documentation is vital because data analysis following data collection can be hindered by poor photography.

A subsequent field survey was completed May 11 and 12, 2011 for collection of additional GPS referenced representative segment photos, and field truthing of substrates and field estimated current and potential AHI ratings. The subsequent field survey of substrate data was necessary, as all substrate information initially incorporated into the draft FIM and AHI was an estimate based on interpretation from air photos and digital representative segment photos during post-processing. Accurate representation of substrates is an important factor in the AHI, and the FIM and AHI was subsequently updated as necessary in 2012.

3.2 Methodology

All of the methods outlined in Appendix A for Foreshore Inventory and Mapping projects were generally adhered to for this assessment. Data collected by the field crews was provided to Ecoscape for post-processing, data analysis and reporting. Ecoscape has attempted to ensure the data is as accurate as possible. However, due to the large size of the dataset, small errors may be encountered. These errors, if found, should be identified and actions initiated to resolve the error.

The following additional information was collected during field surveys:

1. The spatial extent of emergent grasses on flood benches, and areas of submergent and floating vegetation were mapped and photographed, to determine the approximate area where aquatic vegetation occurs. Aquatic vegetation includes any plants growing below the high water level of the lake because these areas are important fish habitat. Also, areas of extensive overhanging vegetation (from the high water level) were also mapped. It should be noted that on larger littoral areas, vegetation mapping may not have captured all occurrences.

2. Small stream confluences, seepage areas, and other features were also recorded.

3.2.1 Aquatic Vegetation Mapping and Classification

Aquatic vegetation mapping was carried out for the entire shoreline, with focus on foreshore areas. For the purposes of this assessment, aquatic vegetation includes any plant life occurring below the high water level of the lake (including flood benches). Although some of the plants are not truly aquatic, all are hydrophilic (water loving) and contribute to fish habitat. Vegetation mapping was completed by digitizing vegetation polygons from field observations recorded on air photos. Aquatic Vegetation polygons are similar to Zones of Sensitivity identified by the Okanagan and Windermere projects. Vegetation communities were classified using the Wetlands of British Columbia – A guide to identification (Mackenzie and Moran, 2004) and were categorized as:

Marsh (Wm)
A marsh is a shallowly flooded mineral wetland dominated by emergent grass-like vegetation. A fluctuating water table is typical in marshes, with early-season high water tables dropping throughout the growing season. Exposure of the substrates in late season or during dry years is common. The substrate is usually mineral, but may have a well-decomposed organic veneer derived primarily from marsh emergent. Nutrient availability is high (eutrophic to hyper-eutrophic) due to circum-neutral pH, water movement, and aeration of the substrate.

Low Bench Flood Ecosystems (Fl)
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 understory and humus development.

Mid Bench Flood Ecosystems (Fm)
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 and red alder.

Swamp
A swamp is a forested, treed, or tall-shrub, mineral wetland dominated by trees and broadleaf shrubs on sites with a flowing or fluctuating, semi-permanent, near-surface water table. Swamps occur on slope breaks, peatland margins, inactive floodplain back-channels,

back-levee depressions, lake margins, and gullies. Tall-shrub swamps are dense thickets, while forested swamps have large trees occurring on elevated microsites and lower cover of tall deciduous shrubs.

Aquatic Vegetation

Sites not described by the current nomenclature developed by Mackenzie and Moran (2004) were stratified into the following biophysical groups:

1. Emergent Vegetation (EV) generally refers to grasses, *Equisetum* spp. (i.e., horsetails), sedges, or other plants tolerant of flooding. Coverages within polygons needed to be consistent and well established to be classified as EV. These areas were generally not dominated by true aquatic macrophytes and tended to occur in steeper sloping areas.

2. Sparse Emergent Vegetation (SEV) refers to the same vegetation types as emergent vegetation, but in these areas coverage was generally not very dense or was very patchy. This vegetation was often patchy, due to the association with rocky beaches or due to intensive beach grooming.

3. Overhanging Vegetation (OV) consists typically of broadleaf vegetation that is growing over the lake, shading the near shore littoral zone. Overhanging vegetation was mapped where it was observed. Overhanging vegetation also occurred with Emergent Vegetation (EVOV) and with Sparse Emergent Vegetation (SVOV).

4. Submergent Vegetation (SUB) areas generally consisted of native *Potamogeton* spp. and is considered aquatic vegetation that does not break the water surface for most of the growing season. These areas were uncommon and only occurred in a few shallow bay areas.

5. Floating Vegetation (FLO) areas generally consisted of species such as native *Potamogeton sp.*, pond lilies, and other types of vegetation that has vegetative parts that float.

3.2.2 GIS and FIM Database Management

Data management for this project followed methods provided in Appendix A and generally involved the following steps:

- Data and photos were backed up to a computer/laptop on a daily basis.
- A digital camera and GPS video were used to facilitate data review and interpretation.
- Air photo interpretation was completed using high resolution air photos that were acquired during flights in the summer of 2009.
- During data analysis, numerous checks were completed to ensure that all data was analyzed and accounted for.

- A spatial elevation model was run using GIS software, in combination with air photo interpretation and TRIM shoreline files to accurately determine the high water level of the lake. It is believed that for the length of the shoreline, the high water level used is within 5 m of the mean annual high water level for at least 50% of the lake. A site specific survey must be conducted to accurately determine the high water level for any site specific considerations and the line presented in this assessment should not be considered a surveyed HWL.

The following data fields were added to the FIM data dictionary

1. An Electoral Area field was added to define the electoral area within a Regional District that shoreline segments were part of.

2. A Community Field was added to the database, but has not been utilized.

3. Several fisheries fields were added. These fisheries fields are similar to the Zones of Sensitivity that were developed for the Okanagan and Windermere projects. The following describes fisheries fields added to the database:

   a. Juvenile Rearing shoreline habitat value (High, Moderate, and Low) was prepared by Ecoscape for this project. Since shoreline utilization data is unavailable, the juvenile rearing was based upon known rearing habitat requirements (e.g., proximity to spawning streams, littoral area, field observations, etc.). Please refer to the methodology section for the Aquatic Habitat Index to find out how juvenile rearing categories were developed for this project.

   b. Migration – Probable juvenile and adult fish migration routes (Yes or No) are important migration corridors used by resident fish at some point in their life cycle. These routes were prepared for this project and are based upon areas where fish will concentrate during significant spawning or out migrations from streams. To develop these migration areas, key habitat characteristics were used and included adjacency to spawning rivers, outmigration considerations, and review of fish life history characteristics. The limited data available for migration corridors on this lake has resulted in some assumptions regarding these corridors and further research is recommended to better understand the spatial extents of key migration corridors.

   c. Salmon Spawning Stream - A Yes / No flag for this field was added. This field was added for the Juvenile Rearing Habitat value assessment and describes the shoreline segments where known salmon spawning streams occur. The spatial extent of these criteria is very similar to the Staging field.

   d. Staging – A Yes / No field to describe salmon staging areas was added. Staging areas are areas where fish will concentrate or congregate prior to migrations. Staging areas were identified based on review of orthophotos and the shoreline's spatial extents, as well as existing available fisheries data such as the Provincial Habitat Wizard, fisheries information data queries (BC MOE, 2011a) and Fisheries Information Summary System database (BC MOE, 2011b) and existing stream assessment reports. This information was used to determine salmonid spawning streams. Overlap occurs between migration and staging areas and generally occurs near the confluence of the lake and its tributaries. The information presented is limited to the confluences of known salmon spawning streams, where fish are known to congregate before migrations. It may not entirely reflect all locations or spatial extents of staging areas. Future surveys should be used to better understand where mature adults hold during migrations.

4. Aquatic Habitat Index results field was (AHI_CUR) added. This field reflects the results of the AHI discussed below.

5. An Aquatic Restoration potential analysis (AHI_POT) was also completed by removing instream features from the AHI results. This analysis provides a summary of potential locations where habitat improvements are possible along the shoreline. This analysis *does not consider improvements to riparian vegetation*.

4.0 AQUATIC HABITAT INDEX METHODOLOGY

The AHI is a tool that is used to help assess the relative habitat value of a shoreline relative to other areas within the lake. An index is a numerical or categorical scale used to compare variables with one another. Use of an index to assess shoreline sensitivity has been utilized on Okanagan, Shuswap and Mabel Lakes and Windermere Lake (McPherson and Hlushak, 2008). Indices are also currently in preparation for numerous lakes in the Kootenays. The purpose of the AHI is to facilitate land use planning around shorelines by identifying the relative value of shoreline areas within a lake system. The relative habitat value of an area can then be used to infer the environmental sensitivity of the shoreline (i.e., areas of higher relative value have greater environmental sensitivity).

The AHI utilizes a number of parameters collected during the FIM. The index uses a points based mathematical index to assign the relative habitat value to each different parameter. Thus, features of more estimated significance are assigned higher relative values. Features that have impaired the habitat value (e.g., groynes) are assigned negative scores to better reflect the current condition of the shoreline.

A subsequent analysis was conducted to determine the habitat potential of a segment. This analysis involved removing ALL negative habitat parameters to determine if shoreline restoration could achieve a measurable benefit. This Habitat Potential index can be used to help assess where restorative efforts should be directed. The habitat potential analysis did *not include effects of riparian restoration* due to the extent of database and predictive mapping that would be required to facilitate such an analysis. More detailed habitat restoration analyses are required.

The index generated has only utilized information that is currently available or that can be safely inferred based upon previous works. In many instances, data gaps have been identified and assumptions have been made. As more information is collected regarding shoreline areas of the West Arm of Quesnel Lake, the Aquatic Habitat Index may need to be updated.

4.1 Parameters

The parameters of the index each reflect a certain type of habitat found along the shoreline. The parameters were broken down into three categories as follows:

1. Biophysical;
2. Fisheries;
3. Shoreline Vegetation; and,
4. Modifications;

The following table identifies the parameters and logic used in the index.

Table 1: The parameters and logic for the Aquatic Habitat Index of the West Arm of Quesnel Lake

Category	Criteria	Maximum Point	Percent of the Category[1]	Percent of the Total[1]	Logic	Uses Weighted FIM Data	Value Categories
Biophysical	Shore Type	15	31.3	16.5	% of Segment * Maximum Point	Yes	Stream Mouth = Wetland (15) > Gravel Beach = Rocky Shore (12) > Sand Beach (8) = Cliff /Bluff (8), Other (5)
	Substrate	12	25.0	13.2	% Substrate * Maximum Point	Yes	Cobble (12) > Gravel (10) > Boulder = Organic = Mud = Marl (8) = Fines (8), Sands (4) > Bedrock (2)
	Percentage Natural	5	10.4	5.5	% Natural * Maximum Point	Yes	
	Aquatic Vegetation	8	16.7	8.8	% Aquatic Vegetation * Maximum Point	Yes	
	Overhanging Vegetation	4	8.3	4.4	% Overhanging Vegetation * Maximum Point	Yes	
	Large Woody Debris	4	8.3	4.4	Large Woody Debris Category Score	Yes	**Relative Value** >25 LWD +4, 5-25 LWD=3, <5 LWD=2, 0 LWD=0
	Juvenile Rearing	10	50.0	11.0	High (10), Moderate (6), Low (2)	No	High (10), Moderate (6), Low (2)
	Migration Corridor	2	10.0	2.2	Present (2), Absent (0)	No	Present (2), Absent (0)
	Staging Area	8	40.0	8.8	Present (8), Absent (0)	No	Present (5), Absent (0)
Shoreline Vegetation[2]	Band 1	8	66.7	8.8	Vegetation Bandwidth Category * Vegetation Quality * Maximum Point	Yes	**Vegetation Bandwidth Category** 0 to 5 m (0.2) < 5 to 10 m (0.4) < 10 to 15 m (0.6) < 15 to 20 m (0.8) < 20 m (1)
	Band 2	4	33.3	4.4	Vegetation Bandwidth Category * Vegetation Quality * Maximum Point	Yes	**Vegetation Quality Category** Natural Wetland = Disturbed Wetland = Broadleaf = Shrubs (1) > Coniferous Forest = Mixed Forest (0.8) > Herbs/Grasses = Unvegetated (0.6) > Lawn = Landscaped = Row Crops (0.3) > Exposed Soil (0.05)
Modifications	Retaining Wall	-0.75	7.0	-0.8	% Retaining Wall * (-5)	Yes	% Retaining Wall * (-5)
	Docks	-2.10	19.7	-2.3	# Docks/km * (-0.1)	Yes	# Docks per Kilometer * (-0.1)
	Groynes	-3.79	35.6	-4.2	# Groynes/km * (-0.25)	Yes	# Groynes per Kilometer * (-0.25)
	Boat Launch	-2.00	18.8	-2.2	# Launches * (-0.25)	No	# Launches * (-0.25)
	Marina	-2.00	18.8	-2.2	# Marina * (-1)	No	# Marina * (-1)

1. Numbers have been rounded to 1 decimal place. All calculations were completed without rounding.

2. The Shoreline vegetation category has been calculated to include an estimate of quantity (i.e., bandwidth) and quality (i.e., relative value). In cases where two bands are present, there is a higher diversity which is more productive, resulting in a higher score.

The parameters selected for the index were similar to the other indices developed. A description of each is found below.

4.1.1 Biophysical Parameters

The following summarizes the biophysical parameters of the index:

1. Shoretype – A shoreline type is related to many aspects of productivity. Previous habitat indices (e.g., Schleppe and Arsenault, 2006) have used a habitat specificity table to determine the value of a shoreline. This similar approach was used for Windermere Lake (McPherson and Hlushak, 2008). However, in these previous versions, wetlands were difficult to account for utilizing the fish habitat specificity approach originally developed for Okanagan Lake (Schleppe and Arsenault, 2007). Wetlands are considered to be highly valuable shoreline areas for several reasons, including their contributions to biodiversity, biomass, and water quality. Other aspects of the fish habitat specificity approach developed for Okanagan and Windermere Lakes are appropriate and have been utilized in this assessment. Wetlands have been defaulted to the highest value possible shore value (i.e., equivalent to a stream confluence) because of their rarity, their contributions to habitat diversity, and their contributions to biomass and water quality.

2. Substrate – Substrates also relate directly to productivity. There are generally two types of productive substrates, those utilized for spawning and those that produce more biomass. The substrate values and parameters used were consistent with other lakes, including Okanagan, Shuswap and Mabel. Cobble received the highest value, followed by gravel, and areas of bedrock were considered least valuable

3. Percent Natural –Areas of natural shoreline have a relative habitat value that is greater than disturbed shoreline areas where riparian and foreshore modifications have occurred. The value of this parameter in the index is consistent with Shuswap and Mabel Lakes.

4. Aquatic Vegetation – The benefits of aquatic vegetation are many and include forage, biomass production, cover, etc. For the purposes of the AHI, all vegetation below the high water level is considered to be productive. The aquatic vegetation category included submergent, floating and emergent vegetation types. In addition to completion of the database in terms of percent along the shoreline, the field crew identified where aquatic vegetation polygons occurred on the field maps. These areas were subsequently digitized and incorporated into the FIM/AHI mapping deliverables.

5. Overhanging Vegetation – Overhanging vegetation provides nutrients, forage opportunities, shade and cover. Therefore, as in other recent FIM/AHI projects, it has been included in the index.

6. Large Woody Debris (LWD) – LWD provides cover, nutrients and foraging opportunities, and was included in the index. Numerous studies have identified the importance of LWD to salmonids in lake and stream systems. LWD was present along most segments of The West Arm of Quesnel Lake, and in many cases, over 100 and as many as 1000 were documented within an individual segment. The field data dictionary did not allow for numbers greater than 100 to be entered into the system; therefore, density of LWD/km would not be an accurate representation where the actual count was not included in the database. For the AHI, the LWD scoring category was changed from a density of pieces per km to the general category (ie. 0-5, 5-25, >25).

4.1.2 Fisheries Parameters

The fisheries parameters used for the AHI were based upon those described above in Section 3.2.2 – GIS and Data Management. These different parameters are considered important for fish production and were prioritized in the AHI accordingly. The following were the fisheries parameters added to the AHI:

1. Juvenile Rearing shoreline habitat value (High, Moderate, and Low) was prepared for this assessment. Juvenile rearing values were prepared using an index similar to the AHI. The index prepared was based upon original surveys of Shuswap Lake by Graham and Russell (1979) and Russell *et al* (1981) who documented juvenile utilization along the shoreline. In these assessments, habitat criteria similar to those collected in the FIM were utilized to assess areas as High, Moderate, or Low Juvenile Rearing Value. Similar to Russell's approach, a Juvenile Habitat Suitability Index was developed for the West Arm of Quesnel Lake (without a field sampling confirmation component). The following criteria were used in the Juvenile Rearing Habitat Suitability Index for the West Arm of Quesnel Lake. In contrast to the AHI Logic for LWD on this system, LWD was evaluated for density of LWD/km for the juvenile rearing logic. Density of LWD is an important factor for juvenile rearing, and all segments which had 100 or more LWD pieces entered in the database received the maximum score available for this category. Therefore, the LWD category was not changed to address the issue of the field data dictionary only allowing a maximum number of 100 to be entered into the database. In one instance, the data comment indicated that as many as 1000 pieces of LWD occurred within a single segment and this value was entered into the database during post-processing.

Table 2: The parameters and logic for the Juvenile Rearing Habitat Suitability of the West Arm of Quesnel Lake.

Category	Criteria	Maximum Point	Percent of the Category[1]	Logic	Uses Weighted FIM Data	Value Categories
Criteria	Shore Type	12	22.6	% of Segment * Maximum Point	Yes	Stream Mouth (12) > Wetland (8) = Sand Beach (8)> Gravel Beach = Rocky Shore (6) = Cliff /Bluff (4), Other (1)
	Substrate	9	17.0	% Substrate * Maximum Point	Yes	Organic(9) = Mud (9) = Marl (9) = Fines (9) > Boulder (8) > Cobble (7) > Gravel (7) > Sands (6) > Bedrock (4)
	Aquatic Vegetation	5	9.4	Aquatic Vegetation Category Score	No	**Aquatic Vegetation Category Score** Aq. Veg > 80% = 5, Aq. Veg 50% to 80% = 3. Aq. Veg < 50% = 1
	Littoral Width	12	22.6	Littoral Width Category Score	No	**Littoral Width Category** Wide (>50m) = 12, Moderate (10 to 50 m) = 8, Narrow (<10m) = 3
	Overhanging Vegetation	1	1.9	% Overhanging Vegetation * Maximum Point	No	
	Large Woody Debris	4	7.5	Large Woody Debris Category Score * Maximum Point	No	**Large Woody Debris Category Score** >15 LWD (1) > 10 to 15 LWD (0.8) > 5 - 10 LWD (0.6) > 0 - 5 LWD (0.4) > 0
	Migration Corridor	5	9.4	Present / Absent	No	Present (5), Minor (0)
	Salmonid Spawning Stream Present	5	9.4	Present / Absent	No	Present (5), Minor (0)

1. Numbers have been rounded to one decimal place. All calculations were completed without rounding.

2. The Shoreline vegetation category has been calculated to include an estimate of quantity (i.e., bandwidth) and quality (i.e., relative value). In cases where two bands are present, there is a higher diversity which is more productive, resulting in a higher score.

The juvenile rearing suitability is only one fishery criteria and comprises 11% of the overall West Arm of Quesnel Lake AHI. The above index has not been field confirmed using a sufficient sampling protocol, but is consistent with best estimates of productive juvenile areas. Duplicate parameters between the AHI and the Juvenile Rearing suitability index occur because of correlations that exist between the different parameters (i.e., the estimate of shore type productivity is correlated with juvenile rearing habitat suitability for example). Because duplicates can only account for less than 3% of index as a whole (i.e., Shore Type in AHI (16.5%) X Shore Type Juvenile Rearing (22.6%)), they do not represent a significant enough duplication to significantly alter the outcome of the analysis.

2. Migration – Juvenile fish migration routes are the most important migration corridors and these were prepared based upon selection of known spawning areas in streams. Migration areas generally only encompass shoreline where fish are migrating in or out of a river system. These areas overlap extensively with Staging

Areas. Migration routes consider both resident (e.g., rainbow and kokanee) and anadromous salmonid species. For the West Arm of Quesnel Lake, the migration score for the AHI was reduced, as the entirety of the shoreline was allotted a migration score. This corridor provides a migration route for all anadromous species migrating between the Fraser River and the Quesnel River, and subsequently through the West Arm of Quesnel Lake through to the North and East Arms of Quesnel Lake and the Horsefly River Watershed. Reducing the migration score prevents all segments from receiving a very high AHI rating, while still providing an indicator of habitat value.

3. Staging – Staging areas were identified based on review of orthophotos and the shoreline's spatial extents, and existing available fisheries data. This information was used to determine salmonid spawning streams. Overlap occurs between migration and staging areas and generally occurs near the confluence of the lake and its tributaries.

As this information was determined during post-processing, additional watercourses or shoreline segments with shore spawning activities may be added for migration, staging and spawning categories based on local knowledge and field crew observations, which may subsequently alter the AHI scoring for juvenile rearing and overall AHI value.

4.1.3 Shoreline Vegetation Parameters

The FIM provides a distinction between the lakeside vegetation (Band 1/Riparian) and the areas behind (Band 2/Upland) up to 50 m from the high water level. To address this new data available, the index was modified slightly. The index was modified to include a factor assessing vegetation quality (i.e., tall shrub thickets or wetland areas have a higher quality than landscaped *yards*). As with the other indices, vegetation bandwidths were categorized and points were assigned. Vegetation bandwidth categories included 0 to 5 m, 5 to 10 m, 10 to 15 m, 15 m to 20 m and greater than 20 m. The Band 1 vegetation, directly adjacent to the lake was given more points than the Vegetation Band 2 because of its direct proximity to aquatic habitats. Due to the relatively natural state of the shoreline, the bandwidth for Band 1 was often consistent within the 50 m; therefore, information for Band 2 was not included.

4.1.4 Habitat Modifications

Habitat modification parameters are described by Schleppe and Arsenault (2006). These descriptions provided a rationale for inclusion of these different parameters in the AHI. Other habitat modification parameters, such as Percent Substrate Modification or Percent Roadway were not included in the analysis because they may compound (i.e., groynes typically constructed from shoreline substrate modification, therefore gets counted twice). The following is quoted directly (shown in italics) from Schleppe and Arsenault (2006) completed by EBA Engineering Consultants Ltd. The City of Kelowna provided permission to utilize data from their assessment. Further information on these parameters can also be found in the Windermere Lake assessment (McPherson and Hlushak, 2008).

Textual areas below that are not in italics have been added to the wording of Schleppe and Arsenault for specific references regarding the applicability to this project.

Retaining Walls

Retaining walls are considered to be negative habitat features for a variety of reasons. These structures are generally constructed to armour or protect shorelines from erosion. Kahler et al (2000) summarized the effects of piers, docks, and bulkheads (retaining walls) and suggested that these structures may reduce the diversity and abundance of near shore fish assemblages because they eliminate complex habitat features that function as critical prey refuge areas. Kahler et al. (2000) found evidence of positive effects for armouring structures along a shoreline in the published literature. Carrasquero (2001) indicated in his review of overwater structures that retaining walls might also reduce the diversity of benthic macroinvertebrate communities more than other structures such as riprap shoreline armouring because they reduce the habitat complexity.

Natural erosion along a shoreline can be the result of removal of riparian or lakeside vegetation, which may have been the cause of the erosion in the first place. In other cases, retaining walls have been constructed to hold up soil material, possibly reclaiming land, so that lawns can be planted or for other landscaping purposes. As indicated in the FIM report by the RDCO, the construction of structures by residents, may lead to neighbours imitating their neighbours. Also, construction of one retaining wall may lead to energy transfer via waves resulting in erosion somewhere else. The above arguments highlight the consequences of retaining wall construction and the potential negative habitat effects that they have.

Photo 1: Looking towards a retaining wall and associated anthropogenic impacts.

Docks

The negative effects of docks on fish habitat are controversial. On one hand docks may provide areas of hiding for ambush predators, reductions in large woody debris inputs, and these structures are often associated with other anthropogenic disturbances such as retaining walls (Kahler et al. 2000; Carrasquero 2001). On the other hand, docks also provide shaded areas that can attract fish and provide prey refuge, and pilings can provide good structure for periphyton growth (Carrasquero 2001). Numerous factors, such as the scale of study and the cumulative effects of these structures, are also important and should be considered when discussing overwater structures (Carrasquero 2001).

Docks have also been documented to increase fish density due to fish's general congregation around structure, but decrease fish diversity in these same areas (Lange 1999). Coupled with this result, Lange also found that fish diversity and density were negatively correlated with increased density and diversity of shoreline development, meaning that increases in dock density may reduce fish abundance and diversity. Chinook salmon have been documented to avoid areas of increased overwater structures (e.g., docks) and riprap shorelines, and therefore, construction of these structures may affect juvenile migrating salmonids (Piaskowski and Tabor, 2000).

Regardless of the controversy, it is apparent that docks do affect fish communities and the degree of effects are most likely related to the intensity of the development, the scale of the assessment, and fish assemblage life history requirements. Different fish assemblages may respond differently to increased development intensity, and fish assemblages containing salmonids may be more sensitive than southern or eastern fish assemblages (e.g., bass, perch, and sunfish, etc.). It is for these reasons that dock density was included in the index, and that docks were treated as a negative parameter, with increasing dock density considered as having more negative effects than lower dock densities.

Photo 2: Looking towards a private moorage along the Quesnel lake foreshore.

Groynes

Groynes are structures that are constructed to reduce or confine sediment drift along a shoreline. These structures are typically constructed using large boulders, concrete, or some other hard, long lasting material. Reducing the movement of sediment materials along the shoreline can have a variety of effects on fish habitat, including increasing the embeddedness of gravels. Published literature regarding the specific effects of groynes on fish habitat are few, but because these structures are often considered Harmful Alterations, and Disruptions of Fish Habitat (HADD) as defined under the federal Fisheries Act, they are believed to have negative effects, mostly associated with the loss of area available for fish (e.g., Murphy 2001).

Photo 3: Groynes are visible along the foreshore of this property along the West Arm of Quesnel Lake.

Boat Launches

Boat launches were considered to be a negative parameter within the AHI. Boat launches are typically constructed of concrete that extends below the high water level. The imperviousness of this material results in a permanent loss of habitat, which ultimately reduces habitat quality and quantity for fish. Concrete does not allow growth of aquatic macrophytes, and reduces foraging and/or refuge areas for small fish and macroinvertebrates. The extent of the potential effects of boat launches relates to their size. Thus, multiple lane boat launches tend to have a large effect on fish habitat than smaller launches with fewer lanes because there is more surface area affected. The AHI treated each different boat launch lane as one unit, and therefore one launch could have multiple boat ramps. The intent of using the data in this fashion was to incorporate the size of the structure (i.e., more ramps, decrease in available habitat).

Other impacts of boat launches include prop scour of substrates in shallow water launches.

Marinas

Marinas are a concentration of boat slips, offering a place of safety to vessels. Marinas likely have a variety of effects, but there is very little literature investigating the positive or negative habitat consequences of marinas. Large marinas also tend to have breakwaters, which can further affect wave action, sediment scour and deposition, and circulation. In general, when marinas are constructed in the littoral zone there tends to be a large increase in shading, which reduces the potential for aquatic macrophyte growth and therefore reduces the productivity of a particular shoreline area. Also, marinas tend to have other activities associated with them, including extensive boat movements, which can reduce the use of an area by more timid species (e.g., rainbow trout). Other activities in marinas include fuelling stations, boat cleaning, bilge water, and sanitary waste disposal stations. Each of these activities has the potential to alter benthic communities, possibility altering the fish assemblage (i.e., congregations of more tolerant species and displacement of less tolerant species) and potential resulting in a loss in biodiversity, which can ultimately affect fish and/or fish habitat. Marinas also tend to be associated with other high intensity land developments, which may have a variety of effects including reducing water quality through inputs of chemicals, etc., increases in water turbidity, reduction in oxygen concentration, etc.

Photo 4: Looking towards a portion of the marina documented to occur along the West Arm of Quesnel Lake.

The above were common modifications that were observed that could be easily quantified and added to the habitat index. The negative effect of modifications was somewhat increased in comparison to AHI projects completed previously, as the extent and magnitude of impacts on the West Arm of Quesnel Lake were relatively low and the modifications that were documented were resulting in negligible devaluing of segment scores.

4.2 Index Ranking Methodology

The AHI was used to analyze the relative habitat value of a segment to those compared around the different lakes assessed. The output of the index is a five class ranking system, ranging from Very Low to Very High. Two different runs of the index were completed as follows:

1. Current Value (AHI_CUR) – This is the current index value for each shore segment based upon the total biophysical, riparian, fisheries, and modifications present.

2. Potential Value (AHI_POT) – This is the value of habitat index when the modifications are removed. It is the total value based upon the biophysical, riparian, and fisheries parameters only. This highlights segments where restoration is possible and would have the most potential benefit of removal of instream works. This category does not consider riparian restoration impacts.

4.2.1 Calculating the Index

The AHI consists of a variety of parameters and each parameter has a range in potential scores based upon the physical properties of each shore segment. Table 1 contains the logic and the maximum score possible for a particular habitat parameter. To calculate the index score, the score for a shore segment was applied based upon the physical characteristics in the FIM database for that segment. Weighted averages were used where possible to most accurately evaluate the score. Once the scores had been assigned to all parameters, the total scores for each different category 1) Biophysical, 2) Fisheries, 3) Shoreline Vegetation; and, 4) Modifications were summated for each segment. The total habitat value for each shoreline segment included all positive and all negative index parameters.

The output of the AHI is a five class ranking system, ranging from very low to very high. This ranking reflects the current value of the shoreline. The index was calibrated using previously completed AHIs, including Okanagan, Shuswap and Mabel Lakes. From this base, numerous iterations were run (i.e., the index was run at least 50 times) and changes were made as necessary to reflect current conditions. For each iteration of the index, the minimum, maximum, median, and distribution of scores was reviewed. After reviewing the distribution of the data from the iterations, logical score breaks were used to determine the category for Very High, High, Moderate, and Low. These breaks were made because of the clustering of scores based upon the output of the results. Ultimately, the value of habitat is a continuum, and there is room for some interpretation of this information. Further review, addition, and improvements to the index are encouraged and this database has been designed to allow inclusion and update of information. The ultimate purpose of the index is to act as a flagging tool based upon baseline information currently available.

The following provides a description of Very High through Very Low rankings:

1. Very High - Areas classified as Very High are considered integral to the maintenance of fish and wildlife species. Most areas identified as Very High occur in either an important floodplain area adjacent to a salmonid spawning stream, or are important wetland habitats. These areas should be considered the highest conservation priority.

2. High Value Habitat Areas - Areas classified as High Value are considered to be very important to the maintenance of fish and wildlife species around the lake. These areas could be high for a variety of reasons, including high rearing value, extensive aquatic vegetation, or a salmonid stream confluence area. These areas should be considered for maintenance of habitat value priority. Goals and objectives should be set to ensure maintenance of existing values, and prioritizing habitat improvements where feasible.

3. Moderate - Areas classified as Moderate are areas that are common around the lake, and have likely experienced some habitat alteration. These areas may contain important habitat areas and these important habitat characteristics should be considered independently of the overall shoreline segment value. Within these areas, developments should be balanced between nodes of high density development and nodes of single family. All developments should include some form of habitat restoration, with priorities to return the shoreline to a more natural state (i.e., change the classifications from Landscaped to Broadleaf or Coniferous) and remove significant instream habitat impairments (e.g., groynes, dock/groynes, infills, substrate alterations, etc.).

4. Low - Low value habitat areas are generally highly modified. These areas have been impaired through land development activities. 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.

5. Very Low - Very Low habitat areas are extremely modified segments that are not adjacent to any known important habitat characteristics.

5.0 DATA ANALYSIS

5.1 General

General data analysis and review was completed for the FIM database. Data collected was reviewed and analysis focused on shore segment length. Analyses for this project were completed as follows:

1. The shoreline length for the shore segment was determined using GIS and added to the FIM database;

2. For each category, the analysis used the percentage natural or disturbed field to determine the approximate shoreline segment length that was either natural or disturbed. This was done on a segment by segment basis. In some cases, the percentage natural or disturbed was reported because it made comparison easier than comparing shoreline lengths.

The above summarizes the general analysis approach. The following sections provide specific details for the biophysical analyses.

5.2 Biophysical Characteristics and Modifications Analysis

Biophysical characteristics of the shoreline segments were analyzed. For definitions of the categories discussed below, please refer to Appendix A (Detailed Methods) for a description / definition. The following summarizes the analyses that were completed:

1. Percent distribution of natural and disturbed shoreline;
2. Total shoreline length that remained natural or disturbed for each slope category that occurs along the shoreline;
3. Total shoreline length that remains natural or has been disturbed for each land use identified along the shoreline;
4. Total shoreline length that remained natural or has been disturbed for each shore type that occurs along the shoreline;
5. Total length of shoreline that contained aquatic vegetation, emergent vegetation, floating vegetation, or submergent vegetation;
6. Total number of modification features recorded along the shoreline. This data represents point counts taken during the survey and is reported for groynes, docks, retaining walls, marinas, marine rails, and boat launches; and,
7. Total shoreline length of different shoreline modifiers (roadways, substrate modification, and retaining walls) was determined.

5.3 Aquatic Habitat Index Analysis

A brief summary of the shoreline lengths and shore types is presented. The summary provides information regarding the AHI results (Very High to Very Low) analyzed by shore type, including the percent of the shoreline that is within each of the AHI categories.

6.0 RESULTS

The following section provides an overview analysis of the portion of the West Arm of Quesnel Lake that was sampled. Data is presented graphically and summarized in the text for ease of interpretation. Data tables for the different analyses are presented in Appendix B.

6.1 Biophysical Characteristics of the West Arm of Quesnel Lake

Foreshore Inventory and Mapping was completed on 70,196.4 m (70.2 km) of shoreline along the West Arm of Quesnel Lake. The total length of disturbed shoreline was 9,235 m (9.2 km), which represents 13% of the shoreline that was sampled (Figure 2). The total length of natural shoreline was 60,961 m (61 km), which represents 87% of the shoreline that was sampled (Figure 2).

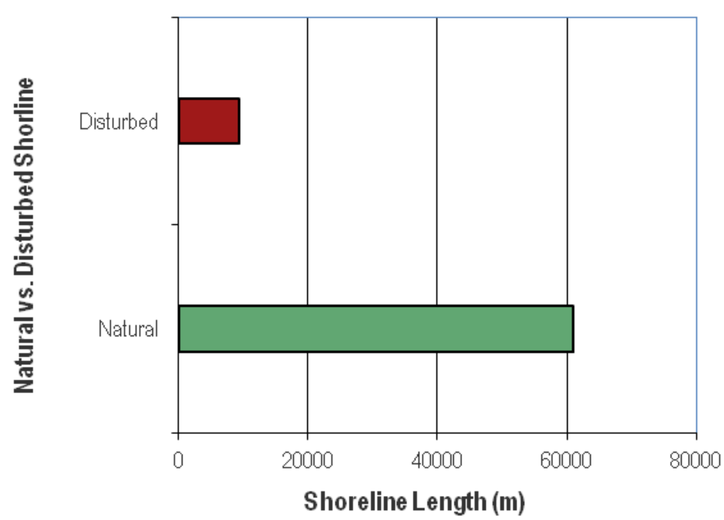


Figure 2 The total shoreline length that is either natural or disturbed along the portion of the West Arm of Quesnel Lake that was sampled.

The slope analysis is a summary of slope categories (% slope) that occur in upland areas above the high water mark. Areas of a lower gradient tend to have the highest level of disturbance, likely because they are easier to develop. The West Arm of Quesnel Lake has a total of 16,669 m (16.7 km) of low gradient (0-5%) slopes, accounting for nearly 24% of the total shore length (Figure 3). Low gradient areas were described as being 29% disturbed. Moderate (5-20%) and steep (20-60%) gradient areas along the West Arm of Quesnel Lake shoreline were described as being 9 and 10% disturbed, respectively. Very steep areas accounted for around 3.9 km of shoreline and were found to be 100% natural.

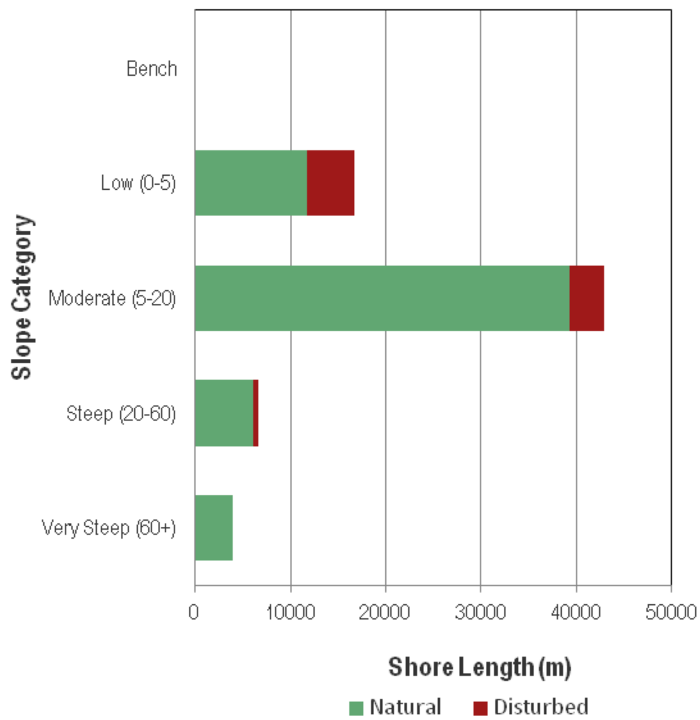


Figure 3 The total shoreline length that is either natural or disturbed along different shore gradients around the West Arm of Quesnel Lake.

The most predominant land use type around the West Arm of Quesnel Lake was Natural Area, accounting for 72% of the shore length, or 50.6 km (Figure 4). The Natural Areas were found to be around 95% natural and 5% disturbed. In addition to the data collected during the FIM field inventory, zoning from the Cariboo Regional District was also used to identify land use. Many of the expansive undeveloped areas around the West Arm of Quesnel Lake appear to be Crown Land; therefore, resulting in the Natural Area description. Rural land use accounted for nearly 17% of the shore length, or 11.6 km. Approximately 81% of the rural land parcels remain in a relatively natural state. However, these large, privately-owned parcels represent areas of potential future build-out, as development pressures increase, including subdivision and subsequent anthropogenic impacts.

The category of single family was the next largest land use, representing 8% or 5.6 km of the shoreline. Within the single family residential areas, the shore length was nearly 72% disturbed. Single family land use was applied to those parcels zoned lakeshore residential. Anthropogenic impacts, including substrate modification, removal of riparian vegetation, and development within the West Arm of Quesnel Lake riparian area, were most evident along single family areas.

Park and transportation occurred over 1.4% and 1.2% of the total shore length, respectively, and the levels of disturbance were found to be 9% and 12.3 %. While many of the single family and rural areas of this lake are likely used for recreational purposes, the category of recreation accounted for only 0.3% of the shore length, or 199 m, and occurred in Segment 1. Recreation was described as 80% disturbed. Commercial land use occurred along 312 m, or 0.4% of the shoreline, and was described as 95% disturbed.

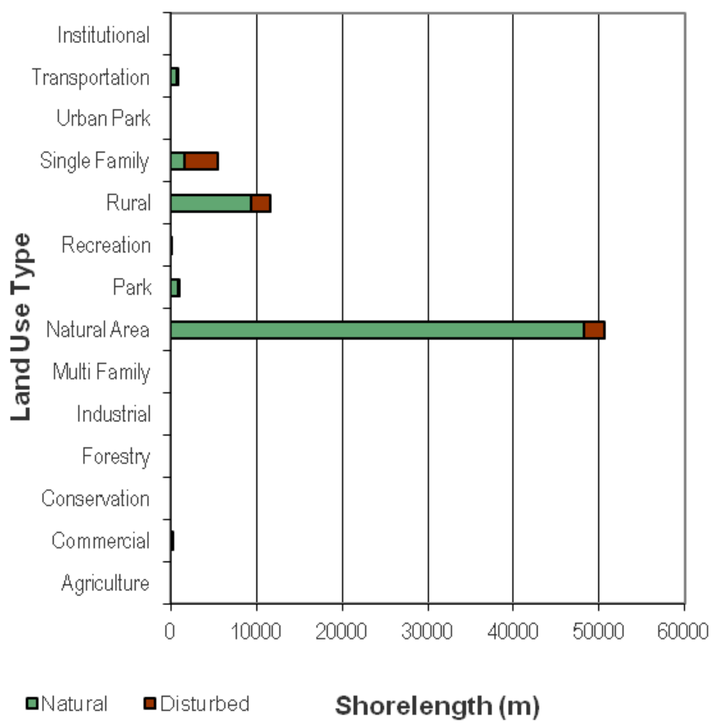


Figure 4 presents the natural and disturbed shoreline length by the different types of land use occurring around the West Arm of Quesnel Lake.

The most predominant shore type observed around the West Arm of Quesnel Lake was gravel beach, which accounted for 49% or 34 km (Figure 5). Gravel beach shores were described as 79% natural, with only an estimated 7.1 km of shoreline disturbed. Rocky shore types were documented over 35% of the shore length, or 24.2 km, with only 7% of the shoreline disturbed. Stream mouths accounted for 8.3 km, or 12%, of the total shore length, with stream mouth areas described as 96% natural. Cliff/bluff shoreline occurred over 3%, or 2.2 km, of the shore length, with 97% described as natural. Sand beach accounted for 1049 m, or 1.3% of the shore length and with sand beach areas 94% remained natural. Data was collected documenting current condition of the shoreline and it should be noted that groyne construction along rocky shorelines has created areas of gravel or sand beaches.

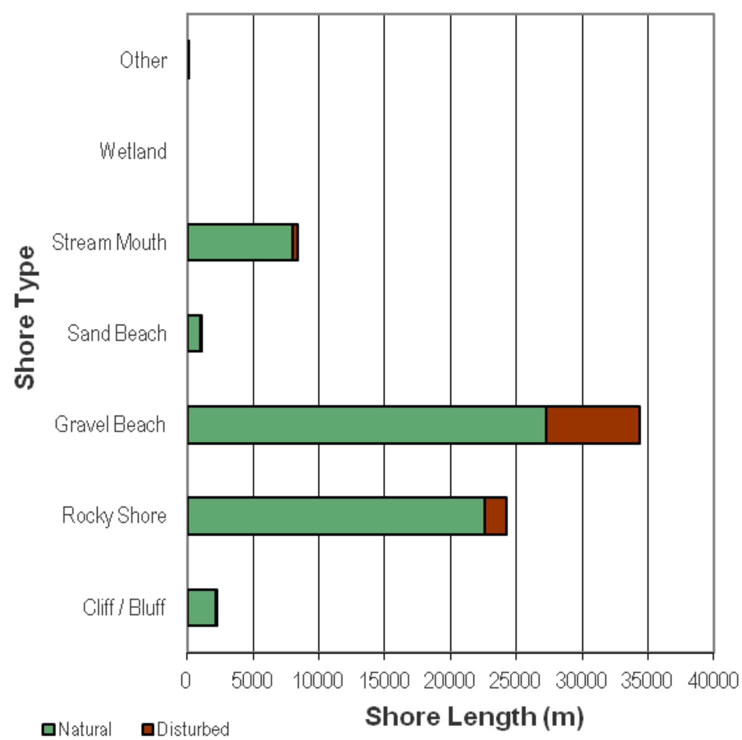


Figure 5 presents the length of natural and disturbed shoreline along each of the different shore types documented around the West Arm of Quesnel Lake

Photo 5: Looking towards an example of stream mouth habitat with a well-vegetated riparian area.

Photo 6: Looking towards an example of a rocky shore type along the West Arm of Quesnel Lake.

Aquatic vegetation is loosely defined as any type of emergent, submergent, or floating vegetation that occurred below the high water level. Thus, the aquatic vegetation field includes true aquatic macrophytes and those plants that are hydrophilic or tolerant of periods of inundation during high water level. Studies have shown that even terrestrial vegetation, during periods of inundation provides important food for juvenile salmonids and other aquatic life and this is why it has been included (Adams and Haycock, 1989).

There is approximately 25.1 km of shoreline that has aquatic vegetation, which represents approximately 36% of the total shoreline length (Figure 6). Most of the vegetation observed was emergent, including grasses and herbaceous vegetation below the high water level, which occurred along 33% of the shoreline or 23.1 km. Areas of native submergent vegetation and floating vegetation were documented along 6% or 4.5 km and 3% or 2.4 km, respectively. Ecoscape digitized areas of aquatic vegetation based on air photo interpretation and polygons of vegetation recorded on field maps, which resulted in a higher representation of aquatic vegetation than what was represented in the database. The total area of both dense and sparsely vegetated areas, including emergent, floating, submergent, low flood bench and marsh aquatic vegetation types is 799,913 m^2.

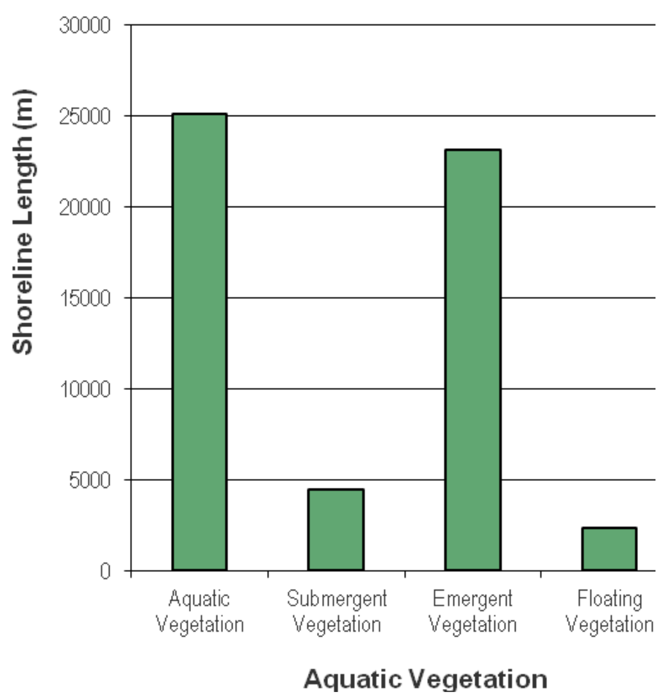


Figure 6 presents the total shoreline length that has aquatic, submergent, emergent, and floating vegetation along the West Arm of Quesnel Lake.

Docks were the most commonly observed type of shoreline modification, occurring within both rural and single family residential areas (Figure 7). There were a total of 129 docks counted during the assessment, which equates to 1.8 docks per km. Groynes were the next common type of modification with 51 recorded. A total of 36 retaining walls were documented along the shore length. There were 24 boat launches recorded, not including gravel access to the foreshore which could facilitate boat launching. Two (2) marinas accommodating multiple slips were documented along the West Arm of Quesnel Lake, while 2 marina rails were recorded along private parcels. Modifications to some degree occurred wherever privately held parcels occur along the lakeshore.

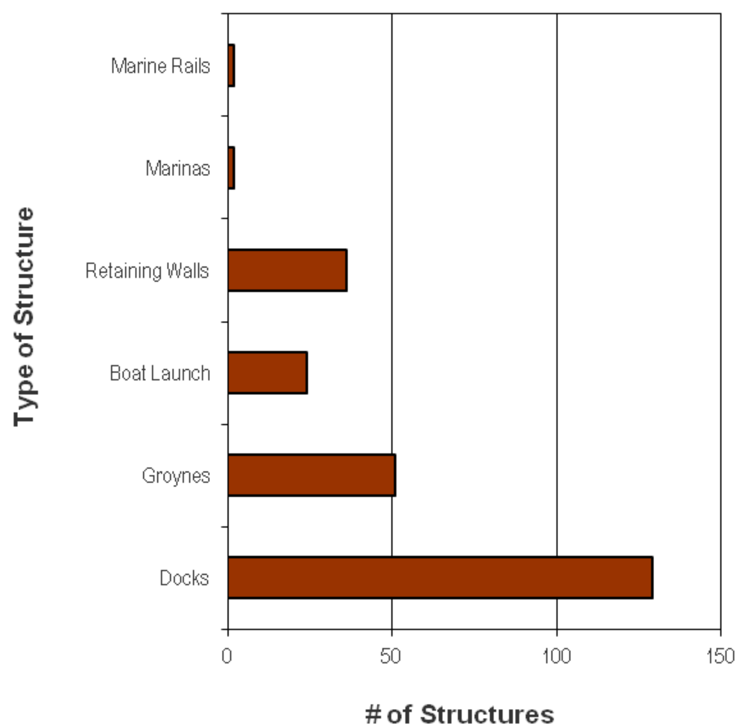


Figure 7 presents the total number of various shoreline modifications documented to occur around the West Arm of Quesnel Lake.

Photo 7: Looking towards an example of a retaining wall and associated anthropogenic impacts occurring along the West Arm of Quesnel Lake.

The percentage of the shoreline that was impacted by roads, railways, retaining walls, and where substrate modification has occurred was recorded. These estimates allowed an approximation of the total shoreline length that has been impacted by these different activities (Figure 8). The below figure highlights the relatively undeveloped nature of the West Arm of Quesnel Lake. Substrate modification was observed along approximately 3%, or 2 km of the shoreline. Substrate modification was variable and was most commonly associated with construction of groynes to create gravel beaches, historic fills (e.g., retaining walls below HWL) or associated with road/railways (e.g., structural fill material, etc.). Retaining walls were found to occur along 1042 m of shoreline, or 1% of the surveyed shore length. Road influence within the riparian area was documented along 1% of the shoreline, or 857 m, while railways were only documented at 27.2 m of the total shore length.

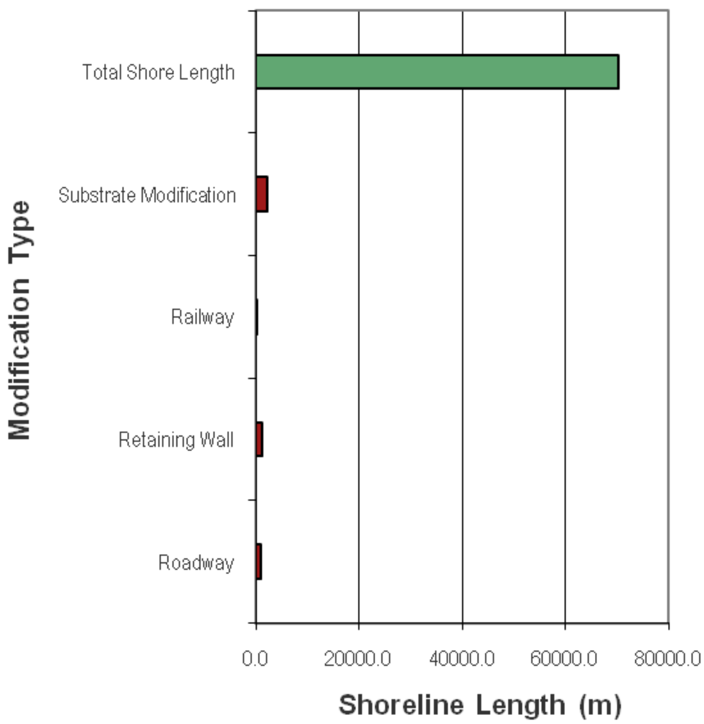


Figure 8 presents the total shoreline length that has been impacted by substrate modification, road and railways, and retaining walls along the West arm of Quesnel Lake.

The surveyed length of the West Arm of Quesnel Lake was found to primarily have a low level of impact (Figure 9). Approximately 54 km, or 77%, of the shoreline was described as having less than 10% impact. Nearly 10% of the shoreline, or 6.9 km exhibited little to no impact. Areas of moderate (10-40%) impacts accounted for 1.7 km of shoreline, or 2.4%. Approximately 11% (7.6 km) of the West Arm of Quesnel Lake exhibited high levels of impact where greater than 40% of the shoreline was impacted.

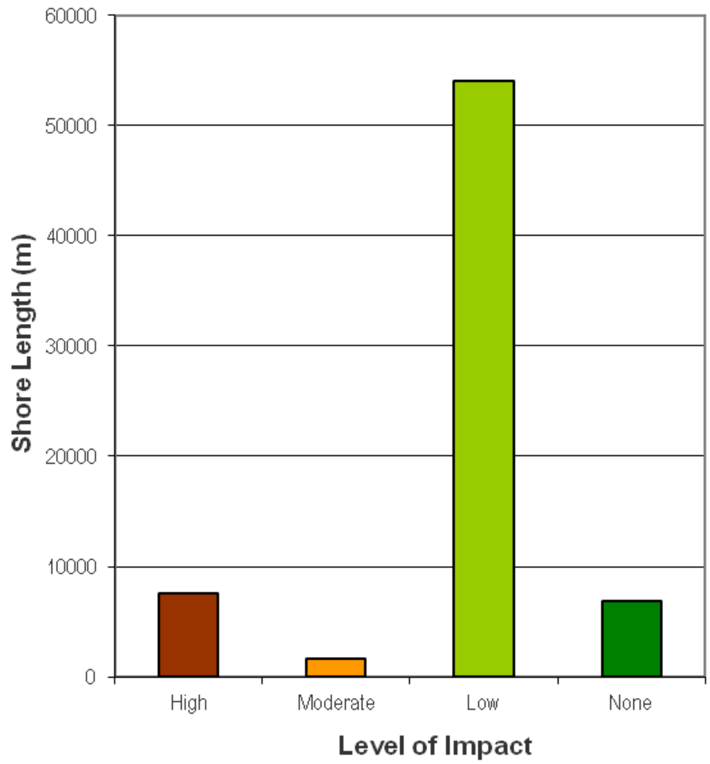


Figure 9 presents the level of impact (High, Moderate, Low, or None) observed along the West Arm of Quesnel Lake.

The analysis below indicates that areas of high juvenile rearing value occur along 14 km and have been disturbed along 2% or 322 m (Figure 10). Areas of moderate rearing value occur along 48 km of shoreline and are 10% disturbed. Areas of low rearing value occur along 8.2 km of shoreline and had the highest level of disturbance, at 52.5%.

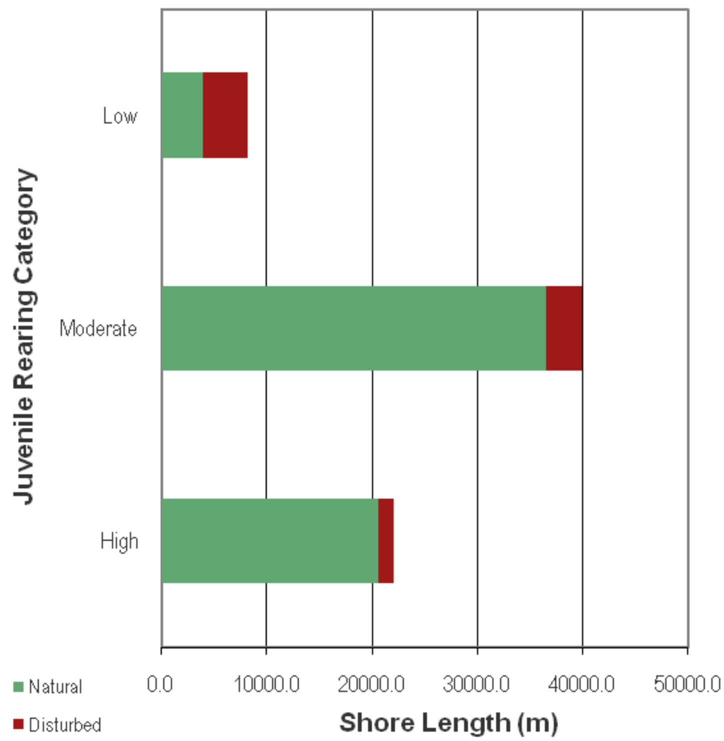


Figure 10 presents the natural and disturbed shore length within areas classified as having High, Moderate, or Low Juvenile Rearing value along the West Arm of Quesnel Lake.

6.2 Summary of Foreshore Modifications

The West Arm of Quesnel Lake remains relatively natural over approximately 87% of the 70.2 km shore length, with disturbance to some extent documented over 13%. Around 72% of the shoreline was described as Natural Area in terms of land use, with disturbance estimated around 5%. Privately owned rural and single family lakeshore residential property accounts for nearly 25% of the total shore length. While rural land was estimated to remain 81% natural, there is the potential for future development and associated anthropogenic impacts. Smaller, single family parcels were estimated to remain 28% natural, with higher levels of development and foreshore modifications. The FIM and AHI analysis highlights the necessity to begin to implement long term objectives for the lake to help conserve important natural areas that remain.

As with other shoreline studies of similar scope (e.g., Okanagan Lake, Shuswap Lake, Mabel Lake, Moyie Lake, etc.), lower gradient shoreline slopes tended to have higher disturbance. Common modifications include removal of native riparian vegetation, construction of single family dwellings and permanent structures within close proximity to the lake high water level, moorages, and substrate modification (boat launches, groynes and boat basins). Many of the privately held parcels along the lake appear to be used primarily for recreational purposes and structures were often noted to be integrated into the natural landscape, retaining native tree canopy and riparian buffers. However, as development pressure along the lakeshore increases with time, smaller cabins and dwellings used for recreation may give way to larger single family dwellings used on a year-round basis. Inevitable larger building footprints will of course result in increased levels of disturbance.

Varying degrees of foreshore development are present along the West Arm of Quesnel Lake. Some of the main issues identified are summarized below:

- Within more intensely developed areas, landscaping with turf and removal of a native riparian buffer was common. While most properties had some mature trees retained, native herbaceous and shrubby vegetation in the understory had largely been modified. While only three (3) segments were described as landscaped in the riparian class category, there were several others where distribution was described as patchy due to removal of riparian vegetation associated with development. Opportunities for riparian enhancement are present along many private properties.

- Docks were the most commonly observed shoreline modification. Docks were constructed in various styles, sizes and materials, many of which do not appear to conform to best management practices. In many areas, these docks were associated with groynes constructed from lakebed materials (i.e., coarse cobble and boulder substrates placed in piles under dock) and boat basins, with associated excavation, lake fill and overall foreshore modification. Construction of many foreshore modifications likely required the use of heavy equipment at or below the high water level. The extent of permitting and licensing obtained for moorages and associated structures are not known; however, some degree of non-compliance is assumed. The impact of non-compliance may be small on an individual scale, but cumulatively, foreshore modifications result in habitat degradation.

- A total of 24 private boat launches were documented along the shoreline. Boat launches are associated with vehicular access, which has impacted riparian vegetation. It is likely that most of these private boat launches were constructed without a provincial Water Act, federal Fisheries Act approval or receipt of Crown land tenure.

- Retaining wall construction was noted to occur along privately held lakefront parcels. Retaining walls were constructed out of varying materials, but frequently substrates from the lakebed were used to construct the walls, or imported material was brought in for placement below or at the high water level. As mentioned above, it is probable that many of the retaining walls observed have been constructed without a Water Act or Fisheries Act approval.

6.3 Aquatic Habitat Index Results

The results of the Aquatic Habitat Index are best reviewed graphically. The attached Figure Binder presents the spatial results of the assessment. The figure binder has been prepared to show a summary of all the information contained within this report.

The Aquatic Habitat Index uses biophysical information to assess the relative value of a shoreline area. The AHI indicates that approximately 51% of the shoreline is ranked as Very High and High (Figure 11). Nearly 48% of the shoreline length is moderate, and the remaining 2% is ranked Low and Very Low. Only 0.4% of the shoreline length received a ranking of Very Low. The distribution of data for the West Arm of Quesnel Lake resulted in few segments with Low values. The entire length of the Quesnel Lake shoreline has not been inventoried, which may also play a role in the small representation of low value habitat. Areas of High and Very High habitat value were typically in association with stream confluences and expansive natural areas associated with gravel and rocky shorelines. Most of the lower value sites were located in areas impacted by development with associated modifications.

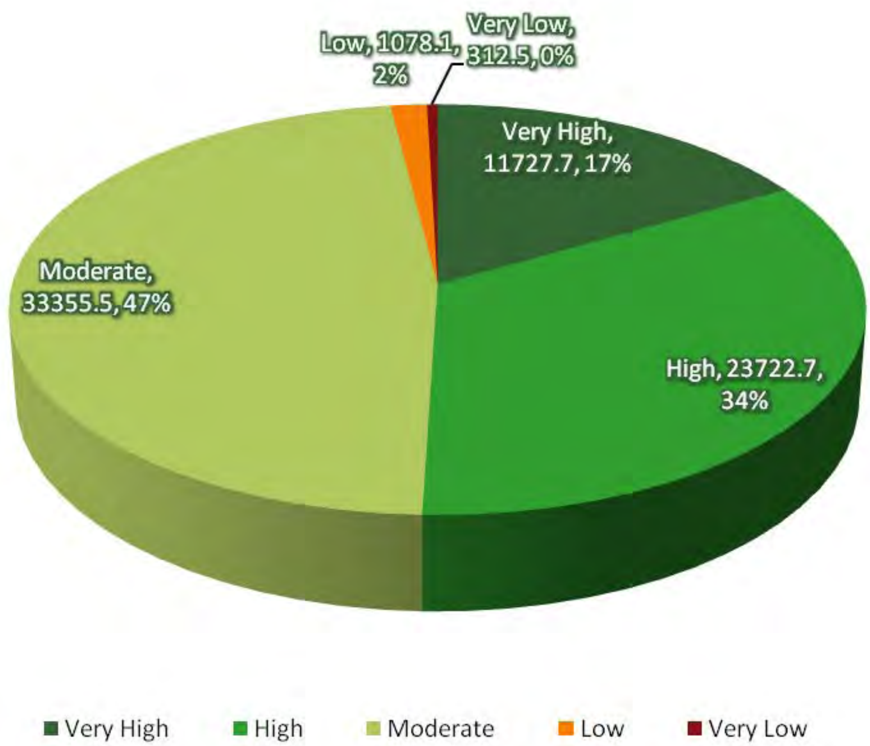


Figure 11 presents shore length and percentage of areas classified as being Very High, High, Moderate, Low, and Very Low ranking by an Aquatic Habitat Index along the West Arm of Quesnel Lake

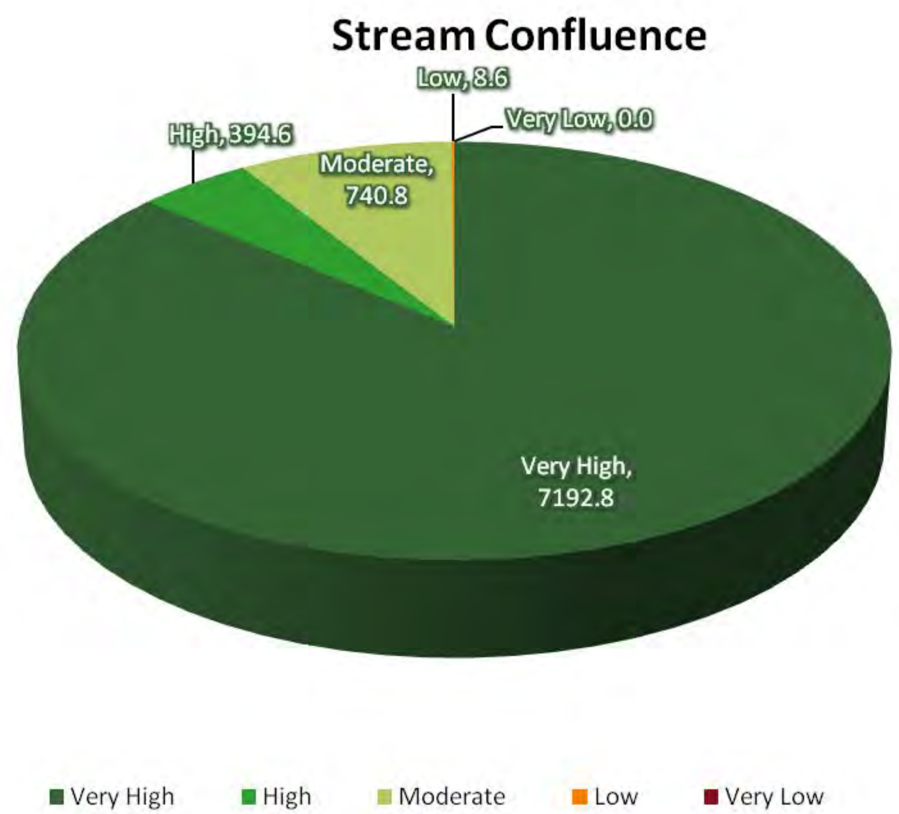
Table 3 below provides further details on the breakdown of shorelines ranked as Very Low through Very High.

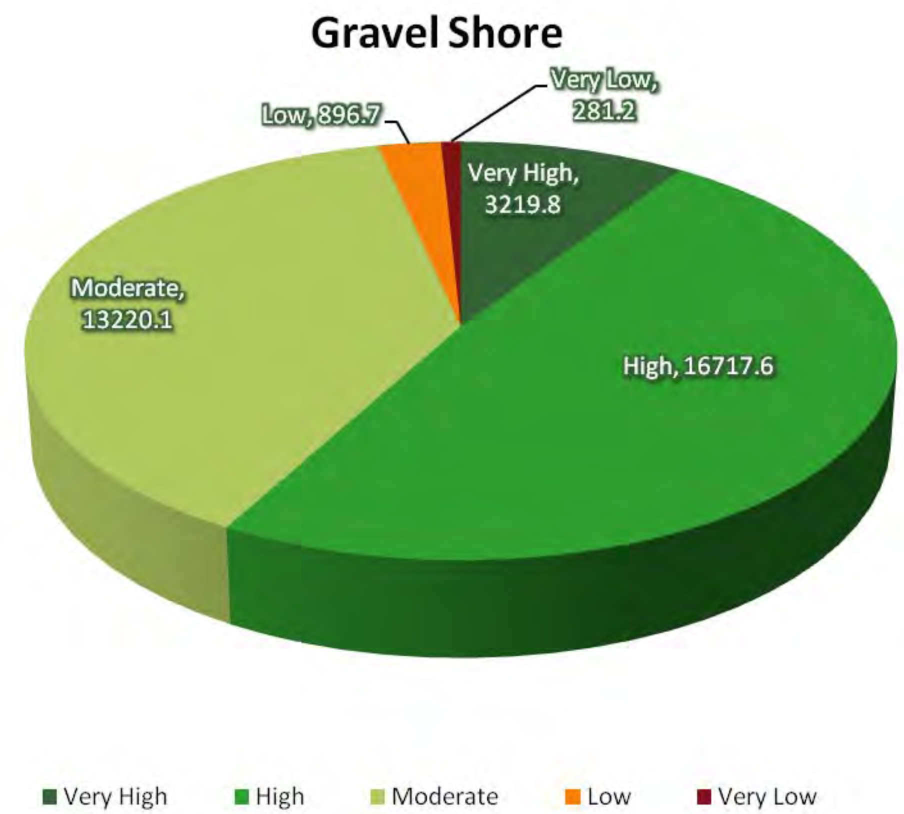
Table 3: Summary of the Current Value and Potential Value shoreline lengths, number of segments, and percentage of the shoreline for the different habitat index categories (Very High to Very Low)

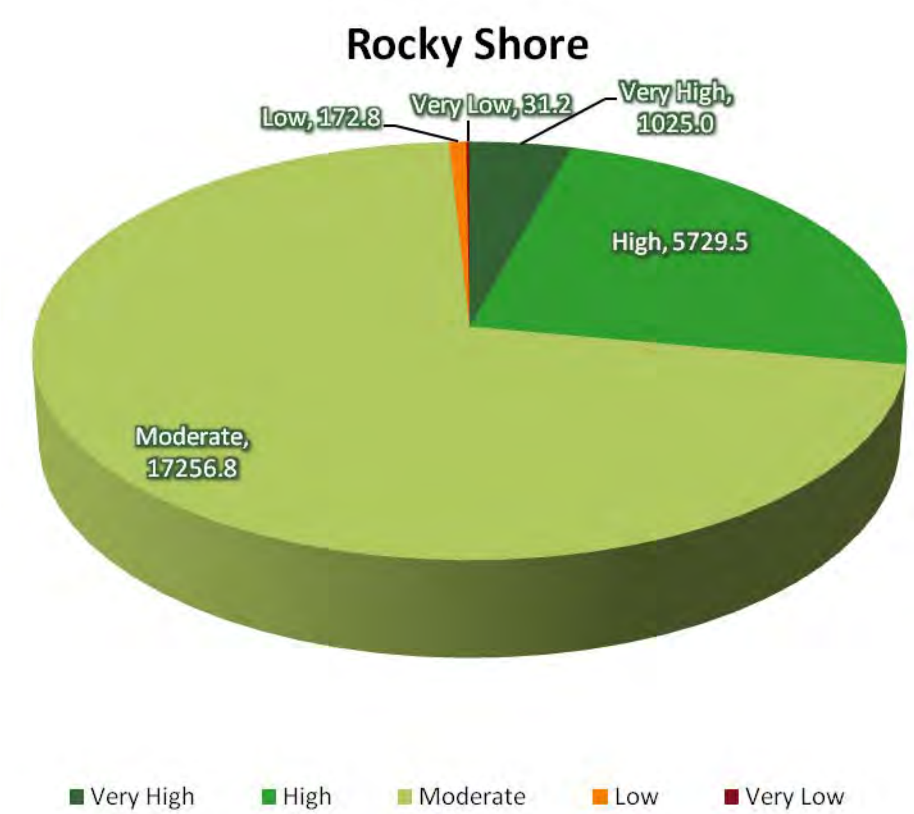
Categories	Current Value			Potential Value		
	# of Segments	Shoreline Length (m)	% of Shoreline	# of Segments	Shoreline Length (m)	% of Shoreline
Very High	8	11727.7	16.7	8	11727.7	16.7
High	8	23722.7	33.8	9	28231.4	40.2
Moderate	13	33355.5	47.5	13	29703.9	42.3
Low	2	1078.1	1.5	2	533.4	0.8
Very Low	1	312.5	0.4	48	0.0	0.0
Total	32	70196.4	100.0	80	70196.4	100

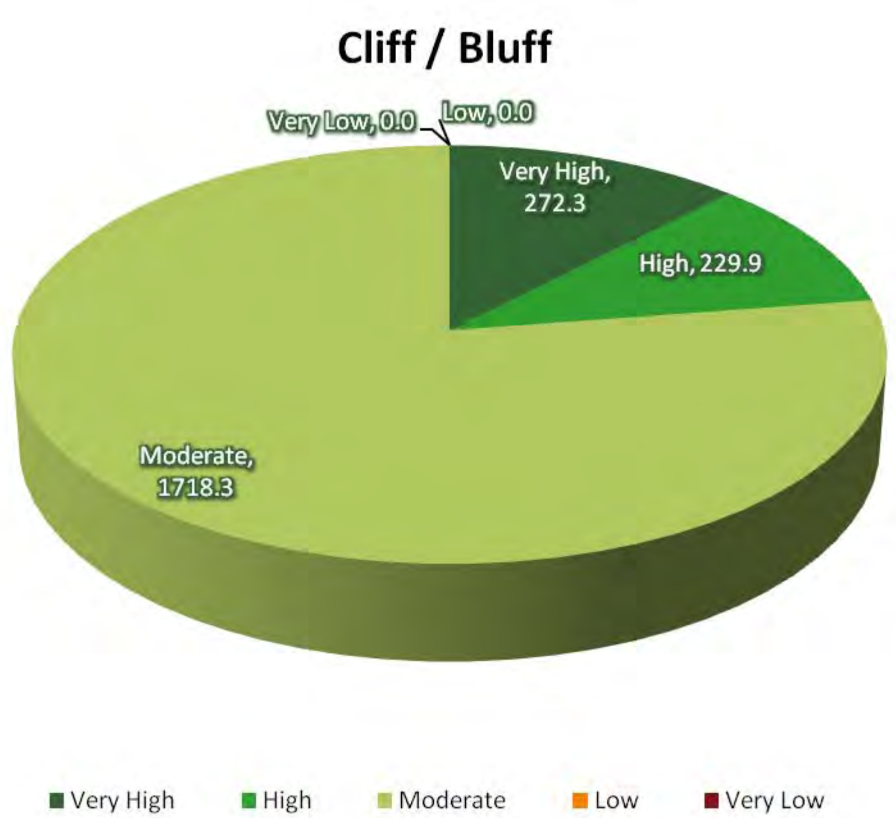
The AHI results were analyzed to determine the distribution of habitat values by shore type (Table 4). The analysis indicated that very high value shorelines occurred primarily adjacent to stream mouths and gravel shores, with a reduced representation of very high value habitat occurring along rocky and cliff/bluff shores. Very high value habitat only represented 0.2% of sand shores. The West Arm of Quesnel Lake exhibited limited very low AHI ratings. Low and very low value habitat was noted to occur along gravel and rocky shores. Around 8.6 m of low value habitat also occurred within the stream confluence category, due to the presence of tributaries within a developed segment of the West Arm of Quesnel Lake. Several stream lines occur along the West Arm of Quesnel Lake which may be ephemeral watercourses or gully features.

The AHI highlights the importance of the connection between our diverse streamside, wetland and lakeshore habitats. Stream confluences and their adjacent features (e.g., shore marshes, large woody debris, and diverse riparian vegetation communities) are areas that tend to contain the highest fish and wildlife diversity. These areas are extremely important for maintaining viable populations, and most importantly are water quality buffers that are required to preserve source drinking waters.


Stream Confluence
Low, 8.6
Very Low, 0.0
High, 394.6
Moderate, 740.8
Very High, 7192.8
Very High
High
Moderate
Low
Very Low


Gravel Shore
Very Low, 281.2
Low, 896.7
Very High, 3219.8
Moderate, 13220.1
High, 16717.6
Very High
High
Moderate
Low
Very Low


Rocky Shore
Very High, 1025.0
Low, 172.8
Very Low, 31.2
High, 5729.5
Moderate, 17256.8
Very High
High
Moderate
Low
Very Low


Cliff / Bluff
Very Low, 0.0
Low, 0.0
Very High, 272.3
High, 229.9
Moderate, 1718.3
Very High
High
Moderate
Low
Very Low

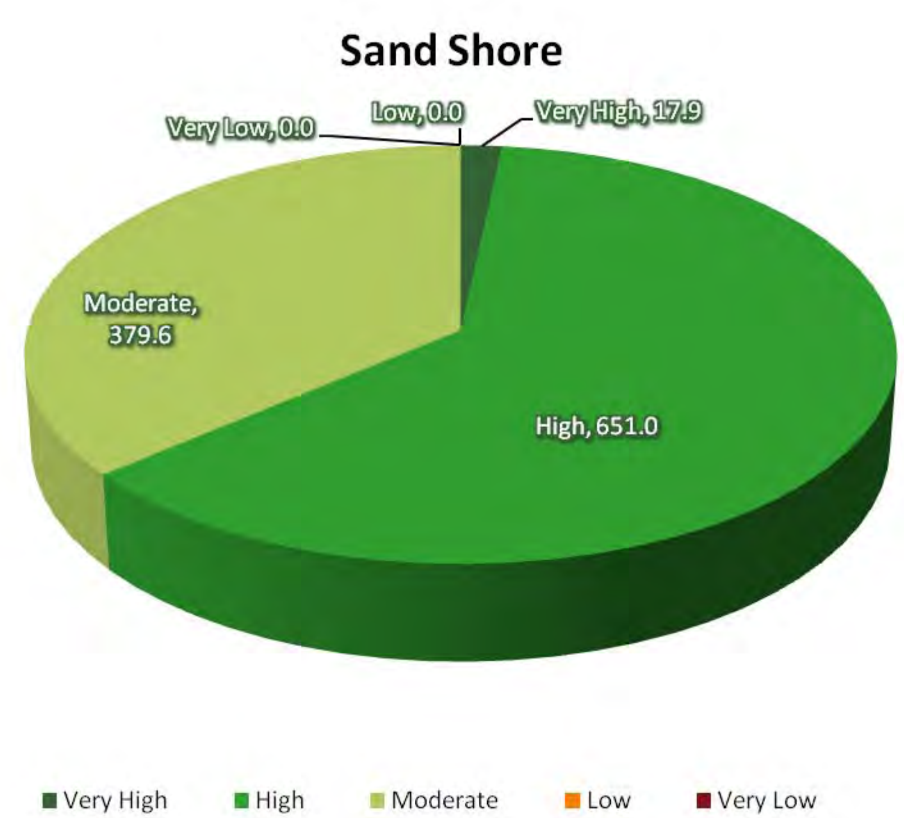

Sand Shore
Very Low, 0.0
Low, 0.0
Very High, 17.9
Moderate, 379.6
High, 651.0
Very High
High
Moderate
Low
Very Low

Table 4: Summary of the Aquatic Habitat Index results for the different shoretypes for the Current Value of the Shoreline.

	Current Value			Cliff_Bluf		Rocky		Gravel		Sand2		Stream_mou		Wetland		Other	
Categories	# of Segments	Shoreline Length	% of Shoreline	Shoreline Length	% of Shoreline Length	Shoreline Length	% of Shoreline Length	Shoreline Length	% of Shoreline Length	Shoreline Length	% of Shoreline Length	Shoreline Length	% of Shoreline Length	Shoreline Length	% of Shoreline Length	Shoreline Length	% of Shoreline Length
Very High	8.0	11727.7	16.7	272.3	2.3	1025.0	8.7	3219.8	27.5	17.9	0.2	7192.8	61.3	0.0	0.0	0.0	0.0
High	8.0	23722.7	33.8	229.9	1.0	5729.5	24.2	16717.6	70.5	651.0	2.7	394.6	1.7	0.0	0.0	0.0	0.0
Moderate	13.0	33355.5	47.5	1718.3	5.2	17256.8	51.7	13220.1	39.6	379.6	1.1	740.8	2.2	0.0	0.0	39.9	0.1
Low	2.0	1078.1	1.5	0.0	0.0	172.8	16.0	896.7	83.2	0.0	0.0	8.6	0.8	0.0	0.0	0.0	0.0
Very Low	1.0	312.5	0.4	0.0	0.0	31.2	10.0	281.2	90.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The Potential Value summary presents what the habitat value would be if the modifications were removed (Table 5). This analysis highlights areas where restoration may result in a benefit. It is important to note that this analysis does not consider riparian improvements. Riparian improvements would also likely result in habitat improvements which have not been accounted for in this analysis. In general, there was a shift from very low upwards. Subsequent analysis may help better interpret where restoration may be more feasible and cost effective.

Table 5: Summary of the Aquatic Habitat Index results for the different shoretypes for the Potential Value of the Shoreline.

	Potential Value			Cliff_Bluf		Rocky		Gravel		Sand2		Stream_mou		Wetland		Other	
Categories	# of Segments	Shoreline Length	% of Shoreline	Shoreline Length	% of Shoreline	Shoreline Length	% of Shoreline	Shoreline Length	% of Shoreline	Shoreline Length	% of Shoreline	Shoreline Length	% of Shoreline	Shoreline Length	% of Shoreline	Shoreline Length	% of Shoreline
Very High	8	11727.7	16.7	272.3	2.3	1025.0	8.7	3219.8	27.5	17.9	0.2	7192.8	61.3	0.0	0.0	0.0	0.0
High	9	23722.7	33.8	229.9	1.0	5955.0	25.1	20865.6	88.0	696.1	2.9	484.8	2.0	0.0	0.0	0.0	0.0
Moderate	13	33355.5	47.5	1718.3	5.2	17160.0	51.4	9792.0	29.4	334.5	1.0	659.2	2.0	0.0	0.0	39.9	0.1
Low	2	1078.1	1.5	0.0	0.0	75.4	7.0	458.0	42.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Very Low	0	312.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The following analysis summarizes the natural and disturbed shoreline areas that are within each of the different Aquatic Habitat Index Rankings. Within areas ranked as Very High, the shoreline was 96% natural. In High value areas, the shoreline was 95% natural and within Moderate value areas the shoreline was 80% natural. Areas of Low Value were around 48% natural, while areas with Very Low value had 5% of the shoreline remaining natural.

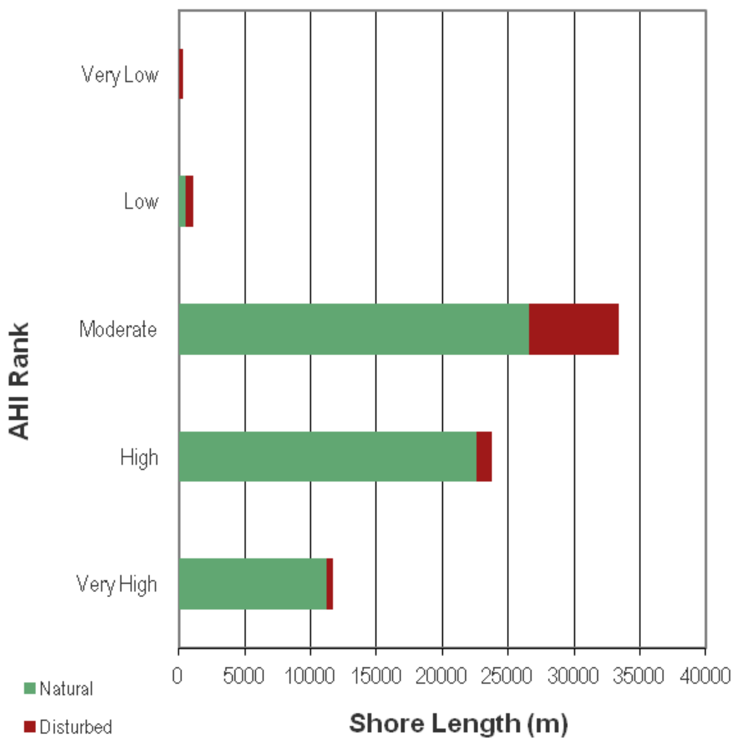


Figure 13 presents the Natural and Disturbed shore length of areas classified as being Very High, High, Moderate, Low, and Very Low ranking by an Aquatic Habitat Index along the West Arm of Quesnel Lake.

7.0 RECOMMENDATIONS

7.1 Foreshore Protection

The following provides a summary of recommendations for foreshore protection along the West Arm of Quesnel Lake. Some of the recommendations below are similar to other recent FIM reports that were completed. In cases of similarity, credit to the work should be given to the original authors. The following are recommendations for development of foreshore protection policies:

1. **The FIM and AHI should be expanded to include the remainder of the West Arm of Quesnel Lake**. Additionally, detailed inventory of the remaining Quesnel Lake shoreline should be considered for the future.

2. **A Shoreline Guidance Document (Step 3) should be developed by local government, the Ministry of Natural Resource Operations, First Nations bands, and Fisheries and Oceans Canada for the West Arm of Quesnel Lake that incorporates the results of this analysis.** The AHI provides a basis for identification of sensitive shoreline areas, forming the basis for a risk based approach to lakeshore management. The shore guidance document will facilitate inter-governmental cooperation for lakeshore management. Funding should be sought to complete this next step. A staged approach in the development of this guidance document may be required, with a series of interim measures developed to allow sufficient effort in the development of long and short term goals (i.e., see recommendations below regarding a lakeshore management plan).

3. **FIM and AHI data should be integrated into existing watershed-based fish sustainability planning initiatives.** A substantial amount of work has been completed and is ongoing which may benefit from the spatially accurate documentation of current shoreline habitats and sensitivity analysis.

4. **Maintenance of riparian vegetation and sufficient natural riparian management areas/setbacks with property development.** Private parcels may currently be undeveloped or have minimal impacts, but will be vulnerable to redevelopment in the future. Numerous different possibilities exist for areas identified as sensitive, including Section 2.19 No Build / No Disturb Covenants, creation of Natural Areas Zoning bylaws (i.e., split zoning on a property), or by other mechanisms (donation to trust, etc.). The very high and high shoreline areas are considered the most important areas around the lake and mechanisms to protect these key habitat features need to be developed. Further, site specific assessment of individual properties should occur to evaluate proposed activities and ensure maintenance and enhancement of sensitive aquatic and terrestrial ecosystems and habitat features.

5. **Historical habitat impacts should be restored during re-development activities, with measures in place to ensure successful completion**. While the West Arm of Quesnel Lake remains largely natural, this is something to consider with lakeshore development. In areas where past impacts and modifications have occurred, permitting for building, subdivision or redevelopment of the property should be contingent upon incorporation of habitat restoration, such as retaining wall removal, dismantling of groynes, riparian restoration, etc. Partnerships (i.e., multi agency partnerships with stewardship groups) should be formed or built upon to help facilitate habitat restoration around the lakes.

6. **Key shoreline linkages to sensitive terrestrial habitat should be identified. These habitat linkage areas are extremely important to maintain and should be**

identified as early as possible in the development process. The West Arm of Quesnel Lake remains largely undisturbed; however, maintenance of connectivity between the foreshore and sensitive terrestrial ecosystems is an important factor to consider when regulatory agencies are reviewing applications for redevelopment, including subdivision, which can result in habitat fragmentation and increased density of foreshore impacts. Detailed assessments and identification of core habitat areas for conservation should be done as early in the development process as possible to reduce potential impacts from land use decisions (e.g., zoning a property for commercial purposes without understanding what values are present may result in obligations for a minimum build-out that has significant impacts that are difficult to mitigate later on in the process such as at subdivision).

7. **Environmental information collected during this survey should be available to all stakeholders, relevant agencies, and the general public.** Environmental information, including GIS information and air photos, are an extremely important part of the environmental review process because they provide a lot of information regarding the current condition of an area. This information should be available to the public to increase the knowledge base and contribute to completion of environmental assessments and overall increase in lake stewardship. One agency should take the lead role in data management and any significant studies that add to this data set should be incorporated and updated accordingly.

8. **Compliance and enforcement monitoring of approved works is required, with consequences for failure to construct following standard best practices or failure to apply for necessary permits.** There were several examples of historical and more recent site development observed during this survey that are not in accordance to best practices, which is consistent with observations during surveys of other interior lakes such as Horsefly, Okanagan, Mabel, Shuswap, Windermere, Moyie, Monroe, and Mara Lakes.

9. **A communication and outreach strategy should be developed to inform stakeholders and the public of the findings of this study and improve stewardship and compliance**. Provision of links to the information on the Community Mapping Network is recommended. Press releases and provision of information to local stakeholders and stewardship groups would also be beneficial.

10. **Lakeshore erosion hazard mapping should be conducted for private lands to identify areas at risk, which will streamline the review process and reverse the damaging trend of unnecessary hard armoring and construction of retaining walls along the shoreline of the lakes.** Also, this methodology would be helpful to identify areas that are sensitive to boat wake erosion. The province has formalized methodology for lakeshore hazard mapping and this methodology, or some adaptation of it, would be preferred (Guthrie and Law, 2005). This mapping should be integrated with the FIM data, and be completed for each segment. Flooding, terrain stability, alluvial fan hazard mapping should also be considered for developing areas along the lakeshore. Until lakeshore erosion hazard mapping is

completed, it is advisable to only consider shoreline protection works on sites with demonstrated shoreline erosion. To accomplish this, reports by engineers or biologists should accompany proposals for shoreline armoring to ensure that works are required, minimize impacts and use bioengineering techniques.

11. **Storm water management plans need to adhere to best management practices and be considered in all future development applications.** While not specifically identified as an immediate item of concern on the West Arm of Quesnel Lake, stormwater management is an important consideration as communities grow and associated development activity increases. Adequate detention, retention and infiltration needs to take place, rather than direct discharge to waterbodies.

12. **Local, provincial, and federal governments should only approve proposed developments with net neutral or net positive effects for biophysical resources.** Development of land use alteration proposals should only be approved if the compromises or trade-offs will result in substantial, long-term net positive production benefits for biophysical resources. Developments that have "significant" adverse effects to any biophysical resource (e.g., spawning areas) should not be approved on the basis that compensatory habitat works may offset such effects unless suitable rationale and arguments are presented (e.g., it benefits the general public versus an individual).

13. **Habitat mitigation and compensatory efforts of biophysical resources should occur prior to, or as a condition of, any approval of shoreline-altering projects.** To ensure that works are completed, estimates to complete the works and performance security bonding amounts should be collected. These bonds will ensure objectives for the proposed works are met and that efforts are constructed to an acceptable standard.

14. **Low impact recreational pursuits (biking, non-motorized boating, etc.), pedestrian traffic and interpretive opportunities should be encouraged**. These activities should be directed to less sensitive areas, and risks to biophysical resources should be considered. Only activities that will not diminish the productive capacity of biophysical resources should be considered.

15. **A lakeshore management plan developed at all three levels of government should be considered.** Local, provincial, and federal agencies may need to identify what the maximum proposed build out for the West Arm of Quesnel Lake will be and develop a cross jurisdictional plan to achieve this goal. This decision should be made sooner rather than later, because it is probable that there will be a continued incremental loss over time as rural properties are proposed for increased density. If the build out does not occur with coordination at all levels of government, the impacts cannot be effectively mitigated (i.e., it is better to work as part of a larger regional initiative than as solitary jurisdiction). Items to consider when developing more long term management objectives include:

- Addressing substrate alteration occurring around the lake to prevent degradation of juvenile rearing, spawning habitats and wetland areas;
- Implementing sufficient measures, including adequate budget, to provide for a long term watershed management approach;
- Providing sufficient boat access (e.g., ramps, parking, etc.) in appropriate locations to offset concerns in very high and high value areas;
- Addressing key wildlife corridors, species at risk habitat and sensitive terrestrial ecosystems;
- Addressing waterfowl and shorebird productivity and implementing appropriate best management practices that will help avoid impacts to important breeding habitats;
- Addressing known data gaps including identification of key habitat elements around the Horsefly Lake shoreline that are not included in this analysis. Key linkages not considered include herptile access locations and rare plant communities; and
- Identifying appropriate mechanisms for compliance and enforcement monitoring. Consistent and enforceable mechanisms are required to prevent works that are not in compliance with standard best practices.

16. **Helical screw anchors should be utilized as a first choice for mooring buoy anchors.** Mooring buoys with concrete anchors has been identified as a measurable loss of productive habitat. All current mooring buoys and any new mooring buoys should be installed using screw anchors and should follow other applicable legislation.

7.2 Future Data Management

Ongoing appropriate management of the data is important to ensure that data collected during this survey is kept available, accurate, and up to date. Future data collection should be integrated into the current AHI and additions and edits made as required. The following are recommendations for future management of the dataset:

1. **A single agency should take the lead role in data management and maintenance**. The responsible agency should manage and maintain the "master data set". Although the data may be available for download from numerous locations, one agency should be tasked with keeping the master copy for reference purposes. The Community Mapping Network (CMN) is currently publishing many of the data sets that have been collected. Sufficient funding must be allocated to CMN to keep up with management of the data because typically increasing datasets result in increasing costs.

2. **The shoreline segment numbers used in this report are the unique identifiers. Any new shoreline information that is collected should reference and become linked to the existing shoreline segment number.** This will help maintain consistency and connectivity between current and future data collection and

integration. The responsibility of maintaining this consistency will be that of the single agency described above.

3. **A summary column(s) should be added to the FIM dataset that flags new GIS datasets as they become available.** Examples of this include new location maps for rare species occurrences and fish distributions. Other examples include the addition of appropriate wildlife habitat use data. Where feasible, these new data sets should reference the shoreline segment numbers identified in this report.

4. **Review and update of the FIM/AHI data and mapping should occur on a 5 to 10 ten year cycle.** As the dataset provides baseline data of a snapshot in time, review and update of the FIM will be required to determine if shoreline goals and objectives are being achieved. Ideally, updates to the FIM dataset would be done as projects are approved and completed (i.e., real time).

7.3 Future Inventory and Data Collection

The following are recommendations for future biophysical inventory that will help facilitate environmental considerations in land use planning decisions:

1. **Data regarding shore and stream spawning locations for resident and anadromous fish species should be confirmed.** No occurrences of shore spawning were identified in available information or field data along the shoreline of the West Arm of Quesnel Lake, although Quesnel Lake kokanee are said to largely be propagated by Quesnel Lake shoal spawning given a decline in kokanee stream spawners (Sebastian et al, 2003; Lawrence, 2004; Holmes, 2009). Shoal spawning areas for sockeye and kokanee have been identified along the north and east arms of Quesnel Lake (Department of Fisheries and Oceans Canada, 2001; Sebastian et al, 2003), and the FIM/AHI should be updated if shore spawning is known to occur along the West Arm as well. Inventory of shore spawning reaches for lake trout should also be conducted along Quesnel Lake, as limited information is available for this species in Quesnel Lake.

   Fisheries fields of migration, staging and spawning stream were filled out for each segment during post-processing based on available information from field data and literature review. Habitat types such as gravel and rocky shores with high composition of gravel and cobble substrates score higher in the AHI and correspond to suitable shore spawning habitat. Additional watercourses and segments of shoreline may provide habitat to salmonids, and additional segment breaks may be necessary to allow these high and very high value habitats to be segregated such that their value is not being diluted within longer segments that are not specifically acknowledging salmonid spawning values. This should be verified and included in the FIM and AHI database as knowledge is built upon.

2. **The addition of new segment breaks should be determined in the future.** Some segments, predominantly the longer lengths, should be further assessed to determine

if additional breaks would help better reflect the condition of the shoreline. Future mapping updates may determine new segment breaks along long segments, segments with special features (e.g., shore spawning, stream mouths or wetlands), or as other information is collected.

3. **Complete Foreshore Inventory and Mapping and Aquatic Habitat Index for the remainder of the West Arm of Quesnel Lake, as well as the North and East Arms of Quesnel Lake.** The entire shoreline of Quesnel Lake should be included within future FIM and AHI projects to develop a comprehensive inventory of the entire shoreline and the inherent fisheries resources. This inventory could be incorporated into a Shoreline Guidance document for the entire length of Quesnel Lake.

4. **The Juvenile Rearing Suitability Index should be field confirmed**. The rearing index that was developed for this project is based upon previous work completed on Okanagan Lake, Shuswap Lake and Mabel Lake. There are differences between these systems and the index should be adjusted according to results of a field program that samples different shoreline areas and types during different seasons. This type of analysis could also be replicated across different lake types to better assess the relative value of different shoreline areas to juvenile salmonids. Similar investigations into utilization and importance of the different shore types by resident fish stocks may also yield information regarding the relationships between juvenile rearing suitability, fish stocks, and shore type.

5. **A field sampling program of the different shoreline areas should be developed to confirm the results of the AHI**. The AHI has been developed based upon information that is currently available for the West Arm of Quesnel Lake, upon review of other studies, and air / GPS stamped still photo / GPS Video. However, numerous assumptions have been built into the index and a field sampling program should be developed to confirm the results of the assessment and to test assumptions of the index.

6. **Complete Sensitive Habitat Inventory and Mapping (SHIM) for all watercourses around the lake**. SHIM is a GIS-based stream mapping protocol that provides substantial information regarding streams and watercourses. This mapping protocol provides useful information for fisheries and wildlife managers, planning staff, municipal engineering departments (e.g., engineering staff responsible for drainage), and others. Mapping should focus on significant salmonid rivers and streams first, on smaller tributaries containing less fish habitat second, followed by non-fish-bearing waters. This information is also extremely useful for Source Water Protection initiatives because it identifies potential contaminant sources in an inventory.

   During the 2011 field surveys completed by DFO, it was noted that several stream mouth locations varied in the field from where the TRIM stream lines are depicted. Additional streams were also identified at this time. Formal watercourse inventory would be beneficial and could help to further refine the FIM/AHI database as new data is collected.

7. **Complete Wetland Inventory and Mapping for all wetlands along the shoreline of the lake and associated tributaries.** WIM is another GIS-based mapping protocol that provides information regarding wetland communities. WIM mapping along the West Arm of Quesnel Lake shoreline and associated tributaries is recommended. Mapping of wetlands is also important to ensure that corridors between aquatic and terrestrial habitats are identified. Wetlands are sensitive and productive components of natural ecosystems and these features should be inventoried and mapped. Completion of WIM would help to more accurately identify, classify and describe aquatic vegetation features that occur around the shoreline.

8. **A survey, on a home by home basis, should be conducted to help educate home owners.** A home owner report card could be prepared that would provide land owners with a review of the current condition of their properties. The assessment should provide them with sufficient information to help land owners work towards improving habitats on their property. This assessment is not intended to single out individual owners, but rather to help owners understand the importance of habitat values present on their properties.

8.0 CONCLUSIONS

This report documents the current condition of around 70.2 km of shoreline along the West Arm of Quesnel Lake. The Foreshore Inventory and Mapping (FIM) assessment provides a summary of current and background information characterizing the condition of the shoreline and riparian communities that comprise the foreshore. An Aquatic Habitat Index (AHI) was developed that incorporated the biophysical information collected during the surveys to rank the relative environmental sensitivity and level of disturbance of each of the discrete shoreline segments around the lake. Recommendations are provided to help integrate this information into local land use planning initiatives and incorporate into future development of Shoreline Management Guidelines.

The most prolific shoreline modification was docks with 129 documented, resulting in a density of 1.8 moorages/km. Substrate modification was only estimated to occur over 3% of the total shore length, but was documented in association with modifications such as groynes, boat launches, boat basins, retaining wall construction and riparian vegetation removal. Removal of riparian vegetation was observed in areas of single family, rural, park, agriculture and recreation land use, including replacement of native trees and shrubs with turf to the high water level, resulting in a reduction in structural diversity. These impacts were considered to be the most significant habitat degradations observed around the lake.

There is approximately 86% of the shoreline that appears to remain in a relatively natural condition, representing approximately 61 km of shoreline. Much of the West Arm of Quesnel Lake is surrounded by Crown Land, with areas described as natural land use occurring over 72% of the shoreline. The analysis indicated that very high value shorelines occurred over nearly 17% of the total shore length, primarily adjacent to stream mouths and gravel shores, with a reduced representation of very high value habitat occurring along rocky and cliff/bluff shores. Approximately 2% of the shoreline is ranked as having low or very low value, occurring primarily adjacent to areas impacted by development with associated modifications or along cliff/bluff areas of the shoreline.

Fish, wildlife, recreation and water quality considerations make it essential to identify, manage and protect the shoreline area. The data collected during this assessment provides a baseline upon which goals and objectives can be created and monitored, in order to effectively manage this valuable resource.

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GLOSSARY OF TERMS AND ACRONYMS

Alluvial Fan / Stream Mouth – Alluvial fans are considered to be areas where a stream has the potential to have a direct active influence (e.g., sediment deposition or channel alignment changes) on the lake.

Allocthonous Inputs - Organic material (e.g., leaf litter) reaching an aquatic community from a terrestrial community.

Anadromous – Anadromous fish as sea run fish, such as Coho, Chinook, and Sockeye salmon.

Aquatic Habitat Index (AHI) -The index is a ranking system based upon the biophysical attributes of different shoreline types. The index consists of parameters such as shore type, substrate type, presence of retaining walls, marinas, etc. to determine the relative habitat value based upon a mathematical relationship between the parameters.

Aquatic Vegetation – Aquatic vegetation consists of any type of plant life that occurs below the high water level. In some instances, aquatic vegetation can refer to grasses and sedges that are only submerged for short periods of time.

Biophysical – Refers to the living and non-living components and processes of the ecosphere. Biophysical attributes are the biological and physical components of an ecosystem such as substrate type, water depth, presence of aquatic vegetation, etc.

Best Management Practice (BMP) - Is a method or means by which natural resources are protected during development or construction.

Emergent Vegetation - Emergent vegetation includes species such as cattails, bulrushes, varies sedges, willow and cottonwood on floodplains, grasses, etc. Emergent vegetation is most commonly associated with wetlands, but is also occurs on rocky or gravel shorelines.

Fisheries and Oceans Canada (DFO) – Federal agency responsible for management of fish habitats

Fisheries Productivity - The maximum natural capability of habitats to produce healthy fish, safe for human consumption, or to support or produce aquatic organisms upon which fish depend.

Floating Vegetation -Floating vegetation includes species such as pond lilies and native pondweeds with a floating component.

Foreshore – The foreshore is the area that occurs between the high and low water marks on a lake.

Foreshore Inventory Mapping (FIM) -FIM is the methodology used to collect and document fish and riparian habitats and lake corridors and was performed by the Regional District of Central Okanagan and partners. A full discussion of this mapping can be found in Magnan and Cashin (2005).

Georeferencing - Georeferencing establishes the relationship between page coordinates on a planar map (i.e., paper space) and known real-world coordinates (i.e., real world location)

Groyne – A protective structure constructed of wood, rock, concrete or other materials that is used to stop sediments from shifting along a beach. Groynes are generally constructed perpendicular to the shoreline

Instream Features – Instream features are considered to be construction of something below the high water mark. Instream features may include docks, groynes, marinas, etc.

Lacustrine – Produced by, pertaining to, or inhabiting a lake

Lentic - In hydrologic terms, a non-flowing or standing body of fresh water, such as a lake or pond.

Life History – Life history generally means how an organism carries out its life. Activities such as mating and resource acquisition (i.e., foraging) are an inherited set of rules that determine where, when and how an organism will obtain the energy (resource allocations) necessary for survival and reproduction. The allocation of resources within the organism affects many factors such as timing of reproduction, number of young, age at maturity, etc. The combined characteristics, or way an organism carries out its life, is a particular species' life history traits.

Lotic – In hydrologic terms, a flowing or moving body of freshwater, such as a creek or river.

Non Anadromous – Non anadromous fish are fish that do not return to the sea to mature. Examples include rainbow trout (excluding steelhead), bull trout, and whitefish.

Retaining Wall – A retaining wall is any structure that is used to retain fill material. Retaining walls are commonly used along shorelines for erosion protection and are constructed using a variety of materials. Bioengineered retaining walls consist of plantings and armouring materials and are strongly preferred over vertical, concrete walls. Retaining walls that occur below the Mean Annual High Water Level pose a significant challenge, as fill has been placed into the aquatic environment to construct these walls.

Sensitive Habitat Inventory Mapping (SHIM) - The SHIM methodology is used to map fish habitat in streams.

Shore zone - The shore zone is considered to be all the upland properties that front a lake, the foreshore, and all the area below high water mark.

Streamside Protection and Enhancement Area (SPEA) - The SPEA means an area adjacent to a stream that links aquatic to terrestrial ecosystems and includes both the existing and potential riparian vegetation and existing and potential adjunct upland vegetation that exerts influence on the stream. The size of the SPEA is determined by the methods adopted for the Provincial Riparian Areas Regulation.

Stream Mouth / Stream Confluence / Alluvial Fan – Stream mouths are considered to be areas where a stream has the potential to have a direct active influence (e.g., sediment deposition or channel alignment changes) on the lake.

Submergent Vegetation – Submergent vegetation consists of all native vegetation that only occurs within the water column. This vegetation is typically found in the littoral zone, where light penetration occurs to the bottom of the lake. Eurasian milfoil is not typically considered submergent vegetation as it is non-native and invasive.