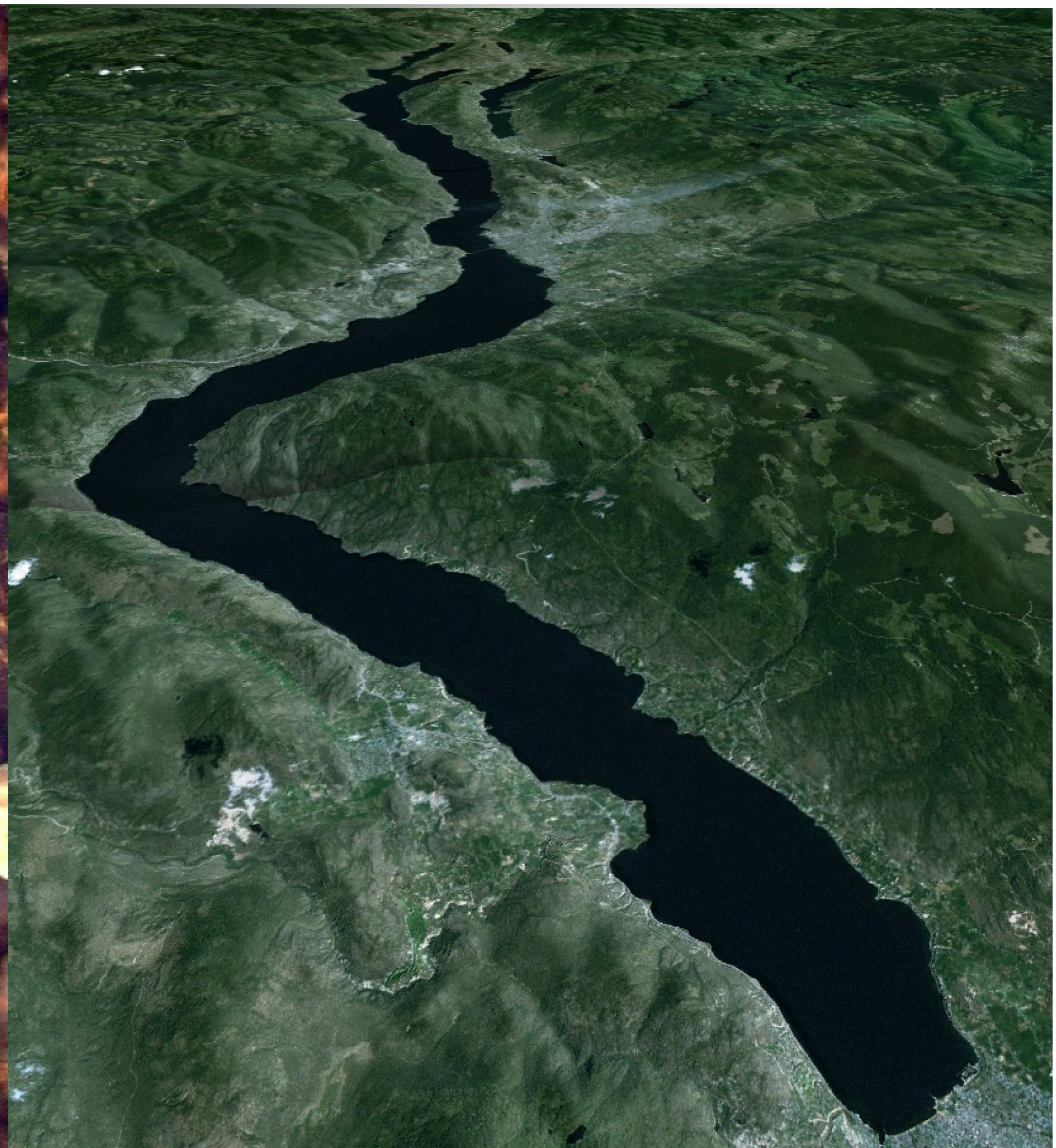
Foreshore Inventory & Mapping / Aquatic Habitat Index

Okanagan Lake: A Compilation of the North, South and Central Okanagan Lake



Prepared For:
Okanagan Collaborative Conservation Program

Prepared By:
ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.

February 2011
File No.: 10-596

FORESHORE INVENTORY AND MAPPING & AQUATIC HABITAT IINDEX

Okanagan Collaborative Conservation Program

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A Compilation of North, South, and Central Okanagan Lake

Prepared For:

OKANAGAN COLLABORTIVE CONSERVATION PROGRAM

Prepared By:

ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.
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ECOSCAPE
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EXECUTIVE SUMMARY

Throughout the first years of the new millennium, the Okanagan watershed has experienced intensive development activity within most areas. As the population within the Okanagan region has grown, development has spread to more remote areas. It is becoming readily apparent that the increased development is degrading shoreline areas along the lake, which is known for its natural beauty and high recreational values. The development pressure is resulting in impacts on fish and wildlife habitat, important terrestrial communities, wetlands, and water quality. The spread of development to remote areas is the result of an increasing demand for lake side properties and year round residences with better overall servicing. For less developed areas, now is an opportune time to address lakeside development concerns to better manage future shoreline impacts.

In response to the need for better and more collaborative lake planning and management, the Okanagan Conservation Collaborative Program, with support of local, provincial, and federal governments, initiated a process to document the current condition of the foreshore and to help develop a more integrated approach to watershed management. This work was a continuation of previous projects initiated in the Central, North, and South Arms of Okanagan Lake. This report has been prepared based upon the belief that it is possible to manage this shoreline and the natural areas surrounding it in a sustainable manner.

Okanagan Lake is arguably the most important resource in the Okanagan Valley, and contributes significantly to the overall production of fish and wildlife. The lake supports populations of rainbow trout, kokanee, mountain whitefish and burbot. Okanagan Lake also contains populations of coarse fish species such as sculpins or longnose/leopard dace, which are often forage fish. Shoreline areas also provide important habitat for numerous wildlife species, including raptors (e.g., Osprey), Western Grebes, song birds, large game (e.g., deer and moose), and numerous other populations of avian and mammal fauna. Finally, the shoreline of Okanagan Lake also provides habitats that are important for rare plant species and communities. Okanagan Lake the primary source of water for agricultural purposes and human consumption for many Okanagan Communities.

Currently, many lake management projects in the province of BC follow a three step process described below. For this project, steps 1 and 2 below were completed.

1. Foreshore Inventory and Mapping (FIM) is a protocol that is used to collect baseline information regarding the current condition of a shoreline. The FIM uses a mapping based (GIS) approach to describe shorelines. These inventories provide information on shore types, substrates, land use, and habitat modifications. This new information has been combined where possible, with other mapping information such as previous fisheries inventories, recent orthophotos, and other information.

2. An Aquatic Habitat Index (AHI) is generated using the FIM data to determine the relative habitat value of the shoreline. This index follows similar methods that were developed for Shuswap Lake and is similar to other ongoing assessments along lakes in the Kootenays. The Aquatic Habitat Index uses many different factors such as biophysical criteria (e.g., shore type, substrate information, etc.) fisheries information (e.g., juvenile rearing suitability, migration and staging areas), shoreline vegetation conditions (e.g., width and type of riparian area), terrestrial ecosystem information (Sensitive Ecosystem Inventory), and modifications (e.g., docks, retaining walls, etc.) to estimate the relative habitat value of a shoreline segment. This assessment was the first known to the author to incorporate areas identified to be important terrestrial habitats. The Habitat Index classifies this information in a 5-Class system from Very

High to Very Low and describes the relative value of the different shorelines areas to one another (i.e., describes shorelines areas within Okanagan Lake to each other and not to other lakes (e.g., Shuswap or Mabel).

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

At this time, there are numerous different shoreline policy documents that have been prepared in response to significant development pressure. At the provincial level, the Okanagan Large Lakes protocol was prepared and this document provides a framework for management of kokanee and the Western ridged mussel. Other documents include the City of Kelowna Shore Zone assessment and the Central Okanagan Lake Foreshore Plan. Currently, there is not a unified framework or policy that is being utilized by local, provincial, and federal governments in management systems.

Foreshore Inventory and Mapping

Foreshore Inventory and Mapping results (FIM) for this project included a compilation of data from the south, central, and north Okanagan. The data compilation provides valuable information regarding features, habitats, and other information for the shorelines of Okanagan Lake. A summary of the data collected indicates the following:

- The level of impact along the Okanagan Lake shoreline was determined based upon categorical descriptions of the level of disturbance observed along the lake. It is estimated that 58% of the shoreline has a high level of impact (greater than 40% disturbance) which accounts for 169 km of shoreline. Areas of moderate (between 10 to 40% disturbance) and low impact (less than 10% disturbance) account for 15% or 44 km and 25% or 72 km of the shoreline respectively. There is an estimated 3.4 km or 1.2% of shoreline that is believed to have little to no impact. Impacts along the shoreline include lakebed substrate modification, riparian vegetation removal, construction of retaining walls, docks, beach grooming, etc. In total, it is estimated that 57% or 164 km of the shore length is disturbed and 43% or 125 km is natural;

- The most predominant land use around the lake is single family areas (32%), followed by rural areas (25%). Other common land uses include natural parks (e.g., Okanagan Mountain Park), urban parks, transportation, and recreational areas;

- Wetlands and stream confluences are the most rare shore type around the lake, accounting for only 8% and 3% of the shore length respectively. The most common shore types around the lake are gravel and cliff / bluff shores accounting for 43% and 23% respectively. Gravel and cliff / bluff shores comprise 31% and 65% natural respectively;

- Aquatic vegetation occurs along 19.5% of the shoreline and is an important habitat feature for juvenile salmonids. Of this, emergent vegetation (e.g., emergent grasses, willows, or other types of vegetation inundated during high water) was the most commonly observed (e.g., emergent grasses, willows, or other areas with vegetation inundated during high water). Native beds of submergent vegetation were only documented along 2.1% of the shoreline, and areas of floating vegetation were only observed along 0.3%;

- The following summarizes habitat modifications observed:

  - Docks were the most common modification, with a total of 2,718 observed. Both pile supported and floating docks were observed. Also, numerous "dock groynes" were also observed, where lake bed substrates were piled under existing moorage structures.
  - Retaining walls were the second most predominant modification, with a total of 1,799 observed. Some retaining walls extended beyond the high water level of the lake. This construction practice is not compliant with Best Management Practices (i.e. bio-engineering practices for new walls or repairs to existing walls). Retaining walls occupied approximately 20% of the shoreline, which accounts for approximately 58 km;
  - Groynes were the next most commonly observed modification, with over 939 observed. Lakebed cobbles and boulders were most commonly used to construct groynes and it is probable that construction may have required the use of heavy equipment in some instances. The use of lakebed substrates to construct groynes has resulted in significant impacts to emergent vegetation, which is an important juvenile salmon habitat feature. Groynes along the shoreline were typically constructed to improve access and create gravel/sand beaches.
  - A total of 222 concrete boat launches and 41 marinas were observed.
  - Substrate modification was also observed alone 47% of the shore length and was most commonly associated with groynes, retaining walls, transportation infrastructure (e.g., roadway fills), and sand importation to create beaches,

The findings of the FIM indicate that the shoreline areas of Okanagan Lake have been impacted by current and historic land use practices. The current trend of reliance on Best Management Practices and voluntary compliance with the regulations and guidance documents are not resulting in the required protection of important fish and wildlife habitats along the shoreline. It appears that neighbors have mimicked each others' activities and this observation has been made in many lakes that have been mapped using FIM. Finally, there were some shoreline modifications that encroached onto Crown land (i.e., below the high water level).

Given this, all agencies and stakeholders are encouraged to work with the public on better communication and education to ensure that all stakeholders are aware of the habitats present, their values, and the potential influences development activities may have upon them. Recommendations for public awareness and education to facilitate public involvement and compliance in the protection of foreshore areas are contained herein. The combination of education and cooperative enforcement will help reduce the continued losses of habitat along the shoreline and help promote stewardship of the foreshore.

Aquatic Habitat Index

The Aquatic Habitat Index (AHI) for Okanagan 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 in a range between Very High and Very Low (Very High, High, Moderate, Low, and Very Low). The index is relative, because it only assesses the sensitivity of one shoreline area relative to another and is not directly transferable to other lake systems. The following provides a definition for each AHI ranking:

1. Very High - Areas classified as Very High are considered integral to the maintenance of fish and wildlife species and these areas generally occur in either an important floodplain areas adjacent to a salmonid spawning, or wetland habitats. These areas should be considered the highest priority for conservation and protection.
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 and areas can be ranked as high for a variety of reasons. These areas should be considered a priority for maintaining current conditions and a high prioritization for conservation should be given to these areas.
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, such as shore spawning kokanee habitats, but these areas are generally considered more appropriate for development. Because areas of high habitat value may be present, caution should be taken when considering changes in land use to avoid unnecessary harm or degradation to existing habitat values.
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.

The following summarizes the results of the AHI analysis:

- Approximately 61% of the combined shoreline is ranked as High or Very High. Many of these areas occur adjacent to critical stream floodplains, wetlands, Grebe nesting areas, along highly vegetated gravel or cobble shoreline areas, and other important natural habitats around the lake such as suitable Western Ridge Mussel habitat. The abundant high value habitat present is related to the significance and high proportion of rare communities and sensitive fish habitats in the lake.

- Approximately 28% of the shoreline was Moderate habitat value. Moderate habitat value areas are typically associated with sand or gravel shorelines that have experienced some level of habitat alteration due to previous development.

- Approximately 11% of the shoreline is ranked as Low Habitat Value. These areas occur in most intensely developed areas that are not adjacent to any known values of importance.

- The AHI found that approximately 1% of the shoreline is ranked as Very Low habitat value. These areas are mostly found along highly developed shorelines and are quite different than natural shore type conditions.

- All shoreline types are considered salmonid habitat (e.g., staging areas, rearing areas, spawning habitats, or general living). For instance, segments identified as having low juvenile habitat suitability still contribute to overall salmonid production in the lake. Further, there are some instances where high value habitats are embedded within shore line areas of moderate value (e.g., a kokanee Black Zone in a segment ranked as Moderate by the AHI) and these critical habitat areas must be considered independently of the AHI ranking because of their high value.

- The AHI highlights the importance of the connection between our diverse streamside, wetland and lakeshore habitats, and important terrestrial upland areas. 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.

- A restoration analysis was completed by removing instream features. This analysis was accomplished by removing negative habitat parameters in the index and assessing which segments increased in relative habitat value. The restoration analysis does not include assess how changes in riparian condition would improve relative habitat value, but does indicate opportunities to repair impacted instream habitats. Habitat restoration opportunities include removal of groynes, bioengineering retaining walls, planting native riparian vegetation, etc. Habitat improvements will help reverse the current trends of habitat degradation that were observed. It is recommended that habitat restoration opportunities be pursued as part of any development or redevelopment applications.

Recommendations have been presented that are intended to aid foreshore protection, guide future data management, and for future biophysical inventory works. A key recommendation is that:

- Shoreline Management Guidelines are the final step in the three step shoreline management process. This inventory and cumulative analysis of Okanagan Lake provides the framework for development of management policies that can be integrated between local, provincial, and federal governments. Shoreline Management Guidelines are currently in place for Okanagan Lake (Okanagan Large Lakes Protocol (OLLP)), but these guidelines generally only consider critical kokanee shore spawning areas, Western Ridge mussel locations, and a few other items (e.g., stream deltas and rare plants). Numerous local governments also have shoreline policies, and the OLLP and these policy documents are not integrated. Within the Shuswap system, the AHI, and layers such as those in the Okanagan Large Lakes protocols (e.g., Kokanee spawning layers) are used together to develop shoreline guidelines. The results of this assessment could be considered an important addition as a data layer to the OLLP. These guidelines can be used to develop shoreline policies and regulations that are integrated between different levels of government. Once adopted, the guidelines will assist decision makers when making land use decisions across multiple agencies. Guidelines will also streamline the permitting and regulatory processes at these different governmental levels by focusing limited resources on areas or activities that pose the greatest risks by allowing lower risk activities to proceed without the involvement of Fisheries and Oceans Canada.

The inventories and analysis completed as part of this study are expected to aid in the protection of important shoreline resources around Okanagan Lake. Although many impacts were observed along the lake shoreline, it is important to note that there are extremely important habitats present that are in good to excellent condition. The value of this work will be especially important in any shoreline land use and marine development proposals because it will help ensure appropriate management of the vast biodiversity of the Okanagan Lake shoreline.

Comparisons between 2010 and 2004 in the Central Okanagan

Foreshore Inventory and Mapping results from 2004 were compared to results from the 2010 survey. The results of this analysis indicate that change along the shoreline is potentially occurring at rates in the magnitude of 1 to 2% per year. This rate of change may not seem substantial when considered just as a percentage. However, when you consider that only 48% remained natural in 2010 (in areas surveyed in 2004 only), even the loss of 1 to 2 percent per year could mean substantial change in the next 10 to 50 years. For example, currently there is 48% of the shoreline in natural condition and if the rate of change is consistent until 2020, it is estimated the shoreline will be 39% natural. This is nearly a 5 percent decline over the next 10 years. This analysis has simplified an extremely complex system and should not be taken literally. Rather, it should be used as a guide because it provides an estimate of the approximate order of magnitude change that is occurring. The analysis found that in nearly every metric considered (e.g., slope gradient, juvenile rearing, Aquatic Habitat Index, etc.), there was a decline in shore line habitat value over time (measured as loss of percent natural shoreline).

Specific examples that are interesting to consider include the density of shoreline modifications observed between 2004 and 2010. The table highlights the densities of modifications in 2010 and the estimate of density in 2020 that were prepared using a simple best of fit line for the two data points. Again, this analysis is very simple and subject to numerous assumptions and potential sources of error and should be used as an order of magnitude interpretation tool rather than to directly predict future densities.

Table: The density of docks, groynes, boat launches, retaining walls, marinas and marine rails on Okanagan Lake in 2010 and predicted for 2020 using a simple best of fit linear line.

Type	2010	2020
	Density (#/km)	Density (#/km)
Docks	10.27	12.0
Groynes	4.66	10.7
Boat Launch	0.72	1.1
Retaining Walls	7.76	11.2
Marinas	0.19	0.4
Marine Rails	0.61	0.9

The comparative analysis provides a clear rationale for the recommendations. The data collected corroborates concerns about shoreline condition that have been raised by citizens, politicians, and environmental practitioners. Implementation of key recommendations should occur in short order because the order of magnitude rates of change are now known and they predict that substantial and measurable change will occur in the period of one or two generations if appropriate steps are not implemented now.

Through continuing FIM and mapping efforts in the future, it will be possible to establish the effectiveness of mitigative and management steps taken. By analyzing rates of changes and relating those to implementation of policy it will be possible to identify if steps taken are effective. An integral part of this policy development will include setting clear and attainable objectives for shoreline condition. Setting of these objectives within a Shoreline Guidance Document is considered the most important next step in policy development for Okanagan Lake.

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Wes Miles, Regional District Central Okanagan
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DISCLAIMER

The results contained in this report are based upon data collected during field surveys occurring over a short durations throughout the period of one year. 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, project partners, nor the authors of this report, are liable for accidental mistakes, omissions, or errors made in preparation of this report because best attempts were made to verify the accuracy and completeness of data collected and presented.

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APPENDIX

1.0 INTRODUCTION

The desire to live and recreate in the Okanagan watershed has resulted in a dramatic increase in development pressure on the system. The Okanagan Collaborative Conservation Program and project partners have undertaken a number of planning initiatives to facilitate better information sharing and develop land use policies along Okanagan Lake. Through these planning processes and initiatives, it can be concluded that past development along Okanagan Lake has impacted fish, wildlife, rare plants and terrestrial communities, and/or water quality. As a result of these impacts, project partners are working cooperatively to prevent future impacts to the lake and foreshore.

A complex relationship exists between development pressure, the natural environment, and social, economic and cultural values. In an effort to balance these various community values, a solid understanding of aquatic and riparian resource values, land use interests, and community concerns is needed to formulate long-term planning and policy objectives. Development of long term planning objectives at the local, provincial and federal agencies is also required so that our aquatic resources are effectively managed in a collaborative framework. Detailed shoreline inventories increases the knowledge base of the environmental resources present, allowing all stakeholders to understand how development may affect these habitat features. With this information, better informed land use planning decisions can be achieved resulting in superior natural resource protection.

Of particular importance and the focus of this report, is the link between the aquatic and terrestrial environments along Okanagan Lake. The foreshore – that part of the shore between the high and low water marks – has significant biological, ecological and social significance to residents in the Okanagan Basin and is extremely sensitive to disturbance. (RDCO, 2005). In this report, foreshore and shoreline are used somewhat synonymously. The shoreline, or the area that occurs in proximity to the lake (e.g., within 50 m) through the foreshore to the end of the littoral zone (area of greatest biological productivity), is also extremely important.

Regulators at all levels of government are becoming increasingly aware of the importance of managing our watersheds in a sustainable manner. Land owners and the general public are often concerned about their watersheds and may not understand how they are being managed. Current management practices being implemented in the Shuswap and Kootenay regions are utilizing a three step process. The goals of this process is to help integrate available environmental data (both quantitative and qualitative) with land use planning information to facilitate review and decision making processes at all levels of government. The specifics for implementation vary by region, but generally utilize this process. This study has resulted in two of three steps having been completed with the third and final step outstanding at this time. The three steps include:

1. Foreshore Inventory and Mapping (FIM) – FIM is a broad scale inventory process defines and describes the shoreline condition 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 or impact (e.g., # of docks, groynes, etc.). Data collection allows 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, additional 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). While the index does provide an indication of the relative value of one shoreline area to another, it does not compare these shorelines with shorelines on other lake systems and is not directly transferable.

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 development applications. It is intended to be the first step for review, planning, and prescribing shoreline alterations (i.e., land development) by applicants and review agencies. At this time, the Okanagan Region Large Lakes Foreshore Protocol (OLLP) is the guidance document for Okanagan Lake at the provincial level. This document identifies known kokanee spawning areas, known western ridge mussel locations, and stream deltas as sensitive features. This policy document is only applicable to works occurring below the high water level. Local governments also have a variety of different policy documents that govern land uses above the high water level, including Official Community Plans and Bylaws. At this time, there is not a common understanding of lakeshore sensitivity, which makes integrated governmental policy difficult. The works contained within this assessment provide a framework for an integrated shoreline policy document. The outcomes of this assessment should be integrated into the Okanagan Region Large Lakes Foreshore Protocol (OLLP) and local government policies when time and budgeting permits in a formal guidance document. It is expected that implementing this work into a new guidance document will facilitate better decision making across all levels of government because not the OLLP is not current in use by local government policies because it pertains largely to

structure below the HWL. Another benefit is that this study considers numerous other biological criteria (e.g., wetlands and shore marshes, Western Grebe nesting areas, aquatic vegetation, adjacency to sensitive terrestrial features as identified by the Sensitive Ecosystem Inventory (SEI), migration and staging areas, etc.) that are not currently being considered in the OLLP or within a regional approach to shoreline management. Thus, incorporation of this assessment will be more inclusive of sensitive shoreline areas if it can be integrated into the existing OLLP in some fashion.

This report presents Step 1 and Step 2 for Okanagan Lake. Ongoing efforts in the development of the Shuswap Lake Shoreline Guidance document will help facilitate integration of this work with the OLLP for Okanagan Lake in a Step 3 Guidance Document. In the absence of a formal shoreline guidance document, the OLLP is considered the guiding policy document for features below the high water level (instream).

2.0 PROJECT OVERVIEW

Okanagan Lake supports many non-anadromous (non-sea run or resident) fish stocks, which significantly contribute to First Nations' and sport fisheries. These fish stocks also contribute significant cultural value to local eco tourism opportunities, such as kokanee spawning observations in Mission or Deep (Peachland) Creeks. The lake also provides critical habitats for numerous fish and wildlife species. Finally, the lake is a source of drinking water for a substantial proportion of Okanagan residents. For these reasons, protection of the various environmental values is extremely important and is integral to a functional lake and watershed.

Okanagan Lake is arguably the most important natural resource in the Okanagan for ecological, social and economic, and cultural reasons. The Okanagan has experienced unprecedented development pressure in recent years and development activities are affecting the natural resource values. Responsible and appropriate management of these resources is increasingly recognized by local, provincial, and federal governments, First Nations and the general populace as vital to the future of this region. Community members have raised a number of concerns with regard to the impacts adjoining land uses and recreational uses are having on the lake. This work provides an opportunity for project partners to support an initiative that will inform future policy development and allow for improved management of these resources. The information generated from this project and future steps, including the development of an integrated shoreline management guideline, will help develop policy and promote management that is more comprehensive than the current OLLP. From a local government perspective the project will provide a valuable resource when reviewing land use applications in the area by flagging areas of concern. This work can also be used in the development of Official Community Plan and Local Area Plan policies.

While local residents have expressed a strong desire to preserve and protect Okanagan Lake, baseline data to support these goals for the lake *as a whole* has been not readily available until now. The previous foreshore inventory works on Okanagan Lake, with the first FIM in 2004, have generally only considered specific shoreline areas within smaller local government jurisdictions (e.g., City of Kelowna, Regional District Central Okanagan, etc.). The intent of this project is to provide a baseline overview of the shoreline condition of Okanagan Lake in its entirety.

The methodology employed for this assessment is discussed in detail below and is a consistent with provincial standards being used to map shorelines around the province. The mapping protocol will allow stakeholders to understand current shoreline conditions, set objectives for better shore management, and measure and monitor changes in the shoreline overtime.

This project is a two part process:

- Compile existing FIM data completed from initial works in 2004 with more recent works in the north, south, and central regions in 2009 and 2010. This involved development of one data base for the entire Okanagan Lake to the most recent version of the Foreshore Inventory and Mapping methodology and provide an overview of shoreline condition for the lake as a whole; and
- Develop an Aquatic Habitat Index and rank the sensitivity of the shoreline of Okanagan Lake.

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 7 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.

The following previous FIM reports were used in this assessment:

1. Central Okanagan Foreshore Inventory and Mapping (2004)
2. Foreshore Inventory and Mapping: Okanagan Lake North (2010)
3. Foreshore Inventory and Mapping: Okanagan Lake South (2010)

This project was funded by the following agencies and organizations:

1. Regional District Central Okanagan
2. City of Kelowna
3. Regional District Okanagan Similkameen
4. Okanagan Collaborative Conservation Program
5. District of West Kelowna
6. District of Lake Country
7. City of Vernon
8. The District of Peachland
9. Okanagan Basin Water Board
10. Fisheries and Oceans Canada
11. Community Mapping Network
12. Ministry of Environment

2.2 Objectives

The following are the objectives of this project:

1. Compile existing resource information for Okanagan Lake;
2. Foster collaboration among the local governments (RDCO, RDOS, Kelowna, Peachland, West Kelowna, Lake Country, Vernon), DFO local staff, Ministry of Environment, First Nations bands, and the local communities;
3. Provide an overview of foreshore habitat condition on the lake;
4. Inventory foreshore, land use, riparian condition and anthropogenic alterations and illustrate foreshore morphology;
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. and Okanagan Habitat Atlas.

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

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

9. Develop an Aquatic Habitat Index that ranks the sensitivity of shoreline areas relative to each other;

10. Act as a "flagging tool" based upon information currently available;

11. Provide a framework and common understanding of sensitive areas of Okanagan Lake as a whole to facilitate improved resource management;

12. Provide a baseline data set for Okanagan Lake as a whole that can be utilized to develop long term objectives, conservation and protection areas, and allow for monitoring of any objectives prepared;

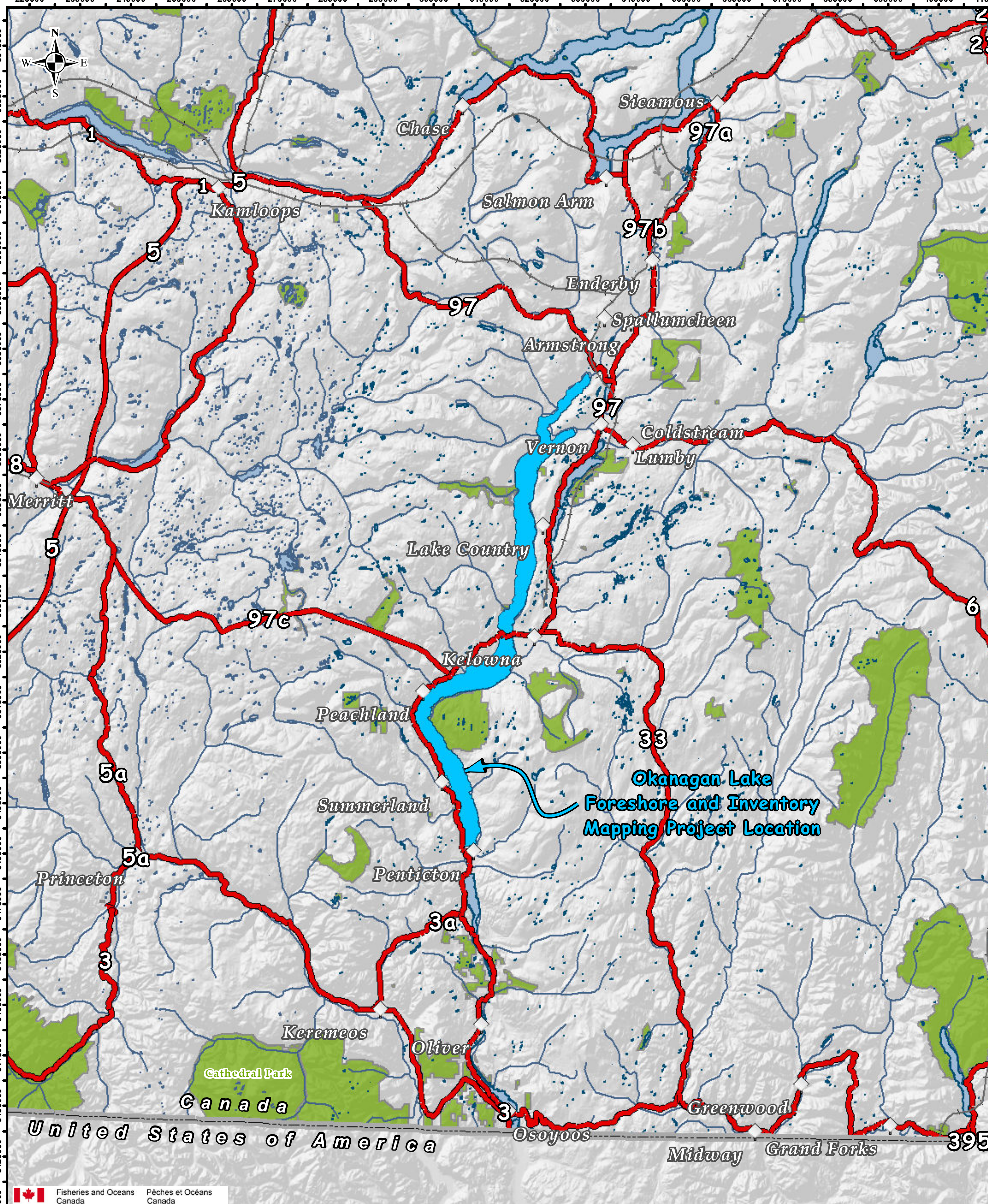
13. Provide a summary of potential locations where habitat improvements are possible along the shoreline based on habitat potential; and,

14. Provide a framework for integration of information with upland development planning in an effort to protect sensitive foreshore areas.

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, that integrate the OLLP and this data will provide more detailed and comprehensive guidelines to meet long term objectives for lake protection.

2.3 Study Location

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



Okanagan Lake

Foreshore Inventory and Mapping

Figure 1 - Project Location

2.4 Important Fisheries and Wildlife Resource Information

Okanagan Lake contains numerous fish stocks that are important public resources. The most important fish stock is kokanee, a land locked sockeye salmon. This fish is considered a keystone species because of its many interactions with other species. Kokanee are a critical fall food source for bears, eagles, Osprey, and other species and the spawned out carcasses of the adults provide fertilizer for terrestrial and aquatic ecosystems. Salmon are also an indicator species for the overall health of the ecosystem because they are highly sensitive to changes in their habitat (e.g., reductions in water quality). Other important fish stocks include rainbow trout, whitefish (both mountain and lake), and burbot (fresh water cod).

The focus of fisheries management is to further recover stocks of kokanee, which are increasing from historical lows several years ago. The Okanagan Region Large Lakes Fisheries Operational Management Plan 2007-2011 (Redfish, 2007) provides an excellent summary of important fisheries management objectives and concerns. Coupled with this work, the Okanagan Lake Action Plan has provided invaluable information to help understand important trophic interactions in the system (see http://www.env.gov.bc.ca/okanagan/esd/olap.html). Some of the key fisheries issues identified in the management plan were: 1) addressing foreshore development, 2) impacts to lakeside riparian habitats, and 3) addressing losses of kokanee shore and stream spawning habitats (Redfish, 2007).

The fish stocks are also very important to First Nations' culture. The stocks have significant cultural value and within the Okanagan watershed, attempts are being made to increase the stock to a point where harvest may again be possible. Kokanee also contribute to local eco-tourism opportunities (e.g. spawning viewing in the Peachland (Deep) Creek or Mission Creek).

Okanagan Lake also has important habitats for wildlife species (e.g., see the numerous SEI inventories, Conservation Data Centre information, etc.). Numerous waterfowl and predatory birds rely upon the lake. For example, the Western Grebe has known breeding grounds in the north arm (Burger, 1997). This breeding ground is one of only three in the southern interior, which elevates the importance of protecting this habitat. These birds nest on floating bulrush mats and are very sensitive to impact from recreational boating activities, which may overturn nests. Along Okanagan Lake, recreational boating and foreshore development were identified as the two greatest threats to the breeding colony (Burger, 1997). This waterfowl species is one of many which use habitat around the lake. There are numerous other wildlife species, such as the reptile group (e.g., Western Rattlesnake), that rely upon the foreshore areas of Okanagan Lake.

This brief overview highlights the importance of fisheries and wildlife resources along Okanagan Lake and provides clear rational for completion of this shore line inventory project. The concerns discussed above but a few of the many that have been, or will continue to be identified in the coming years along the lake.

3.0 FORESHORE INVENTORY & MAPPING METHODOLOGY

The Foreshore Inventory and Field Mapping detailed methodology (FIM) 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 Okanagan Lakes Foreshore Inventory and Mapping.

3.1 Field Surveys

Field surveys for this project have been carried out over the last 3 years and have integrated through this project. The original FIM conducted for the Central Okanagan in 2004 was updated in order to ensure a consistent database to enable an overall analysis of Okanagan Lake as a whole. The South Okanagan Lake assessment was completed between June 22 through June 26, 2009. Field surveys for the North Okanagan Lake were conducted on August 13 and 14, 2009. Field surveys within the Central Okanagan were conducted on September 15 through 18, and October 13, 2009.

Field surveyors were each assigned data to collect during the surveys. Field assessors used 11X17 inch (Tabloid), 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. Finally, digital photographs, with a GPS stamp, were collected.

Other field surveys conducted included the GPS digital video, completed by Fisheries and Oceans Canada staff. The specifics of the GPS digital video are discussed in the FIM methodology.

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

- Photo documentation of the shoreline for the main areas of development;
- Record data relating to the presence or absence of development such as retaining walls and boat launches.

Weather during the surveys was generally overcast, and no significant storm events occurred. 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.

3.2 Methodology

All of the methods outlined in Appendix A for Foreshore Inventory and Mapping projects were carried out for this assessment. Daily information collected was downloaded to a laptop as a backup. Once downloaded, the entire database was reviewed for accuracy and corrections were made as necessary. 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. These areas are important fish habitat. Also, areas of extensive overhanging vegetation (from the high water level) were also mapped. Not all aquatic vegetation areas could be mapped due to the late timing of surveys and significant size of the foreshore in many areas. For these reasons, additional areas of vegetation may also occur that have not been identified within this assessment. Finally, high resolution air photos were only available for a portions of the shoreline; therefore, air photo interpretation accuracy is not as good within lower resolution air photo areas and information has been prepared as accurately as possible with data available. 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. Attempts were made to map the locations of boat launches, boat mooring zones / haul outs, extensive riparian areas, and other features of interest. Not all locations of these features could be mapped due to the quality of air photos available at the time of survey.

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 within the Kelowna Shorezone Assessment. 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 *Potemogeton* 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,* pond lilies, and other types of vegetation that has vegetative parts that floats.

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 GPS camera that stamps photos and creates GIS shapefiles, 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 various flights by numerous agencies. All mapping was completed on the most recent and highest quality we could obtain.
- 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. The HWL assessment for Okanagan Lake could be improved with higher resolution air photos when they become available and better digital elevation modeling. 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. For this assessment, the 343 contour elevation was considered the HWL. It is acknowledged that the mean annual high water level of the lake is approximately 342.6 m above sea level.

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 City of Kelowna Shorezone assessment (Schleppe and Arsenault, 2006). The following describes fisheries fields added and the original data source for the fields:

   a. Juvenile Rearing shoreline habitat value (High, Moderate, and Low) was prepared by Ecoscape for this project. Since shoreline utilization data is unavailable, 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 learn 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. Ecoscape prepared spatial files identifying areas of key migration and these areas were reviewed by Ministry of Environment biologists for confirmation. To develop these migrations 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. 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 this criterion is very similar to the "Staging" field.

   d. Staging – A Yes / No field to describe salmon staging areas was added. Staging areas occur where fish will concentrate or congregate prior to migrations. Staging areas were created based upon liaison with Ministry of Environment and DFO staff through the course of field work on this assessment and based upon professional opinion of the author. Areas where fish were known to stage or hold prior to migrations and shore areas where migrations are likely present were identified (Yes or No). In general, these areas are loosely defined and vary over space and time. The information presented is limited to the confluences of known salmon spawning streams, where fish are known to congregate before migrations. Information is limited and it may not entirely reflect all locations or spatial extents of staging areas. Further, this field has generally not considered shore spawning kokanee migration areas. Future surveys should be used to better understand where mature adults hold during migrations.

e. Mussels - The Western Ridged Mussel is the most important mussel species in the lake. There is limited survey work for this species to identify key habitat areas for all life stages. Further, some of the host species are still unknown. For these reasons, Ecoscape used cautionary principles to apply this feature to the FIM dataset. The Red and Yellow Zones prepared by the Ministry of Environment identify known locations or highly suitable locations for adult stages. These tended to occur in a clustered fashion, primarily in the south with a few in the Vernon arm. Shoreline segments that were in proximity to clusters, were considered to be suitable adult mussel habitat for the index. These areas may not identify all key habitat areas for all stages of the mussel. More detailed surveys should be completed and further work on understanding the life history should be undertaken to confirm and better identify the spatial extent of key habitat areas for all life stages of this species.

f. Kokanee Shore Spawning Zones - The database contains a summary of the percentage and total shore length for the Black (Per_Black, Bl_Shore_Length), Red (Per_Red, Re_Shore_Length), Yellow (Per_Yel, Yel_Shore_Length) and No Colour Zones (Per_Nop_Colour, No_Colour_Shore_Length) identified within the Okanagan Large Lakes Protocol. These areas have been identified as the key habitat areas for spawning adults.

4. Western Grebe suitable nesting areas in the North Arm were identified. Suitable areas were based upon a significant presence of emergent bulrush vegetation. Suitability rather than known nesting locations were used due to the limited breeding area available or provided to us. Given that breeding grounds are limited, all suitable areas should be considered important.

5. A rare plant species layer was added, using data from the OLLP. Only a few sites had rare plants identified, and a Yes / No flag was added to the database indicating the presence of rare plant species. Due to the limited survey information, this database field is not considered inclusive of all occurrences and others may exist.

6. Sensitive Ecosystem Inventory is available for most of the shoreline of Okanagan Lake. To include this sensitive terrestrial information within the AHI, the intersects between Wildlife Corridors, Core Conservation Areas, Other Areas of Importance, and Not Applicable Areas polygons and shoreline segments was completed. For each segment, the total length of these different categories was used. For areas where SEI has not yet been completed, or areas where only Terrestrial Ecosystem Mapping was available, segments were manually classified by Ecoscape using similar criteria to the SEI. The following descriptions, taken directly from the Core

Conservation Analysis and Updated Ecosystem Mapping for Central Okanagan Valley (Haney and Iverson, 2009) have been included for reference[1]:

a. ***Core Conservation Areas -*** *Areas with a large concentration of high and some moderate conservation values were identified as core conservation areas. These would be the areas of highest priority for conservation. Ideally, activities would be primarily directed towards maintaining ecological and wildlife habitat values in these areas. There may be small areas within the core areas that could be accessed and developed without compromising core values (e.g., by fragmentation); further larger scale mapping and wildlife inventory would be needed to identify these areas. Core areas are high priorities for acquisition by land trusts, conservation organizations, for Regional Parks, and should be zoned for environmental purposes.*

b. ***Buffers -*** *Areas with a large concentration of high and some moderate conservation values were identified as core conservation areas. These would be the areas of highest priority for conservation. Ideally, activities would be primarily directed towards maintaining ecological and wildlife habitat values in these areas. There may be small areas within the core areas that could be accessed and developed without compromising core values (e.g., by fragmentation); further larger scale mapping and wildlife inventory would be needed to identify these areas. Core areas are high priorities for acquisition by land trusts, conservation organizations, for Regional Parks, and should be zoned for environmental purposes.*

c. ***Wildlife Corridors -*** *Wildlife corridors provide animals with an opportunity to move freely between two or more habitat patches or habitat types in an otherwise fragmented landscape. This movement is essential to provide genetic links between populations and prevent inbreeding, and to compensate for temporary population declines in one of the habitat patches. The habitat needs of all priority species should be incorporated into the design of the corridor. Corridors must be suitably wide, with appropriate habitat features to provide security cover during movement. Corridors usually consist of linear habitats such as gully or streamside riparian areas; they are often composed of two or more ecosystem types to provide complexity to the corridor. Development and roads should avoid these zones, and mitigation will be required where roads and other developments transect the corridor. Wildlife corridors were identified to connect core areas to each other and to outside the study area.*

In some cases, important corridors have already been fragmented by roads or other disturbances, and connections need to be restored. Although

[1] Additional SEI references are included in the references section of this document. Readers should refer to the full suite of SEI data collected for further information on these various terrestrial projects throughout the Okanagan.

challenging, it is imperative to restore connections through Ellison and the western portion of West Kelowna in particular.
Larger scale mapping and additional wildlife inventory might identify some small areas that could be developed without compromising connectivity and other corridor values. This would depend upon the type and configuration of development, and site-specific issues.

d. ***Other Important Conservation Areas -*** *Areas with a concentration of moderate conservation values, or small and isolated areas of high values, were identified as other important conservation areas. Activities would be directed towards maintaining ecological and wildlife habitat values. There would be areas within that could be accessed and developed without compromising some ecological values; further larger scale mapping and wildlife inventory would be needed to identify these areas.*

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

8. An Aquatic Restoration potential analysis (AHI_POT) which was completed by removing instream features from the AHI results was also incorporated into the database. 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*. A more detailed analysis of habitat restoration opportunities, including riparian restoration is advised in the future.

3.2.3 2004 Foreshore Inventory and Mapping Comparison

In 2004, the original FIM mapping was compiled for Okanagan Lake. The premise of this initial work was to inventory the shoreline of the lake and provide a basis to measure change along the shoreline. In 2010, the shoreline of Okanagan Lake was inventoried again using the same methodology. It has been approximately 6 years since the lake was last surveyed and an analysis of change has been complete for all jurisdictions that fall within the original 2004 survey area. These areas include the Regional District Central Okanagan (Areas East and West), City of Kelowna, District of West Kelowna, District of Lake Country, and Westbank First Nations.

The databases between 2004 and 2010 are slightly different. The FIM database version used in 2010 is the most commonly used version in use at this time. Primary differences between the two include differences in Land Use Categories and Shore Types. For these reasons, the analysis focused on the comparing the following factors:

1. Percentage of Natural and Disturbed Shoreline;
2. The percentage of natural shoreline along different slope categories (e.g., Bench, Low (<10%), etc.
3. The density of shoreline modifications (e.g., docks, groynes, retaining walls, etc.).

4. The percentage of shoreline classified as having a High, Moderate, or Low level of Impact;
5. The percentage of natural shoreline found within areas classified as being High, Moderate, or Low Juvenile Rearing Value.
6. The percentage of natural shoreline within areas classified as a Black, Red, Yellow, or No Color Kokanee shore spawning area.
7. The percentage of natural shoreline in areas classified as being Very High, High, Moderate, Low, or Very Low by the Aquatic Habitat Index.

To complete the above analysis, the segment numbers in the databases were rectified with each other between 2004 and 2010. The databases needed to be rectified because some segments were split out in 2010 due to changes in shore type and due to recent developments. A qualifier is contained in the database to identify how the segments were split. Some small changes were made to the 2004 database to reflect the changes in the 2010 database. These changes were minor and ensured consistency between the databases. For example, in 2004, some shorelines classified as a High Level of Impact were 40% natural and some were classified as Moderate if they had 40%. This example was only apparent in a few circumstances. Other examples of changes made include assuming that for split segments, the disturbance levels of each resultant segment split was the same. However, in one or two cases, this assumption skewed results which became apparent in the jurisdictional analysis. In all cases where data were skewed due sampling changes such as this, adjustments were made using air photo interpretation, appropriate assumptions, or other logic to correct for the changes. Best attempts were made to rectify the two databases to ensure a consistent level of comparison between years.

The analysis of data for the two databases focused on the rate of change. By looking at the percent of natural shoreline in 2004 and in 2010, it allowed tracking of the change in shoreline condition from a natural state to a disturbed state. In looking at the data in this fashion, it is possible to understand both the rate of change and the direction (i.e., is the shoreline becoming more natural or more distured). A simple best of fit line (using Excel) was used to determine this. The equations for the best of fit lines can be found on the figures.

4.0 AQUATIC HABITAT INDEX METHODOLOGY

An Aquatic Habitat Index (AHI) can be used as a tool that 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 Shuswap Lake, Mabel Lake, 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 with higher estimated significance are assigned higher relative values by increasing the weight applied to them within the index. Features impairing the habitat value (e.g., groynes) are assigned negative scores to better reflect the current condition of the shoreline.

Subsequent analysis assessed the habitat potential of a segment. This analysis involved removing ALL negative habitat parameters to determine if shoreline restoration could achieve a measurable benefit. The Habitat Potential index can be used to help assess where instream restorative efforts are best 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 from previous works. In many instances, data gaps have been identified and assumptions have been made. As more information is collected regarding shoreline areas of Okanagan 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;
4. Terrestrial; and,
5. 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 Okanagan 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	8.8	% 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	7.0	% Substrate * Maximum Point	Yes	Cobble (12) > Gravel (10) > Boulder = Organic = Mud = Marl = Fines (8), Sands (4) > Bedrock (2)
	Percentage Natural	5	10.4	2.9	% Natural * Maximum Point	Yes	
	Aquatic Vegetation	8	16.7	4.7	% Aquatic Vegetation * Maximum Point	Yes	
	Overhanging Vegetation	4	8.3	2.3	% Overhanging Vegetation * Maximum Point	Yes	
	Large Woody Debris	4	8.3	2.3	# of Large Woody Debris/km * Relative Value * Maximum Point	Yes	**Relative Value** >15 LWD/km (1) > 10 to 15 LWD/km (0.8) > 5 - 10 LWD/km (0.6) > 0 - 5 LWD/km (0.4) > 0 LWD/km (0)
Fisheries	Kokanee Spawning	20	29.4	11.7	% Shore Length of Colour Zone * Score	Yes	Black Zone = 20, Red Zone = 10, Yellow Zone 5, No Colour Zone = 0
	Juvenile Rearing	10	20.8	5.8	High (12), Moderate (6), Low (3)	No	High (12), Moderate (6), Low (2)
	Migration Corridor	8	21.1	4.7	Present (8), Absent (0)	No	Present (5), Absent (0)
	Staging Area	8	26.7	4.7	Present (8), Absent (0)	No	Present (5), Absent (0)
	Mussel	12	54.5	7.0	Present (12), Absent (0)	No	Present (12), Absent (0)
	Grebe	10	14.7	5.8	Present (10), Absent (0)	No	Present (10), Absent (0)
Shoreline Vegetation[2]	Band 1	8	66.7	4.7	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	2.3	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)
Terrestrial	Conservation Core Areas	10	28.6	5.8	% Shore Length of Colour Zone * Score	Yes	% Length of Conservation Area * Value
	Conservation Buffer Areas	3	8.6	1.8	High (12), Moderate (6), Low (3)	Yes	% Length of Buffer Area * Value
	Wildlife Corridor	8	22.9	4.7	Present (8), Absent (0)	Yes	% Length of Wildlife Corridor * Value
	Other	8	22.9	4.7	Present (8), Absent (0)	Yes	% Length of Other Area * Value
	N/A	1	2.9	0.6	Present (8), Absent (0)	Yes	% Length of N/A Area * Value
	Rare Plants	5	14.3	2.9	Present (8), Absent (0)	Yes	% Length of N/A Area * Value
Modifications	Retaining Wall	-2.00	25.1	-1.2	% Retaining Wall * (-2)	Yes	% Retaining Wall * (-2)
	Docks	-1.76	22.0	-1.0	# Docks/km * (-0.05)	Yes	# Docks per Kilometer * (-0.05)
	Groynes	-1.71	21.4	-1.0	# Groynes/km * (-0.1)	Yes	# Groynes per Kilometer * (-0.1)
	Boat Launch	-0.50	6.3	-0.3	# Launches * (-0.25)	No	# Launches * (-0.25)
	Marina	-2.00	25.1	-1.2	# Marina * (-1)	No	# Marina * (-1)

1. Numbers have been rounded to the nearest whole number. 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. The general habitat specificity for Okanagan Lake follows that of the original assessment for the central regions of Okanagan Lake, except that wetlands have been accorded the highest shore value possible (i.e., equivalent to a stream confluence). This was done because of the rarity of wetlands on this lake, the habitat diversity present in wetland areas, and their contributions to biomass and water quality.

2. Substrate – Substrates also relate directly to productivity. In general, there are two types of productive substrate, those utilized for spawning and those that produce more biomass. The substrate values and parameters used for Okanagan Lake are similar to Shuswap and Mabel and are originally based upon species habitat matrices developed for Okanagan Lake in the Kelowna Shorezone Assessment (Schleppe and Arsenault, 2006). Substrates utilized for spawning were given higher weighting than those for foraging. Areas of bedrock were considered the least valuable because they are not utilized for spawning and do not provide good foraging areas for fish.

3. Percent Natural –Areas of natural shoreline have a relative habitat value that is greater than disturbed shoreline areas because the condition of the habitat is better. The value of this parameter in the index is the same as Shuswap and Mabel but is still less than the original AHI for central regions of Okanagan and Windermere Lakes. This value was given less weighting from the original AHI within the City of Kelowna limits on Okanagan Lake (Schleppe and Arsenault, 2006) Lake because the devaluing effects of disturbance are believed to be less than original inferred in the AHI for the City of Kelowna areas.

4. Aquatic Vegetation – In more recent versions of the FIM database, more detailed information regarding aquatic vegetation was collected. On Okanagan Lake, all vegetation below the HWL is considered productive. Since the FIM now allows analysis of this parameter, it was added to the index following the same methods as Shuswap Lake. The benefits of aquatic vegetation are many and include forage, biomass production, cover, etc. For Okanagan Lake, the relative value of aquatic vegetation was increased slightly from Mabel and Shuswap because impacts to historical vegetation areas is considered to be greater. The remaining vegetation areas have a slightly higher relative value because of the historical impacts (e.g., most shoreline areas within the City of Kelowna have had almost all large woody debris and emergent floodplain areas affected reducing the cover of aquatic vegetation).

5. Overhanging Vegetation – In the more recent FIM database versions, more detailed information regarding overhanging vegetation was collected. Along Okanagan Lake, overhanging vegetation was documented infrequently, likely due to the dry arid climate, steep shorelines in many areas, and past historical development along floodplain areas within Kelowna. Since it provides nutrients and opportunities to forage, it was added to the index.

6. Large Woody Debris – The detailed large woody debris information collected was used in the index because it has importance for salmonid and other species. Large Woody Debris was not present in many areas. Woody debris was absent for several reasons, including proximity and quantity associated with sources such as large rivers, and removal from "beach grooming" activities by residents in areas where shore drop would typically occur. Since large woody debris provides nutrients, cover, and opportunities to forage, it was added to the index. Numerous studies have identified the importance of large woody debris to salmonids in lake and stream systems.

4.1.2 Fisheries Parameters

The fisheries parameters used for the Aquatic Habitat Index were based upon those described above in Section 3.2.2 – GIS and Data Management. These different parameters are considered important for fish production in the Okanagan system 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 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 Okanagan Lake (without a field sampling confirmation component). The values of Sand shore types and sand substrates was increased in the Okanagan Lake index (when compared to Mabel) to account for the increased substrate modification and impacts to historical floodplain shores that would have been classified as wetlands. The following criteria were used in the Juvenile Rearing Habitat Suitability Index for Okanagan Lake.

Table 2: The parameters and logic for the Juvenile Rearing Habitat Suitability of Okanagan 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/km (1) > 10 to 15 LWD/km (0.8) > 5 - 10 LWD/km (0.6) > 0 - 5 LWD/km (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 the nearest whole number. 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 h

The juvenile rearing suitability is only one fishery criteria and only comprises 6.5% of the overall Okanagan 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 in Okanagan Lake. 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 (13.8%) 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 proximity to known spawning areas in streams. Areas classified as Migration routes encompass shoreline areas where fish must either migrate out from or into a river or stream system. These areas overlap extensively with Staging Areas. Migration routes consider only resident species (e.g., rainbow and kokanee). The value of migration areas was increased from the Mabel Lake assessment because the development intensity around key spanwing streams (e.g., Mission Creek) was greater, increasing the importance of this habitat requisite.

3. Staging – Staging areas were prepared based upon liaison with Ministry of Environment field staff, the spatial extents of a shore segments, and the best professional judgments of important staging areas. During the field collections, field staff indicated to Ecoscape where fish were known or suspected to stage or hold prior to migrations. The areas generally only encompass shoreline areas where fish must either migrate out from or into. These areas overlap extensively with Migration areas. Staging areas were also increased in value from Mabel Lake, to adjust for the increased development pressure around key salmonid spawning streams.

4. Mussels –The Western Ridged Mussel is the most important mussel species in the lake. Shoreline areas considered to be suitable to Mussels were included in the index.

5. Kokanee Shore Spawning Zones - Kokanee shore spawning significance, determined by the Ministry of Environment Okanagan Large Lakes Protocol, was used in the index.

4.1.3 Shoreline Vegetation Parameters

The riparian parameters added to the index were similar to those added in the Mabel, Shuswap and Windermere Lakes. The FIM provides a distinction between the lakeside vegetation (Band 1/Riparian) and the areas behind (Band 2/Upland). To address this new data, the index was modified to include a factor assessing vegetation quality (i.e., tall shrubs 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 m to 10 m, 10 m to 15 m, 15 m to 20 m and greater than 20 m. The Band 1 vegetation, directly adjacent to the lake is attributed more points than the Vegetation Band 2 because of its direct proximity to aquatic habitats.

4.1.4 Terrestrial Parameters

The terrestrial data fields discussed above were included in the habitat index. The following were criteria that were added:

1. Rare plant species have been documented in a few areas along the shoreline. The occurrences of these species is important because of their rarity. Because data was limited, this criteria was not given much weight in the index.

2. Core Conservation Areas are extremely important terrestrial areas because they are critical to wildlife and sensitive terrestrial communities. This criteria was included as a weighted parameter in the index. The criteria was incorporated by using the percentage length that these areas occur along the shoreline.

3. Buffers are important to the maintenance of important core conservation areas. This parameter was included in the index as a weight parameter using the percentage length of the segment where corridors are present.

4. Wildlife Corridors are important linkage areas between upland terrestrial areas and Okanagan Lake. The SEI identified important corridors and these corridors were included as weighted parameters using the percentage length they occur along a segment.

5. Other Important Conservation Areas are places of moderate conservation value. These areas were incorporated into the index as a weighted parameter by using the percentage length they occur along the shoreline.

4.1.5 Habitat Modifications

Habitat modification parameters are described by Schleppe and Arsenault (2006). These descriptions provided a good rationale for inclusion of these different parameters in the AHI. Other habitat modifications 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.

On the Okanagan system, many retaining walls have been constructed to create level building areas or level areas for turf and other landscaping. This construction has resulted in significant impacts to riparian vegetation and foreshore substrates.

Docks

The negative effects of docks on fish habitat are controversial. On one hand docks may provide areas of hiding from 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 with 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.

On Okanagan Lake, it has been observed that kokanee avoid spawning under large shaded areas (e.g., docks in excess of 3 or 4 m in width that area close to current water level, J. Schleppe and K. Hawes, personal observation during shore spawning surveys on Okanagan Lake), degrade / shade shoreline vegetation, result in requests for dredging, and facilitate moorage in shallow water resulting in prop scour. These impacts pose unique challenges to site specific and lake wide dock management practices on this lake system.

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)

On Okanagan Lake, groynes are habitat modifications that result in localized impacts that are significant. The total extent of impacts observed was as significant significant as Shuswap Lake, but the individual occurrences had smaller local effects because the foreshore is not as large (i.e., 1m drawdown in Okanagan versus 3 m in Shuswap). Construction of these features was most often accomplished by utilizing local lake bed substrates. Construction of groynes using natural lakebed substrates has resulted in significant degradation of habitat including loss of emergent vegetation zones, possible sediment deposition in possible char spawning zones (unconfirmed), destabilization of shoreline substrates, etc. Migration of juvenile fish may also be affected by groynes. Although not as well understood, it is probable that these structures are forcing migrating juveniles to deeper water zones where they are more susceptible to predation.

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 and the fact that they may also act as groynes affecting natural long shore drift patterns.

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.

The above were common modifications that were observed that could be easily quantified and added to the habitat index. The devaluing effects of modifications were determined through a series of iterations and are consistent with other large lakes. Further research on the extents and magnitude of devaluation due to construction of these features is required.

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 instream restoration will result in the greatest potential benefit. This category does not consider riparian restoration impacts because of the classification effort that is required to generate (i.e., a predictive mapping approach would be required).

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 five class ranking system reflects the current value of the shoreline relative to other areas within Okanagan Lake. The Mabel Lake index was used as a baseline because of the many similarities between the two systems. To calibrate the index, 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, the minimum, maximum, median, and distribution of scores was reviewed. After reviewing the distribution of the data from the iterations, logical breaks in the scores were used to determine the AHI ranking from Very High through Very Low. The breaks created reflect the clustering of scores based upon the output of the results, which somewhat mimic a normal distribution (although an analysis of data distribution was not conducted). If required, additional segment breaks were added to the FIM database and the data was adjusted accordingly. Only a few segments were added due to the AHI and they were added to reflect high value pockets embedded within areas of more moderate value (e.g., some areas identified as Black Zones were embedded in large segments). 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 information currently available.

The following is a description of the five AHI 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 an important floodplain areas adjacent to a salmonid spawning stream, are important wetland habitats, or provide critical spawning for kokanee. These areas should be considered the highest conservation priority and development activities that are considered should only be low impact, low risk types.

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 may score high for a vareity of reasons, including high rearing value, suitable Western Ridge mussel areas, extensive aquatic vegetation, or an important salmonid stream confluence area. These areas should be considered of high habitat value and priority should be given to maintenance of these shoreline areas. Goals and objectives should be set to ensure maintenance of existing values, and prioritizing habitat improvements where feasible.

3. Moderate - Moderate values areas are common around the lake, and have likely experienced some habitat alteration. These areas may contain important habitat areas, such as shore spawning kokanee habitats. These important habitat characteristics should be considered independently of the overall shoreline segment value (e.g., Black Zones within a moderate ranking segment). Proposed development should include some form of habitat restoration, with priorities to return the shore line to a more natural state (i.e., change the classifications from Landscaped to Broadhleaf 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 previous 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. Development within these areas should be carried out in a similar fashion as Moderate shoreline areas. However, restoration objectives should be set highest in these areas during redevelopment.

For the most part, criteria within this index were identical to Mabel, which was expected due to similarities between the systems. Some changes to the Mabel index were made, and have been described within the text.

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 and descriptions of the categories discussed below, please refer to Appendix A (Detailed Methods). 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; and,
7. Total shoreline length of different shoreline modifiers (e.g., roadways, substrate modification, and retaining walls) was determined.

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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 Okanagan Lake system. Data is presented graphically and summarized text for ease of interpretation. Data tables for the different analyses are presented in Appendix B.

6.1 Biophysical Characteristics of Okanagan Lake

Foreshore Inventory and Mapping was completed on 289,311 m (289 km) of shoreline on Okanagan Lake. The total length of disturbed shoreline was 164,226 m (164 km), which represents 57% total length (Figure 2). The total length of natural shorelines was 125,085 m (125 km) or 43% of the total length (Figure 4).

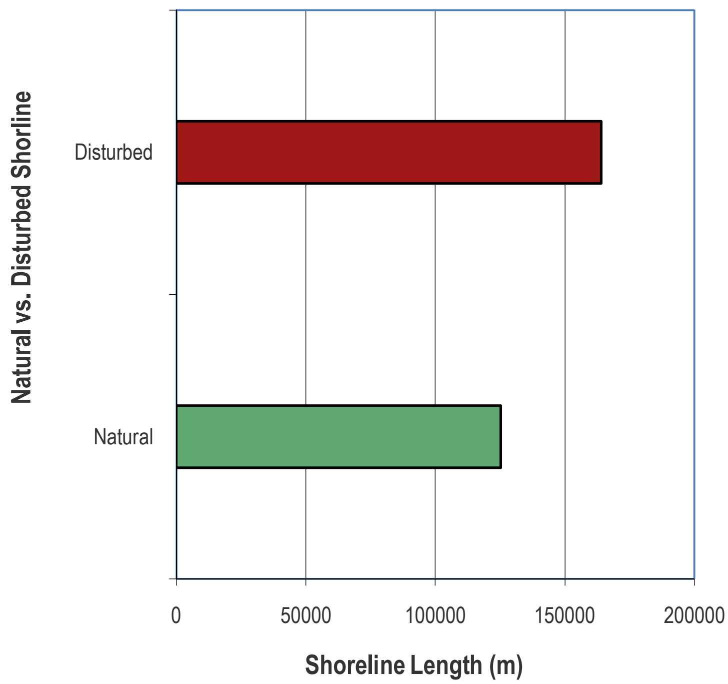


Figure 2 The length of natural or disturbed on Okanagan Lake

The slope analysis is a summary of slope categories (% slope) that occur in upland areas above the high water mark. Not surprisingly, areas of a lower gradient tend to have the highest level of disturbance given their relative ease to develop. A total 104 km of low gradient slopes and these slopes were 86% disturbed. Along steeper shorelines in Okanagan Lake, disturbance only occurred along 32% (27.4 km) and 35% (15 km) of the steep and very steep shore lengths respectively. Benches and Moderate gradient areas on Okanagan Lake were disturbed along 60% (5.2 km) and 58% (26.6 km) of their respective shore lengths within these slope categories.

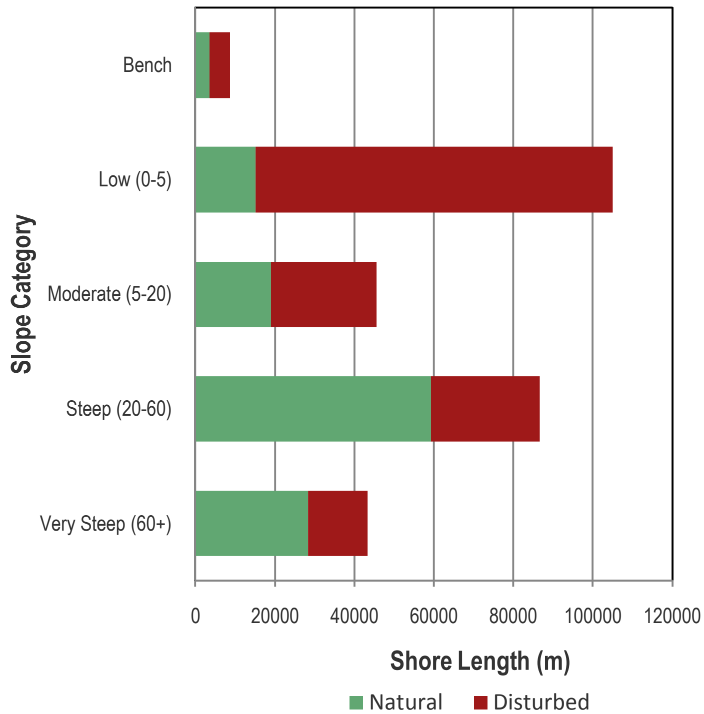


Figure 3 The natural and disturbed shore lengths that are either natural or disturbed within areas of different shore gradients around Okanagan Lake

The following provides a definition of the Land Use categories used in the FIM for easy reference. This wording was taken directly from the FIM methods in the appendices of document.

1. *Agriculture* – The agriculture land use field is the percentage of the shoreline, based upon the shore segment length, which is predominantly used for crop based agricultural or as active livestock range lands (i.e., extensive holding areas, large numbers of cattle etc.). Livestock pastures that are not active rangelands (i.e., a few cows or horses) are typically considered a rural land use and not an agriculture land use (see rural). These lands are typically part of the Agriculture Land Reserve or a provincial range tenure.

2. *Commercial* - The Commercial land use field is the percentage of the shoreline, based upon the shore segment length, which is predominantly used for commercial purposes. Commercial purposes include retail, hotels, food establishments, marinas with fuel, stores, etc. Commercial areas tend to occur along highly impacted shorelines. Where feasibly, significant commercial areas should be part of one segment because the land use on these shore types has a different assortment of potential impacts. Commercially zoned, but yet to be constructed areas, may also warrant there own segment.

3. *Conservation* - The Conservation land use field is the percentage of the shoreline, based upon the shore segment length, which is predominantly used for conservation of critical or important habitats. Examples of conservation shorelines include lands held by the Land Conservancy, biological reserves, etc. Conservation lands cannot occur on privately held shorelines, unless conservation covenants or other agreements are in place to protect areas in perpetuity.

4. *Forestry* - The Forestry Land use field is the percentage of the shoreline, based upon the shore segment length, which is predominantly used for forestry. These areas are typically crown lands that are part of active cut blocks or forestry operations. Log Yards are considered an industrial land use and are not considered a Forestry Land because they tend to have associated industrial infrastructure.

5. *Industrial* - The Industrial land use field is the percentage of the shoreline, based upon the shore segment length, which is predominantly used for industrial purposes. Examples of industrial purposes include log yards, processing facilities, lumber mills, etc. These shorelines are typically heavily impacted by infrastructure, impervious surfaces, buildings, etc.

6. *Institutional* - The Institutional land use field is the percentage of the shoreline, based upon the shore segment length, which is predominantly used for institutional purposes. Examples of institutional land uses include schools, public libraries, etc.

7. *Multi-Family Residential* - The Multi-Family land use field is the percentage of the shoreline, based upon the shore segment length that is predominantly used for multi-family residences. Multi-family developments are typically condominiums, apartments, or town homes.

8. *Natural Areas* - The Natural Areas land use field is the percentage of the shoreline, based upon the shore segment length, which are predominantly undisturbed crown lands. These areas do not occur in provincial or federal parklands and cannot be privately held.

9. *Park* - The Park land use field is the percentage of the shoreline, based upon the shore segment length, which are predominantly natural areas parklands. These parks areas can be provincial, federal, or local government parks. These parks tend to be relatively undisturbed and natural. They differ from urban parks (discussed below), which are used intensively for recreational purposes (e.g., public beaches).

10. *Recreation* - The Recreation land use field is the percentage of the shoreline, based upon the shore segment length, which is predominantly used for recreational purposes. Examples include public or private campgrounds, areas of known cabin rentals, etc. In some cases recreational shoreline may also be referred to as a single family land use, depending upon how much information is known about them. Generally, if a shoreline contains privately held cabins that are rented out occasionally, these should be referred to as single family land uses rather than recreational.

11. *Rural* - The Rural land use field is the percentage of the shoreline, based upon the shore segment length, which is predominantly used for rural purposes. These shorelines are typically large lots, private estates, or hobby farms. Differentiation between rural and single family land use can be difficult when lots are narrow but deep (i.e., buildings appear dense on the shoreline but extend quite far back). When doubt exists between a rural designation and a single family land use, assessors should be consistent in their judgments and refer back to local government zoning or bylaws to help decide on the appropriate land use type.

12. *Single Family Residential* - The Single Family Residential land use field is the percentage of the shoreline, based upon the shore segments length, which is predominantly used for single family residential purposes. Typically, single family residential occurs in more densely developed areas. However, seasonal use cottages or cabins can often be considered single family residential areas if the dwellings have associated outbuildings, docks, and other features consistent with more densely developed areas. In areas where the there are numerous seasonal use cabins and cottages, assessors should consider this single family residential if lots have smaller lake frontages and land uses and buildings are consistent with single family types of development. If lake frontages for seasonal use cabins and cottages are quite large, the land use would be considered rural. The differentiation between

rural and single family in these cases can be difficult and assessors should be consistent in their determination.

13. *Urban Parklands* - The Urban Park land use field is the percentage of the shoreline, based upon the shore segments length, which is predominantly used as an urban park. Examples of this land use include public beaches, picnic areas, etc. Shorelines dominated by this land use tend to have limited riparian vegetation and contain extensive areas of turf in the understory.

14. *Transportation* – The Transportation land use field is the percentage of the shoreline, based upon shore segment length, which is predominantly used for transportation via road or railway. Examples include highways, bridges, or railways that are directly adjacent to the shoreline.

Around Okanagan Lake, the largest land use type observed was single family residential accounted for 32% or 93.3 km of shoreline. Single family developments includes strata style developments that have single family units within the development. Within single family areas, the shore line was approximately 15% natural. Riparian impacts and substrate modification were the most significant impacts observed in these different areas. The next most predominant land use along the shorelines was rural areas, which accounted for 26% of the total shoreline length or approximately 74 km of shoreline. Rural areas had 76% or 56 km km of shoreline that natural while 24% or 17 km remains natural. The next most significant land use occurring around the lake was park areas. Parks occurred along 14% of the shoreline and these areas were generally quite natural (91%).

Transportation, agriculture, recreation (i.e., campgrounds, etc.), and urban parks occupied 17.7 km, 25.5 km, 9.5 km, and 15.5 km respectively. These were similar to single family in terms of the extents of disturbance observed.

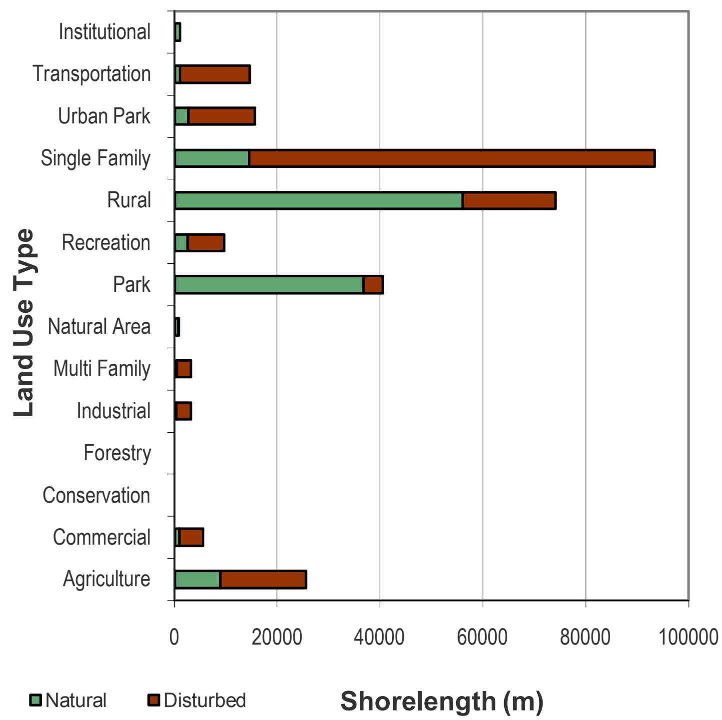


Figure 4 The natural and disturbed shoreline length by the different types of land use occurring around Okanagan Lake.

Fish utilize shoreline areas for a variety of reasons throughout their life cycle. For each species, the importance of shoreline areas depends upon their life stage (e.g., egg, juvenile, adult), their foraging type (e.g., insectivorous (insect eating), plankivorous (plankton eating), piscivorous (fish eating), or some combination thereof, etc.). Given the variability of different life stages and species present within the lake, it is difficult to describe the importance of shore types to species quickly. Despite this, it is currently accepted that areas of high productivity are generally associated with either spawning activities or juvenile rearing. In Okanagan Lake, rocky shores, wetlands, stream mouths, cliff / bluff, and wetlands are considered to be the most important to fish.

The most predominant shore type observed around Okanagan Lake was Gravel, and accounted for 43% or 125 km. Gravel shores were only 32% natural, with only an estimated 39 km of shore natural shoreline remaining. 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. Cliff / Bluff shore lines were the next most predominant shore type and occurred along 23% or 67.3 km of the shore. In Cliff/Bluff areas the shoreline was 66% natural (44 km). Rocky shoreline areas occurred along 14% (41.9 km) of shoreline and within rocky shore areas the shoreline was 72% natural (30.2 km). Stream mouth and Wetland shore types were not very common around the lake and represented only 2.8% (8.1 km) and 8.3% (24 km) of the total shoreline length.

Within stream mouth and wetland shore areas, natural areas of the shoreline accounted for 26% (2.1 km) and 33% (16 km) respectively.

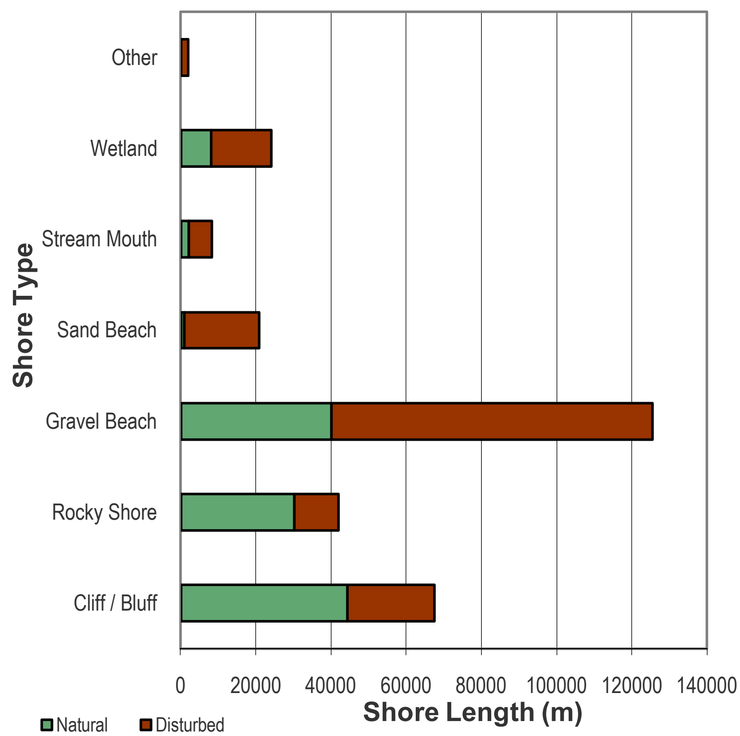


Figure 5 The length of natural and disturbed shoreline along each of the different shore types on Okanagan Lake.

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 provides important food for juvenile salmonids and other aquatic life during periods of inundation and this is why it has been included (Adams and Haycock, 1989). Approximately 56 km of shoreline has aquatic vegetation, which represents approximately 19.5% of the total shoreline length. The total area of both dense and sparsely vegetated areas with aquatic vegetation is 249,398 m^2. Most of the vegetation that was observed was emergent and grass like and occurred along 50 km or 17.4% of the shoreline. Native submergent vegetation and floating vegetation were very rare on Okanagan Lake and were only observed along 2.1% or 6.1 km and 0.3% or 0.9 km respectively. *More detailed mapping of submergent vegetation is recommended because the large littoral zones made it difficult to map all areas.*

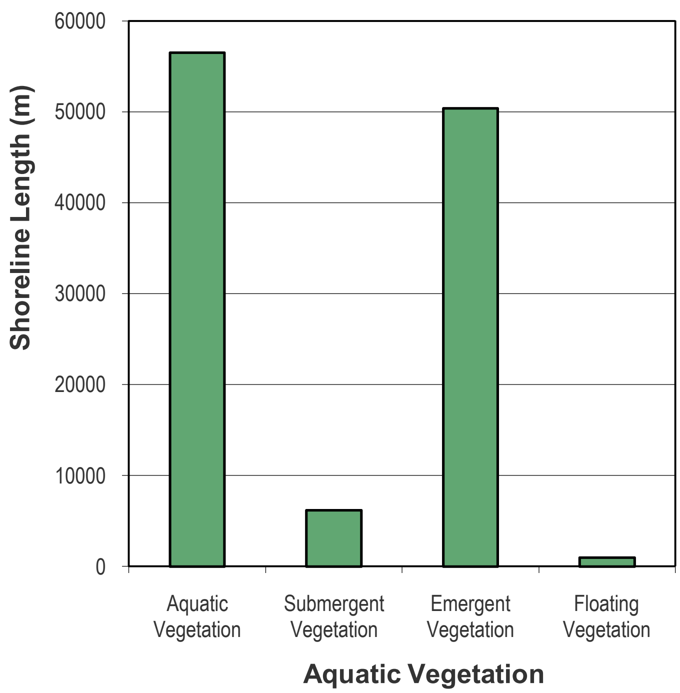


Figure 6 Total shoreline length that has aquatic, submergent, emergent, and floating vegetation along Okanagan Lake.

Docks were the most commonly observed type of shoreline modification. A total of 2,718 docks counted during the assessment. Numerous "dock groynes" were also observed. "Dock groynes" were moorage structures that had lakebed substrates piled underneath, creating a physical structure that was both a moorage and a groyne. Retaining walls and groynes followed docks and totaled 1,799 and 939 respectively. A total of 41 marinas with greater than 6 boat slips and 222 concrete boat launches[2] were observed.

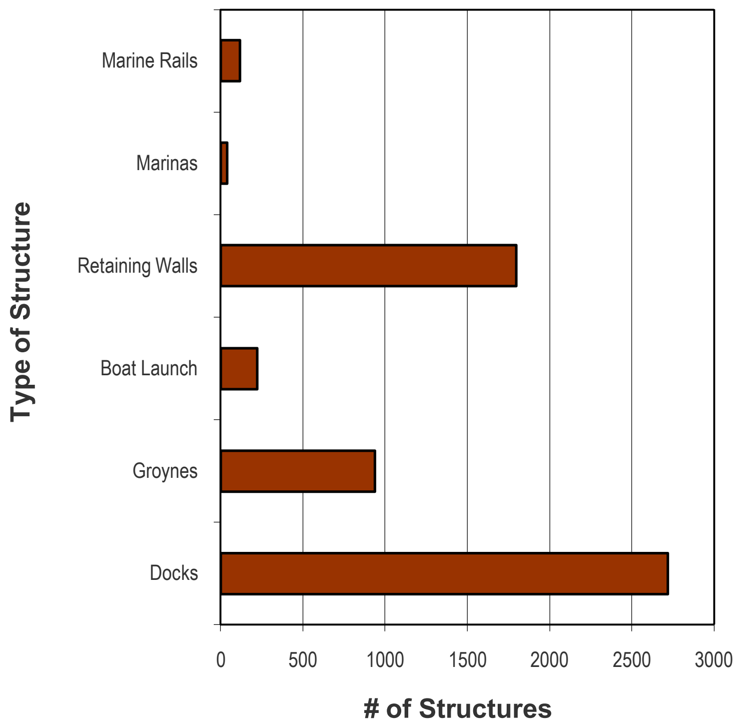


Figure 7 Total number of different shoreline modifications that occur around Okanagan Lake.

[2] Only concrete boat launches were counted during the assessment. This total does not include gravel accesses to the lake.

The percentage of shoreline impacted by roads, railways, retaining walls, and where substrate modification has occurred was recorded. These estimates allowed an approximation of the total shoreline impacted by these different activities (Figure 11). Substrate modification was the most substantial impact that was observed along the shoreline. In total, it is estimated that 137 km or 47% of shoreline has experienced substantial substrate modification. Substrate modification was variable and was most commonly associated with construction of groynes to create gravel beaches, importation of sands, historic fills (e.g., retaining walls below HWL) or associated with road/railways (e.g.., structural fill material, etc.). Retaining walls were the next greatest impact to the shoreline and it is estimated that 58.5 km or 20% has been impacted by retaining walls. Finally, roadway impacts accounted for less than 8% or 22.7 km of shoreline. There were no areas of railway observed along the shoreline.

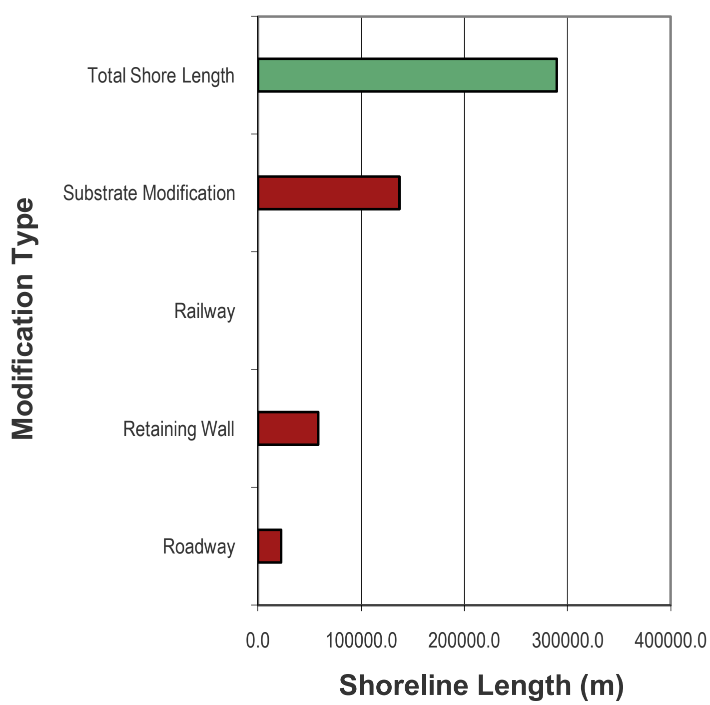


Figure 8 Total shoreline length that has been impacted by substrate modification, road and railways, and retaining walls along Okanagan Lake.

The Level of Impact is a categorical description of disturbance along the shoreline. The following definitions were taken from the FIM methods in the appendix of this document and are included for ease of reference.

1. *Level of Impact* - Level of Impact is a categorical field that is used to describe the general disturbance that is observed along the shoreline. Disturbances are considered any anthropogenic influence that has altered the shoreline including foreshore substrates, vegetation, or the shoreline itself (e.g., retaining walls). Level of impact is considered both looking at the length of the shoreline (i.e., along the segment) and the depth of the shore zone area to between 15 to 50 m back. In more rural settings, typically the assessment area is greater (i.e., 50 m) and in more developed shorelines, typically the assessment area is less (i.e., 15 to 30 m). In cases of roadways or railways, one should generally consider the location of the rail or roadway along the segment (i.e., how far back is it set, is the lake infill, etc.). To facilitate interpretation of this category, air photo interpretation is recommended to better estimate disturbance. Disturbance categories include High (>40%), Medium (10-40%), Low (<10%), or None. Consistency of determination is very important and assessors should use the same criteria to determine the level of impact. The RDCO Foreshore Inventory and Mapping report defines the *Level of Impact* as follows (Magnan and Cashin, 2004):

    a. *Low* - Segments that show little or limited signs of foreshore disturbance and impacts. These segments exhibit healthy, functioning riparian vegetation. They have substrates that are largely undisturbed, limited beach grooming activities, and no to few modifications.

    b. *Moderate* - Segments that show moderate signs of foreshore disturbance and impacts. These segments exhibit isolated, intact, functioning riparian areas (often between residences). Substrates (where disturbed) exhibit signs of isolated beach grooming activities. Retaining walls (where present) are generally discontinuous. General modifications are well spaced and do not impact the majority of the foreshore segment.

    c. *High* - Segments that show extensive signs of disturbance and impacts. These segments exhibit heavily disturbed riparian vegetation, often completely removed or replaced with non-native species. Modifications to the foreshore are extensive and likely continuous or include a large number of docks. Generally, residential development is high intensity. Modifications often impact a majority of the foreshore.

The amount of foreshore modification by these different mechanisms may seem high, but is corroborated by the estimated level of impact observed. It is estimated that 169 km or 58% of the shoreline has a high level of impact. Areas of moderate and low impact occur along 15% or 44 km and 25% or 72 km of the shoreline respectively. *There is an estimated 1.2% or 3.4 km of shoreline that is believed to have little to no impact.*

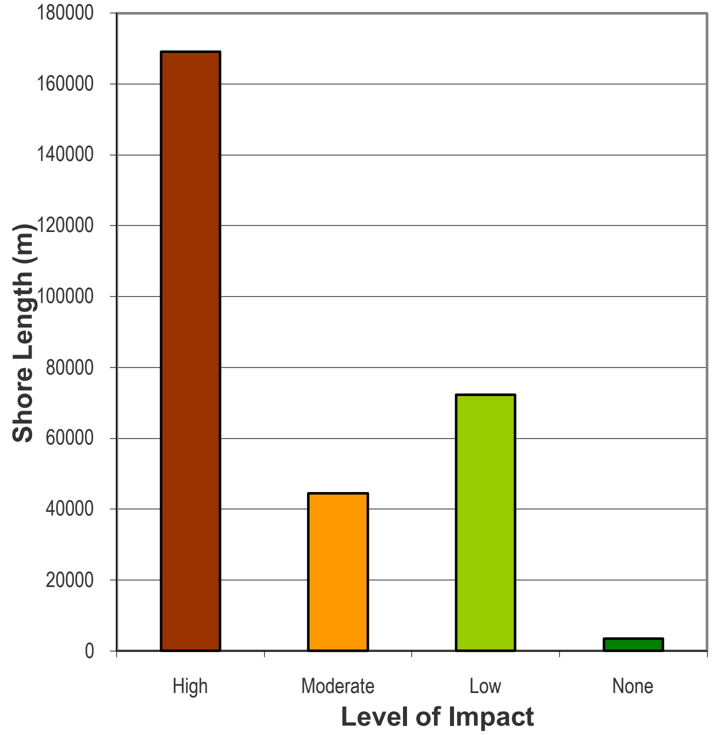


Figure 9 The level of impact (High, Moderate, Low, or None) observed along Okanagan Lake.

Areas classified as having High juvenile rearing values have experienced substantial impacts. The analysis indicates that areas of High Juvenile Rearing value occur along 118 km and have been disturbed along 80 km or 68% of the shoreline. Areas of moderate rearing value occur along 156 km of shoreline and are 51% disturbed. Areas of low rearing value occur along 13 km of shoreline.

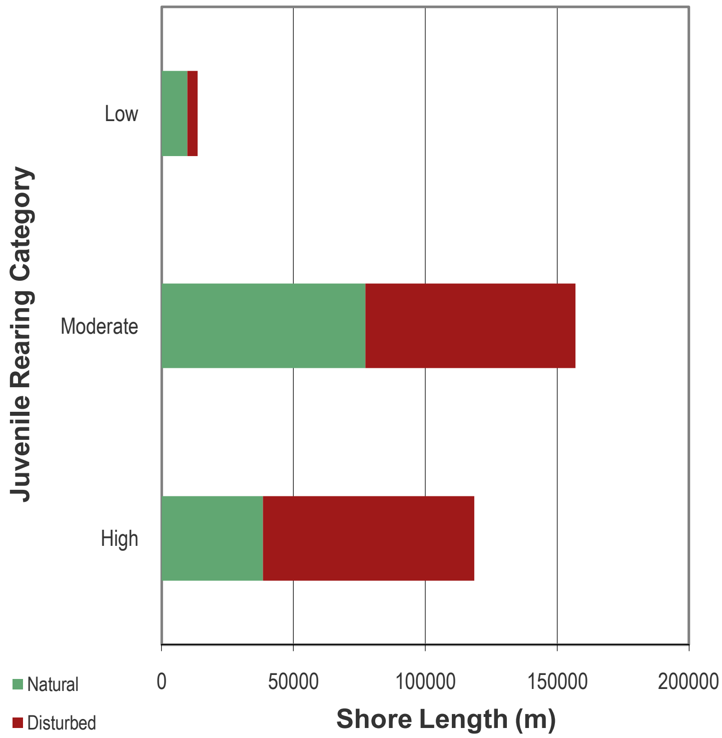


Figure 10 The natural and disturbed shore length within areas classified as having High, Moderate, or Low Juvenile Rearing value along Okanagan Lake.

A review of the natural and disturbed areas within the Okanagan Large Lakes protocol Kokanee shore spawning areas was conducted. This analysis indicated that within Black Zones, shorelines were 80% natural. Within Red Zones, shoreline areas were 61% natural and within Yellow Zones shorelines were 31% natural. In No Colour Zones, shorelines were 35% natural.

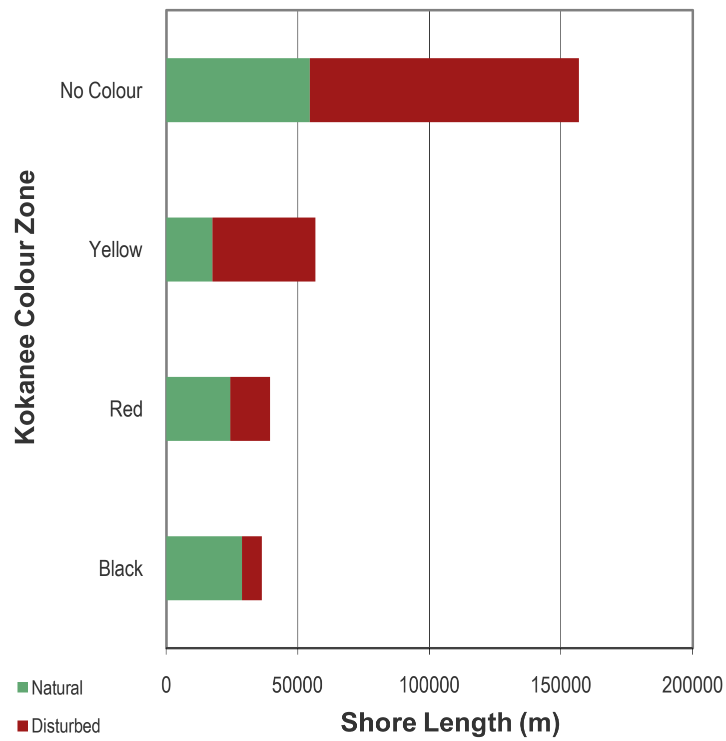


Figure 11 The natural and disturbed shore length within areas classified being a Kokanee Black, Red, Yellow, or No Colour Zone.

6.2 Summary of Foreshore Modifications

The lakeshore of Okanagan Lake contains habitats that are critical for wildlife (e.g., Western Grebe, etc.), rare plants and terrestrial communities, and fish populations (e.g., kokanee, rainbow trout, etc.). The lake provides drinking water for many different local government and First Nation's jurisdictions both around it and downstream. The combination of important fish, wildlife, and water quality considerations make protection the shoreline area a vital consideration. The baseline data collected during this assessment provides much of the information necessary to begin to manage this resource effectively. Further, it provides a baseline upon which goals and objectives can be created and monitored.

The shoreline of this lake is estimated to remain 43% natural based upon the results of this inventory. Much of the natural shorelines occur in Rural areas that are prone to future development. The extents of disturbance observed were of a similar nature to impacts observed in the Shuswap Lake system. The analysis above highlights the importance of to begin to implementing long term objectives in an effort to conserve important natural areas that remain and prioritizing habitat improvements where feasible.

As with other shoreline studies (e.g., Shuswap Lake, Mable Lake, Moyie Lake), lower gradient shoreline slopes tended to have higher levels of disturbance. The most notable disturbances occur in the form of substrate alteration (e.g., boat launches or groynes) and riparian vegetation disturbance. However, even within more intensely developed areas, many natural aquatic vegetation communities remain and many "pockets" of natural shoreline exist.

Although many areas have experienced negative habitat alterations, a few of the floodplains around the lake are still in functioning (at risk) condition and are key critical habitat features supporting numerous fish and wildlife species. Many of these critical areas are susceptible to future land use decisions. The above highlights the need for ongoing and continued management and planning to ensure these important resources are protected.

Varying degrees of foreshore development are present along Okanagan Lake. During the field surveys, numerous observations were made and are summarized in point form below:

- The most significant impact observed below the high water level along the shorelines was substrate modification. The construction of groynes, development of historical wetlands/floodplains, and importation of sands has resulted in numerous impacts including:

  i. the loss of aquatic vegetation (actual loss has not been determined);
  ii. a loss in cover along the shoreline;
  iii. the physical loss of habitat through alteration of shorelines from a rocky shore to gravel or sand beaches;
  iv. loss of structure complexity or habitat diversity;
  v. has resulted in an increased erosion risk around the shoreline;
  vi. increased sediment input that may have reduced shore spawning success for different species; and,
  vii. potentially altered the natural patterns of long shore sediment drift from wind and wave action.

  The extent of habitat related loss associated with substrate modification have not been determined as part of this assessment. In many cases, the construction of groynes may have the use of heavy equipment (or significant manual effort). Many groynes were also part of a dock system. All groynes observed were constructed on Crown lands below the high water level, and it is likely that many, if not all, were not permitted under the BC Water Act or Federal Fisheries Act.

- In many areas, it is apparent that aquatic vegetation[3] has been lost due to foreshore disturbance such as substrate modification. In these areas, emergent riparian vegetation (e.g., willows and cottonwoods), grasses and sedges, and other types of vegetation have been cleared. It is believed that most of this vegetation removal is the result of beach creation (i.e., beach grooming). The loss of soil material that aquatic vegetation grows, particularly in more rocky shoreline areas, will likely take years or decades to naturally regenerate, if ever. The continued loss of vegetation will further impact juvenile salmonids during high water in the spring when they are known to feed upon organisms within the vegetation (Adams and Haycock, 1989).

- Riparian vegetation disturbance has changed the vegetation type from natural broadleaf or coniferous associations to landscaped, lawn, or un-vegetated associations along many shore segments. The substantial losses of riparian vegetation have not been quantified as part of this assessment. There are significant opportunities for riparian habitat enhancements along the shoreline of the lake in disturbed areas. Of particular concern on Okanagan Lake is the extensive riparian

[3] Aquatic vegetation is defined here as any vegetation below the high water level, including shrubs, herbs, and grasses, whether they are true aquatic macrophytes (e.g.,*Potamogeton* spp.) or hydrophilic species (e.g., reed canary grass).

related impacts that were observed on the many low gradient floodplain areas. It is apparent that most large floodplain areas have been impacted or impaired in some fashion.

- The presence of large woody debris was less than expected, particularly in floodplain areas. The losses of this woody debris is likely the result of channelization of the many large stream systems on the lake that have resulted in the need to remove debris jams so they do not pose a flooding hazard. Large woody debris is considered a critical aspect of habitat for juvenile fish, particularly salmonids. Channelization of streams is very apparent in urban areas such as Penticton and Kelowna, where the Penticton Creek, Bellevue Creek, and Mission Creek have all been channelized.

- Several private boat launches constructed out of concrete were observed. These boat launches were almost all associated with vehicular access, which has impacted riparian vegetation. It is conservatively estimated that these boat launches have resulted in the loss of at least 8,658 m^2 of habitat around the lakes (assuming the average boat launch is 3 m wide and 13 m long, which is presumed to be an underestimate). It is likely that most of these private boat launches were constructed without a provincial Water Act, federal Fisheries Act approval or have a Crown land tenure.

- Retaining wall construction around the lake was apparent in nearly all privately held areas, even remote shoreline areas. Retaining walls were constructed out of varying materials, but frequently substrates from the lakebed were used to construct the walls. As mentioned above, it is probable that many of the retaining walls observed have been constructed without a Water Act or Fisheries Act approval.

- Docks were the most commonly observed shoreline modification and it is highly probable that some of these docks have been constructed without appropriate moorage tenures. Many of the docks observed were not constructed following best management practices which require elevated walkways on piles to deeper water zones at low water level. In many areas, these docks were associated with groynes constructed from lakebed materials (i.e., angular cobbles placed in piles under dock), the docks were not elevated, or were simply very large (i.e., one residence with 2 to 3 slips plus seadoo marina rails, etc.). The impact of non compliance is small on an individual scale, but cumulatively the extent of habitat related degradations are noticeable and measureable (i.e., numerous examples of lakebed substrate alteration in kokanee spawning areas) and have affected spawning habitats.

- Boat wake erosion, Crown land trespass, and moorage buoys were observed. Also, evidence of prop scour was present in the some areas. However, detailed assessments and quantification of these impacts was not fully assessed.

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 61.6% of the shoreline is ranked as Very High and High. Twenty eight (28%) of the shoreline length is moderate, and the remaining 11% is ranked Low and Very Low. Areas of high and very high habitat value were typically located adjacent to important kokanee spawning areas, stream confluences, wetlands, areas of suitable Western Ridged Mussel habitat, or were associated with gravel and rocky shorelines with aquatic vegetation in a natural state. Most of the lower value sites were located in more developed areas where habitat function has been severely impaired (e.g., floodplain and wetland areas being converted to dense single family or multi family development) or by anthropogenic impacts.

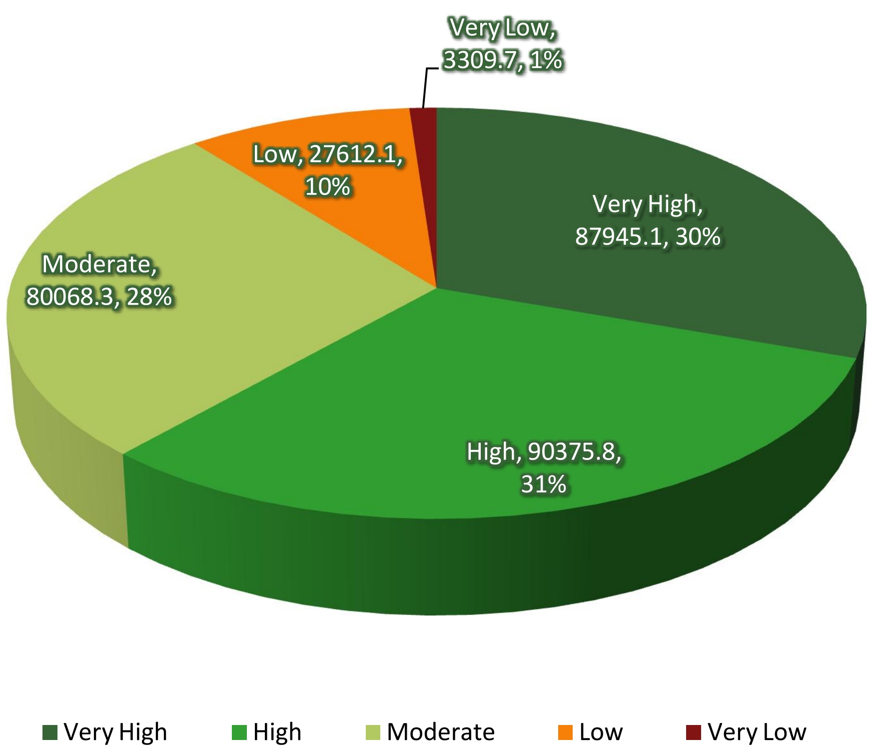


Figure 12 The shore length and percentage of areas classified as being Very High, High, Moderate, Low, and Very Low ranking by an Aquatic Habitat Index along Okanagan Lake.

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

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	84	87945.1	30.4	93	97566.7	33.7
High	95	90375.8	31.2	112	109538.1	37.9
Moderate	91	80068.3	27.7	87	63374.2	21.9
Low	38	27612.1	9.5	19	18045.0	6.2
Very Low	6	3309.7	1.1	3	787.0	0.3
Total	314	289311.0	100.0	314	289311.0	100

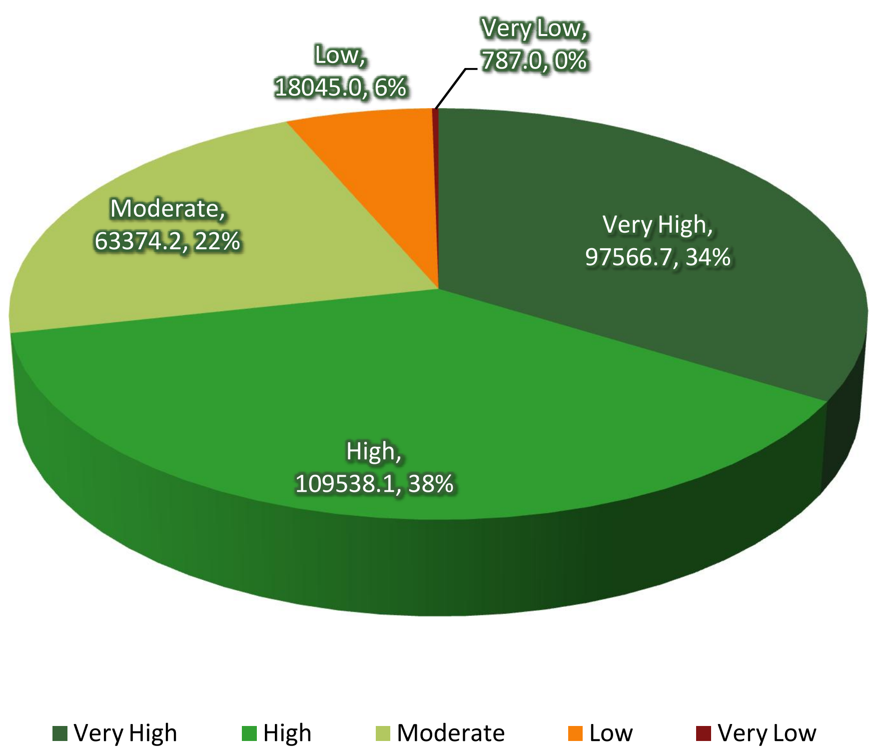
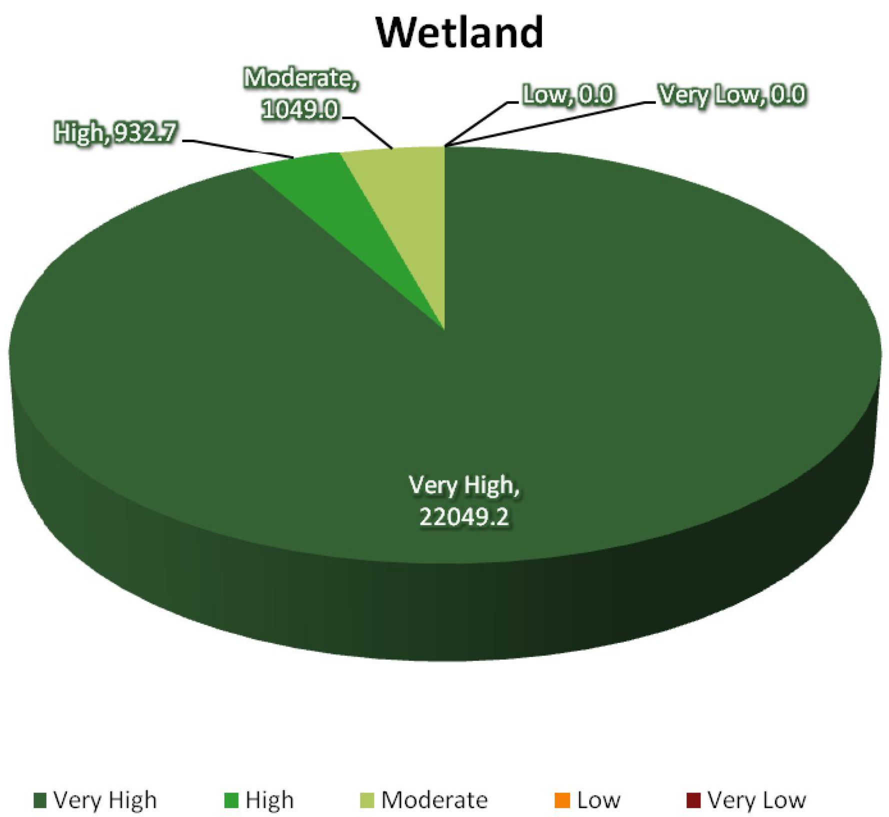
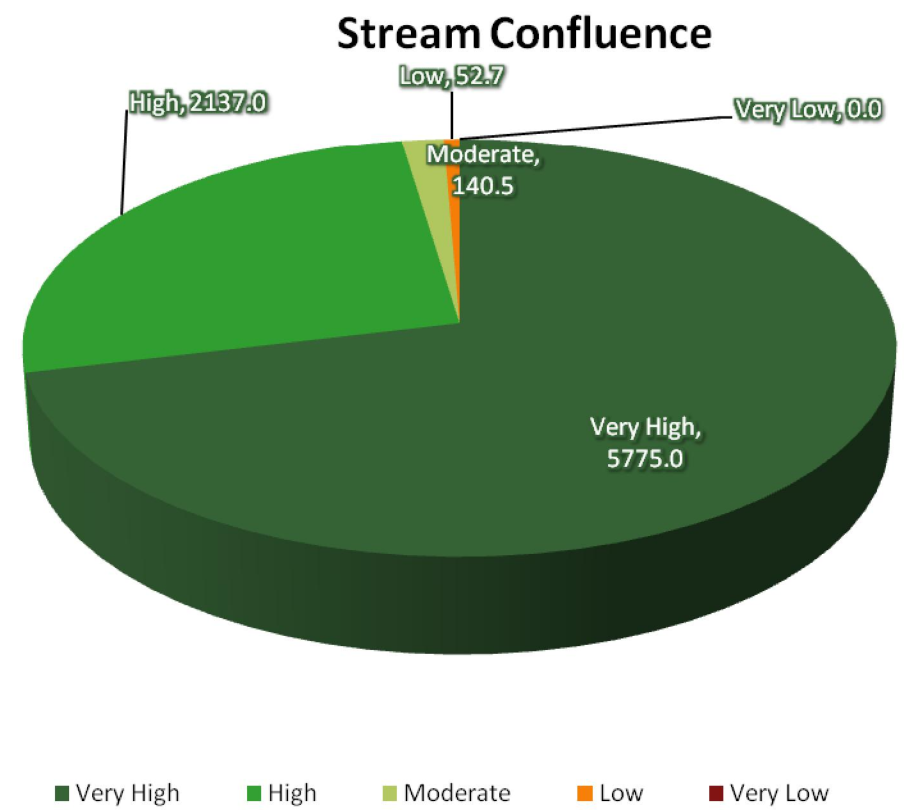
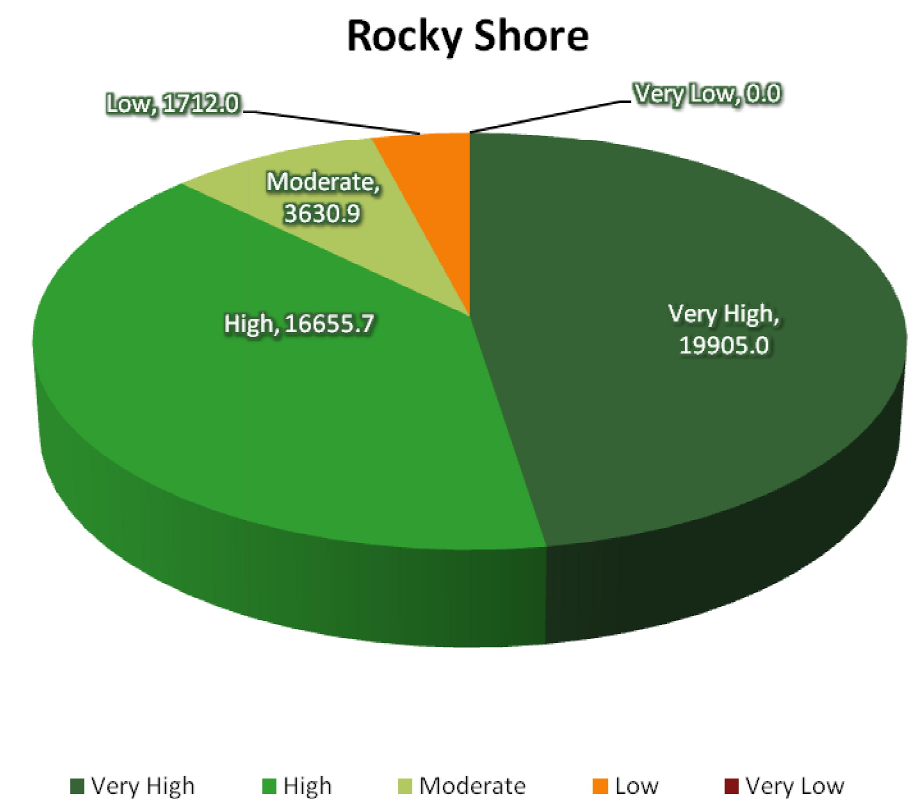


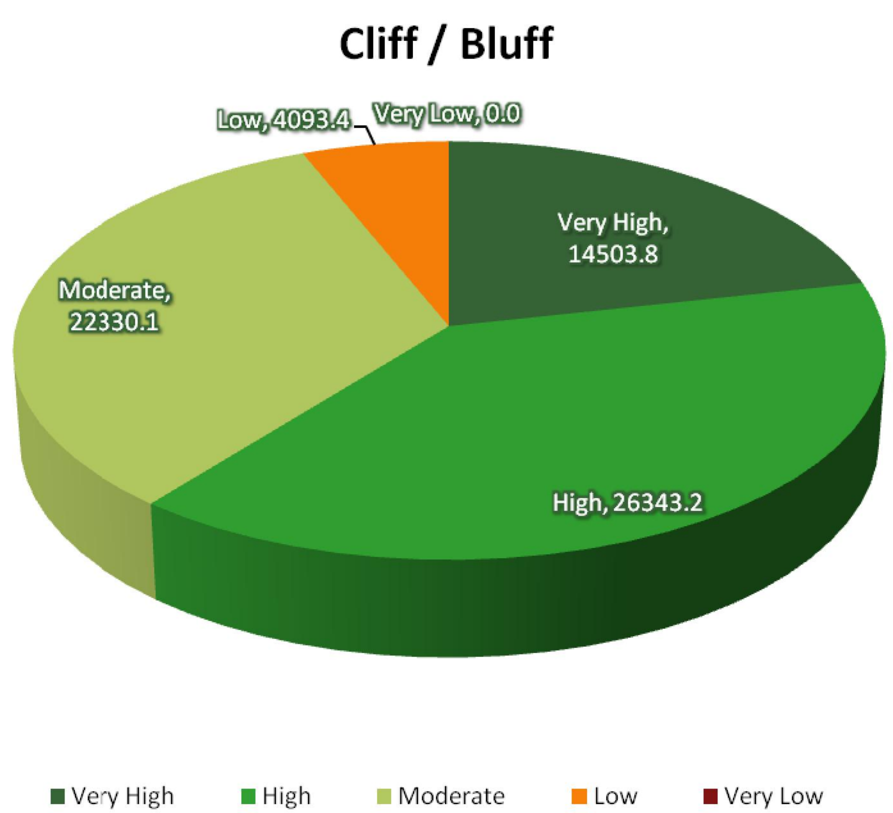
Figure 13 The shore length and percentage of areas classified as being Very High, High, Moderate, Low, and Very Low ranking by an Aquatic Habitat Index in the Potential Value Analysis along Okanagan Lake.

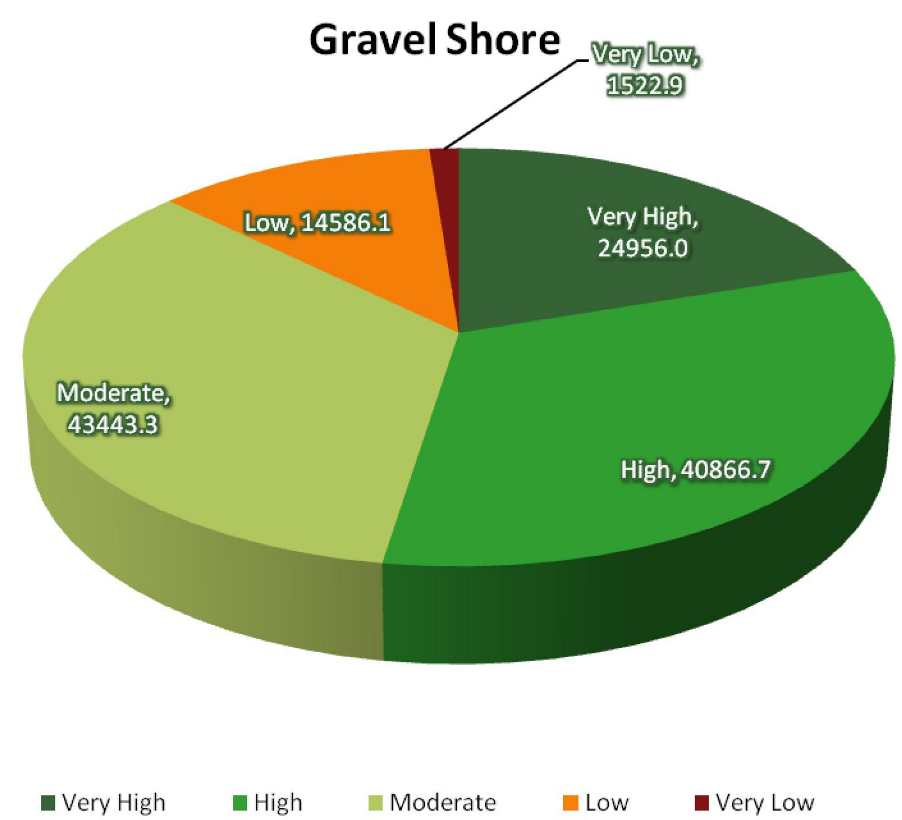
The Aquatic Habitat Index results were analyzed to determine the distribution of habitat values by shore type (Table 4). The analysis indicated that Very High Value shorelines occurred mostly adjacent to stream mouths or wetland areas, with good representation also occurring on rocky, cliff/bluff, and gravel shores. Most of the Very Low value habitat was found on sand or gravel beach areas.

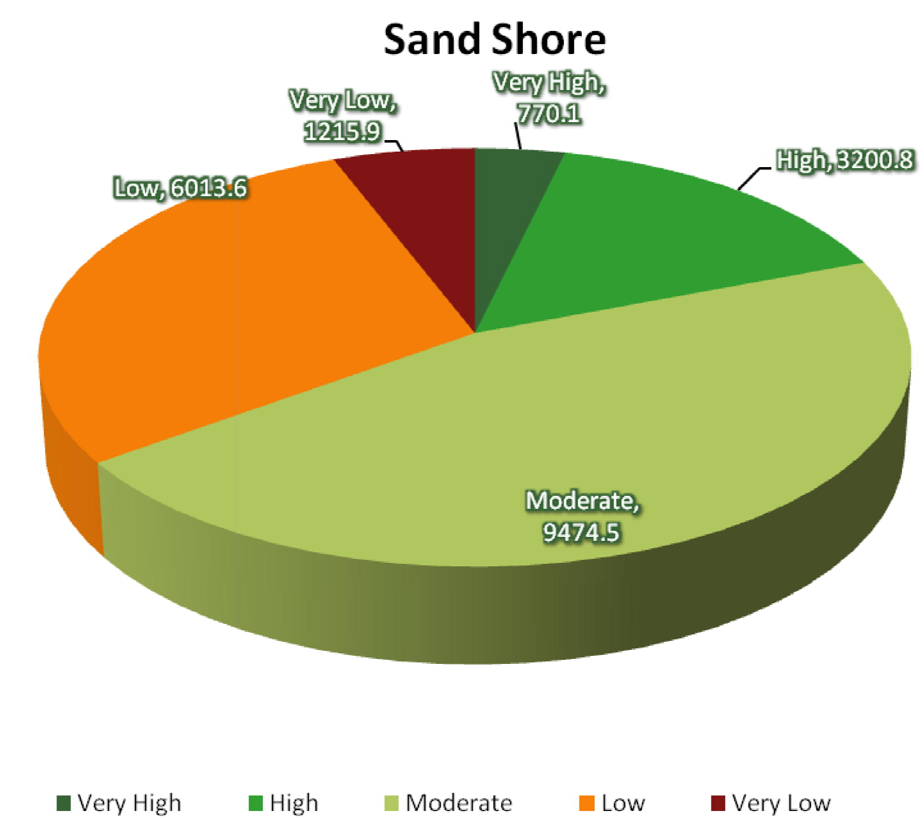

Wetland
Moderate, 1049.0
High, 932.7
Low, 0.0
Very Low, 0.0
Very High, 22049.2
Very High
High
Moderate
Low
Very Low


Stream Confluence
Low, 52.7
High, 2137.0
Very Low, 0.0
Moderate, 140.5
Very High, 5775.0
Very High
High
Moderate
Low
Very Low


Rocky Shore
Low, 1712.0
Very Low, 0.0
Moderate, 3630.9
High, 16655.7
Very High, 19905.0
Very High
High
Moderate
Low
Very Low


Cliff / Bluff
Low, 4093.4
Very Low, 0.0
Very High, 14503.8
Moderate, 22330.1
High, 26343.2
Very High
High
Moderate
Low
Very Low


Gravel Shore
Very Low, 1522.9
Low, 14586.1
Very High, 24956.0
Moderate, 43443.3
High, 40866.7
Very High
High
Moderate
Low
Very Low


Sand Shore
Very High, 770.1
Very Low, 1215.9
High, 3200.8
Low, 6013.6
Moderate, 9474.5
Very High
High
Moderate
Low
Very Low

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 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 Mouth		Wetland		Other	
Categories	# of Segments	Shorelin e Length	% of Shorelin e	Shorelin e Length	% of Shorelin e Length	Shoreline Length	% of Shoreline Length	Shoreline Length	% of Shoreline Length	Shoreline Length	% of Shoreline Length	Shoreline Length	% of Shoreline Length	Shoreline Length	% of Shorelin e Length	Shorelin e Length	% of Shoreline Length
Very High	84.0	87945.1	30.4	14503.8	16.5	19905.0	22.6	24956.0	28.4	770.1	0.9	5775.0	6.6	22049.2	25.1	0.0	0.0
High	95.0	90375.8	31.2	26343.2	29.1	16655.7	18.4	40866.7	45.2	3200.8	3.5	2137.0	2.4	932.7	1.0	239.6	0.3
Moderate	91.0	80068.3	27.7	22330.1	27.9	3630.9	4.5	43443.3	54.3	9474.5	11.8	140.5	0.2	1049.0	1.3	0.0	0.0
Low	38.0	27612.1	9.5	4093.4	14.8	1712.0	6.2	14586.1	52.8	6013.6	21.8	52.7	0.2	0.0	0.0	1154.3	4.2
Very Low	6.0	3309.7	1.1	0.0	0.0	0.0	0.0	1522.9	46.0	1215.9	36.7	0.0	0.0	0.0	0.0	570.9	17.2

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 Mouth		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	Shorelin e Length	% of Shoreline
Very High	86	84892.4	35.6	18995.0	22.4	20503.8	24.2	29068.3	34.2	770.1	0.9	6023.9	7.1	22219.6	26.2	0.0	0.0
High	98	71202.8	29.8	25333.5	35.6	17169.9	24.1	58768.0	82.5	5304.2	7.4	1960.5	2.8	762.3	1.1	239.6	0.3
Moderate	72	62163.7	26.1	19225.3	30.9	3042.1	4.9	29126.6	46.9	10607.5	17.1	68.1	0.1	1049.0	1.7	255.7	0.4
Low	13	17305.5	7.3	3716.7	21.5	1187.8	6.9	8412.2	48.6	3777.0	21.8	52.7	0.3	0.0	0.0	898.6	5.2
0	2	2974.5	1.2	0.0	0.0	0.0	0.0	0.0	0.0	216.2	7.3	0.0	0.0	0.0	0.0	570.9	19.2

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 67% natural. In High value areas, the shoreline was 49% natural and within Moderate Value areas the shoreline was 26% natural. Areas of Low and Very Low value only had 4.3% and 0% of the shoreline remaining natural.

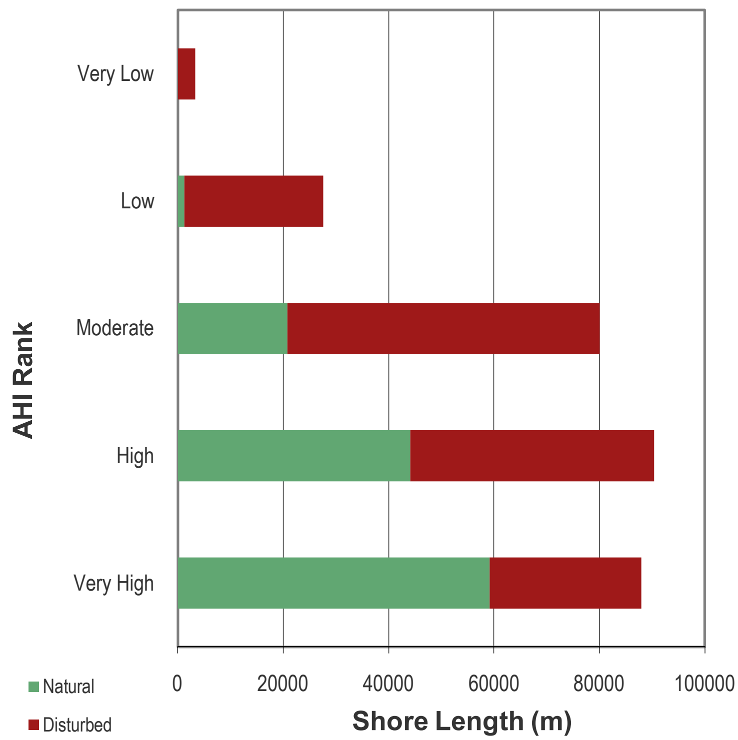


Figure 15 The Natural and Disturbed shore length of areas classified as being Very High, High, Moderate, Low, and Very Low ranking by an Aquatic Habitat Index along Okanagan Lake.

6.4 2004 Foreshore Inventory and Mapping Comparison

In 2004, the shoreline of Okanagan Lake was approximately 48% natural and 52% disturbed within the limits of Central Okanagan. The shorelines of Okanagan Lake in 2010 were 44% natural and 55% disturbed. The rate of change of shoreline along the lake from natural to disturbed was 0.6% per year.

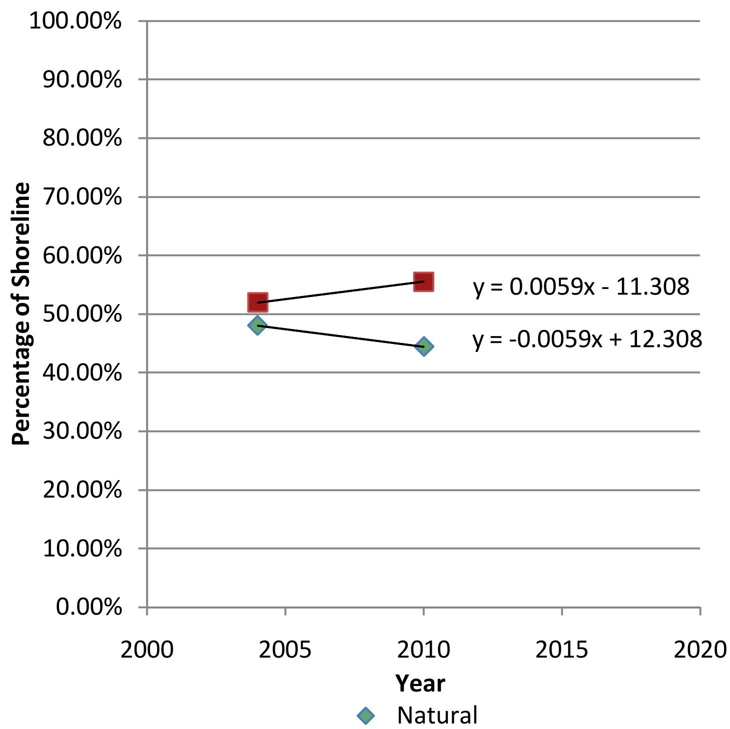


Figure 16 The percentage of Natural and Disturbed shore line in 2004 and 2010 around central Okanagan Lake in.

Table 6: The total shore length of percentage of shore length along Okanagan Lake in 2004 and 2010.

	2010		2004		2020 Projections
	% of Shoreline	Shore Length (m)	% of Shoreline	Shore Length (m)	
Natural	44.47%	57350	48.01%	61916.95	39.00%
Disturbed	55.53%	71618	51.99%	67050.67	61.00%

The loss of natural shoreline along different shore gradients was very similar between the gradient classes. The loss of natural shoreline occurred in a a range between 0.37% (Low) to 0.85% (Steep) per year. The magnitude of change was greatest in steep gradient areas, with very steep (0.5% per year) and steep experiencing the highest rates of change.

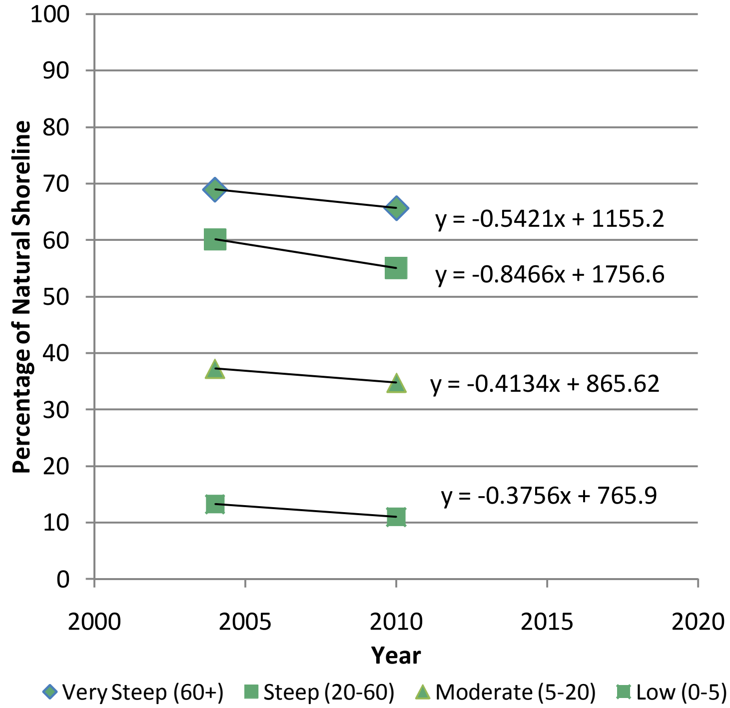


Figure 17 The percentage of natural shore line along very steep, steep, moderate, and low gradient areas in 2004 and 2010 around central Okanagan Lake.

Table 7: The percentage of natural and disturbed shore lengths within each of the different slope categories on Okanagan Lake in 2004 and 2010.

2004							2010						
Slope	% of Total Shore Length	Total Shore Length (m)	Shore Length Natural (m)	Shore Length Disturbed (m)	% Natural	% Disturbed	Slope	% of Total Shore Length	Total Shore Length (m)	Shore Length Natural (m)	Shore Length Disturbed (m)	% Natural	% Disturbed
Very Steep (60+)	25	32497	22402	10094	69	31	Very Steep (60+)	25.2	32497	21346	11151	65.7	34.3
Steep (20-60)	35	45477	27338	18140	60	40	Steep (20-60)	35.3	45477	25028	20450	55.0	45.0
Moderate (5-20)	18	22603	8419	14184	37	63	Moderate (5-20)	17.5	22603	7858	14745	34.8	65.2
Low (0-5)	22	28390	3758	24632	13	87	Low (0-5)	22.0	28390	3118	25272	11.0	89.0
Bench	0	0	0	0	0	0	Bench	0.0	0	0	0	0	0
Total	100.0	128968	61917	67051	48.0	52.0	Total	100.0	128968	57350	71618	44.5	55.5

There was a substantial increase in the number of modifications documented along the shoreline. The total number of docks increased from 1,184 in 2004 to 1,324 in 2010. The most notable increase was the significant number of groynes, increasing from 134 in 2004 to 601 in 2010. The significant increase in groynes may be due to the number of "dock groynes" observed in 2010, which were groynes under moorages. The number of "dockgroynes" was not factored in to the analysis and it is unknown if "dock groynes" were counted in 2004. Although it is not possible to say with certainty how many groynes were newly constructed, it is probable that there were several new groynes added since 2004. Substrate disturbance was readily apparent in numerous locations. There was also a substantial increase in the number of marinas, increasing from 8 to 24 between 2004 and 2010. A few of the marinas counted in 2010 may have been present in 2004 because it is unclear how many slips were considered. Regardless, it is apparent there have been several new moorage constructed since 2004.

The density of modifications and their rates of accumulation along the shoreline were determined. Groynes and docks increased in density from 2004 to 2010 and the rates of accrual ranged from 0.18 docks/km/year to 0.60 groynes/km/year. At this rate, density in 2020 will range from 22.3 docks per km to 15.3 groynes per km. The following tables and figures provide this information for each different habitat modification. The inferences of rates of change for different modifications are subject to numerous different factors, and this simple analysis has insufficient data to accurately predict change. Rather, it is presented to provide at least some level of understanding as to what potential magnitudes of change to expect or have potentially recently been occurring in the last century.

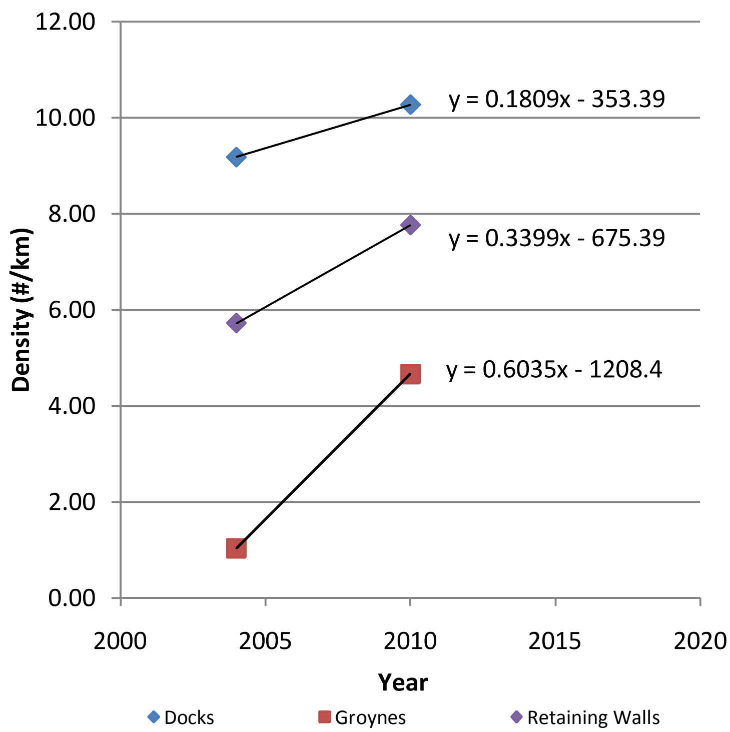


Figure 18 The density (#/km) of docks, groynes, and retaining walls along central Okanagan Lake in 2004 and 2010.

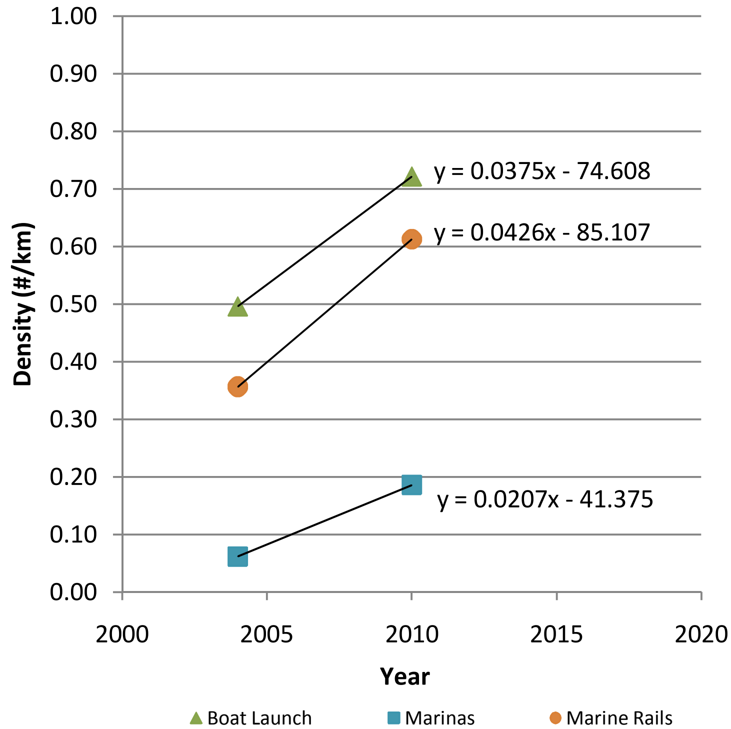


Figure 19 The density (#/km) of boat launches, marinas, and marine rails along central Okanagan Lake in 2004 and 2010.

Table 8: The total number and density (# per km) of different shoreline modifications occurring around Okanagan Lake in 2004 and 2010.

2004			2010			
Type	Total #	# Per km	Type	Total #	# Per km	2020 Density Projections (#/km)
Docks	1184	9.18	Docks	1324	10.27	12.0
Groynes	134	1.04	Groynes	601	4.66	10.7
Boat Launch	64	0.50	Boat Launch	93	0.72	1.1
Retaining Walls	738	5.72	Retaining Walls	1001	7.76	11.2
Marinas	8	0.06	Marinas	24	0.19	0.4
Marine Rails	46	0.36	Marine Rails	79	0.61	0.9

Provided all current patterns continue unchanged, the data indicates that densities of modifications will increase 1.5 to 2 times (e.g., marina will nearly double, increasing in density from 0.19/km to 0.4/km) by 2020.

The RDCO Marine Facilities (2008) study indicates that there is tremendous demand for increased moorage and recreational facilities on Okanagan Lake. The study calls for increases in the number of boat launches, marinas, marine storage locations (both on and off the water), and development of a vision for boating recreation on Okanagan Lake. The rates of change identified within this study should be considered in light of recreational demands. Although demands are substantial, this report identifies a rate of change that will result in significant impacts to Okanagan Lake if not managed carefully. Recreational demand should be considered in light of results from this assessment and more specifically, a carrying capacity analysis focusing on recreation is required prior to consideration of the full spectrum of build-outs recommended in this study.

The analysis of Level of Impact indicates that there will be a loss of low and moderate value shorelines and an increase in the prevalence of shorelines with a high level of impact. The rate of change from low or moderate to a high level of impact is approximately 2.3% per year. Presuming rates of change stay the same, the percentage classified as having a high level of impact could increase from 57% to 89% by 2020. Although this analysis is extremely simple, it is apparent that there will be an increase in the percentage of the shoreline with a high level of impact. This analysis makes no specific inference about what the actual level of impact will be because there is insufficient data to predict with accuracy. Rather, the intent is to provide a "worst case scenario".

Table 9: The Level of Impact around Okanagan Lake (High > 40%, Moderate (10-40%), Low (<10%), None (0%)) in 2004 and 2010.

2004			2010			
Level of Impact	% of Shoreline	Shore Length	Level of Impact	% of Shoreline	Shore Length	2020 Projections (% of shoreline)
High	42.86%	55275	High	56.93%	73426	89.20%
Moderate	19.81%	25551	Moderate	15.32%	19762	4.10%
Low	37.33%	48141	Low	27.74%	35780	6.70%

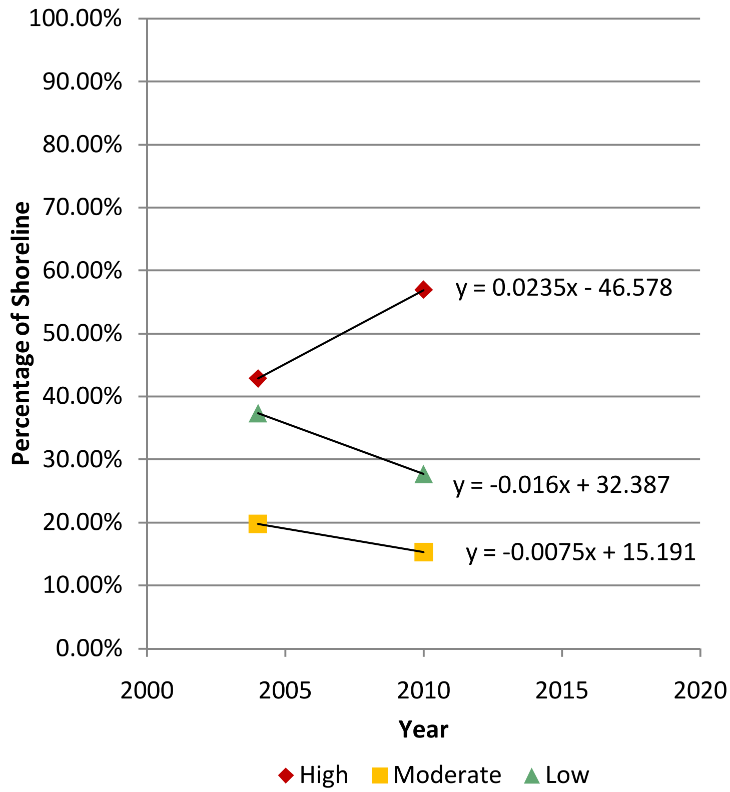


Figure 20 The percentage of shoreline that has a High, Moderate, or Low Level of Impact along central Okanagan Lake in 2004 and 2010.

An interesting result of the investigation into 2004 was the rate of change in areas classified as having a High, Moderate, or Low juvenile rearing value. To complete this analysis, it was assumed that the juvenile rearing value calculated based upon 2010 data would result in the same result using 2004 data. The analysis indicates that in areas of High rearing value, there is a loss of natural shoreline at a rate of approximately 1.3% percent. If the trend continues at this same rate, in 2020 there will only be 35% of the shoreline in natural condition in High value rearing areas. Again, this analysis is extremely simple and no specific inferences are made. It is just useful to identify where impacts are occurring and to potentially identify what species or life stages are being impacted.

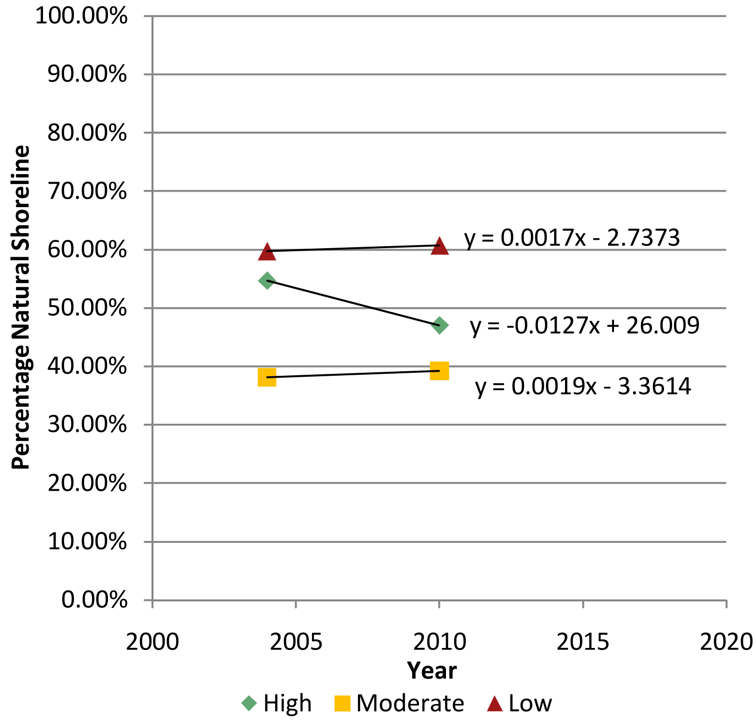


Figure 21 The percentage of natural shoreline in areas of High, Moderate, or Low Juvenile Rearing Value along central Okanagan Lake in 2004 and 2010.

Table 10: The shore length and percentage of shoreline areas classified as having High, Moderate, or Low Juvenile Rearing Value on Okanagan Lake in 2004 and 2010.

2004								2010								
Juvenile Rearing Category	# of Segments	Shore Length (m or %)					Juvenile Rearing Category	# of Segments	Shore Length (m or %)					2020 Projects of % Natural Shoreline
		Natural (m)	Natural (%)	Disturbed (m)	Disturbed (%)	Total			Natural (m)	Natural (%)	Disturbed (m)	Disturbed (%)	Total	
High	81	35016.7	54.68%	29018.33	45.32%	64035.6	High	81	30325.1	47.1%	34113.7	52.9%	64439.2	35.50%
Moderate	90	20921.0	38.09%	33999.55	61.91%	54920.9	Moderate	90	22166.9	39.2%	34361.6	60.8%	56528.9	47.66%
Low	13	5979.3	59.72%	4032.789	40.28%	10012.7	Low	13	4857.7	60.7%	3142.6	39.3%	8001.0	69.67%

Table 10: The lenght of natural and disturbed shorelines within the different Okanagan Large Lakes Protocol Kokanee Shore Spawning areas in 2004 and 2010.

2004								2010							
Black		Red		Yellow		No Colour		Black		Red		Yellow		No Colour	
Natural	Disturbed	Natural	Disturbed	Natural	Disturbed	Natural	Disturbed	Natural	Disturbed	Natural	Disturbed	Natural	Disturbed	Natural	Disturbed
80.51%	19.49%	62.36%	37.64%	32.87%	67.13%	28.37%	71.63%	77.3%	22.7%	60.5%	39.5%	29.9%	70.1%	23.6%	76.4%
22945.4	5555.54	17488.6	10554.3	6841.58	13972.6	14641.3	36968.2	22017	6484	16962	11081	6215	14599	12156	39454

The comparison to 2004 indicated there has been a reduction in the percentage of natural shorelines in all areas identified important to shore spawning kokanee (e.g., Black or Red Zones). The analysis indicates reduction in natural shorelines is occurring at less than 1% in all sites. The consistency in reduction across all identified zones indicates that even though the change is occurring, slowly, it is happening.

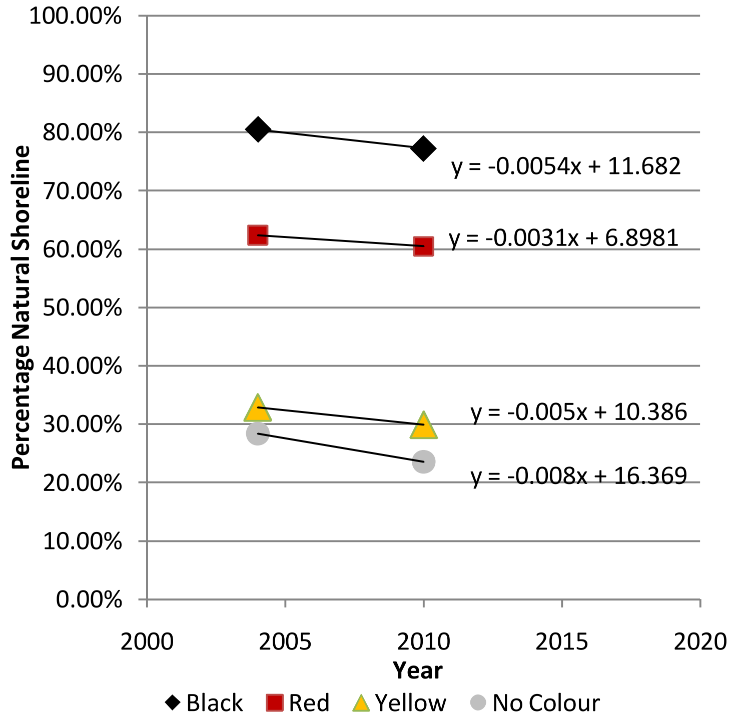


Figure 22 The percentage of natural shoreline in areas identified as being a Kokanee Black, Red, Yellow, or Non Colour spawning zone along central Okanagan Lake in 2004 and 2010.

The rates of loss of natural shoreline in areas classified as Very High, High, Moderate, and Low also show a decreasing trend. The assumption was made the habitat values in 2004 were identical to those resulting from the 2010 habitat index, similar to kokanee black zones and juvenile rearing analyses. The rate of decrease in areas classified as Very High was less than the rate in areas classified as High, Moderate or Low. The most dramatic decrease was a loss of approximately 1% per year and occurred in areas classified as High habitat value.

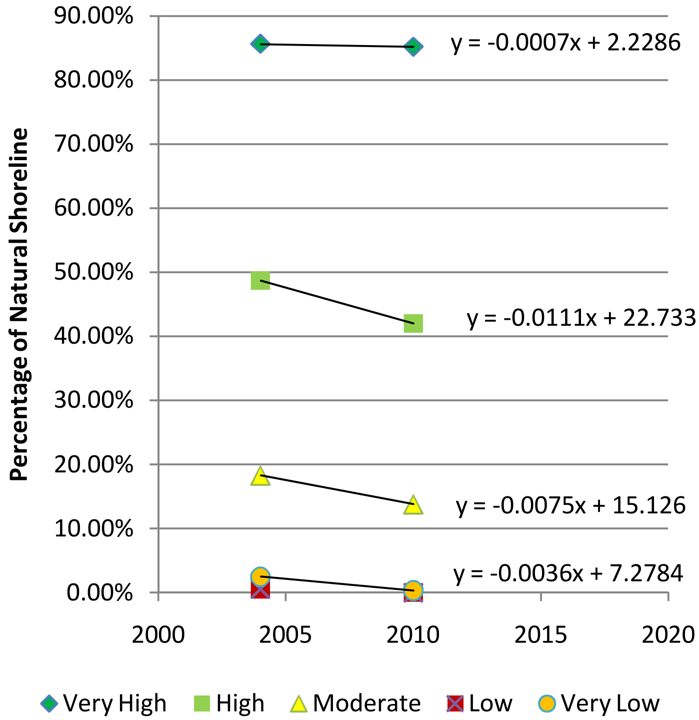


Figure 23 The percentage of natural shoreline in areas identified ranked as Very High, High, Moderate, Low, and Very Low along central Okanagan Lake in 2004 and 2010.

Table 12: The shoreline that is natural and disturbed (m and %) within each of the different AHI rankings in 2004 and 2010.

	2004					2010			
AHI Rank	Natural		Disturbed		AHI Rank	Natural		Disturbed	
	m	%	m	%		m	%	m	%
Very High	35656.37	85.60%	5998.978	14.40%	Very High	35485.19	85.2%	6170.164	14.8%
High	19692.28	48.67%	20767.11	51.33%	High	16997.44	42.0%	23461.96	58.0%
Moderate	6427.599	18.28%	28730.5	81.72%	Moderate	4854.649	13.8%	30303.45	86.2%
Low	44.59968	0.57%	7798.9	99.43%	Low	0	0.0%	7843.5	100.0%
Very Low	96.09355	2.50%	3755.179	97.50%	Very Low	12.45616	0.3%	3838.816	99.7%

7.0 RECOMMENDATIONS

7.1 Foreshore Protection

The following provides a list of recommendations for foreshore protection. Some of the recommendations below are similar to other recent FIM reports that were completed for the North and South portions of Okanagan Lake. 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. **A Shoreline Guidance Document (Step 3) should be developed by local government, the Province, First Nations bands, and Fisheries and Oceans for Okanagan Lake that includes the results of this analysis.** This inventory and cumulative analysis of Okanagan Lake provides a basis for a risk based approach to lake shore management and the framework for development of integrated management policies. The shoreline guidance document will facilitate inter governmental cooperation for lake shore 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 (see recommendations below regarding a lakeshore management plan). In the Shuswap, development of guidance documents such as this are being developed and they are considering the numerous different layers of data, including sensitive shore spawning sites. For these reasons, it should be relatively simple to incorporate both the aspects of the Okanagan Region Large Lakes Foreshore Protocol and results from this assessment into one shoreline guidance document.

2. **A clear set of objectives for the future need to be set and the objectives need to present desired objectives that are achievable.** The review of the 2004 and 2010 data indicate that change is occurring and it is potentially occurring at a fast rate. Clear objectives need to be set because it will help inform future management. Examples of clear targets include identifying the amount of natural and disturbed shore line that is a desired future condition and then using this methedology to determine if this goal has been met.

3. **Historical habitat impacts should be restored during development and re-development activities, with measures in place to ensure successful completion**. This analysis addressed habitat potential where restoration activities will benefit habitat quality. In review of development applications, existing modifications should be addressed with restoration or enhancement of foreshore areas affected by past modifications required if restoration or enhancement is likely to benefit habitat quality. Also, further modification to foreshore areas affected by past modifications should be prevented or mitigated. Examples include dismantling of groynes, placement of large woody debris, live staking and re-vegetating shoreline regions, riparian restoration, etc. Restoration objectives should be set higher in Low rated shoreline areas during redevelopment. There is significant opportunity

for partnerships (i.e., multi agency partnerships with stewardship groups) to be formed to help facilitate habitat restoration around the lakes. Further, it is strongly recommended that local governments develop restoration policies and objectives for disturbance areas to reverse the trends of impacts observed along the lake.

4. **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.** This analysis highlights the importance of conserving important natural areas that remain and prioritizing habitat improvements where feasible. In review of development applications, the protection of critical and natural areas should be addressed. The data in this report should be utilized to identify shoreline areas that should be protected.

5. **Key shore line linkages to sensitive terrestrial habitat have been identified by this assessment. These habitat linkage areas are extremely important to maintain and should be identified as early as possible in the development process.** These linkages should be incorporated into the Okanagan Biodiversity Strategy and the Regional Growth Strategy that is currently being developed. Core habitat areas are larger scale areas[4] have been mapped and these areas should be considered during development. These areas typically contain or are associated with red listed ecosystems or habitats for species at risk and the shoreline areas 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 a obligations for a minimum build-out that has significant impacts that are difficult to mitigate later on in the process). 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.). Finally, these linkages should be incorporated into the proposed Okanagan Biodiversity Conservation Strategy, the RDCO Regional Growth Strategy that is currently being developed, and other local government planning documents as appropriate.

6. **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 extensive information regarding the current condition of an area. This information should be available to the public.

[4] These habitat linkages are difficult to identify on a property basis through a simple setback assessment like the Riparian Areas Regulation assessment)

7. **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 numerous examples of historical and recent poor practice observed during this survey and other surveys of interior lakes have identified similar problems. An increase in compliance and enforcement monitoring at all levels of government is required because current practices do not appear to be working effectively (i.e., there were numerous, recent examples of construction inconsistent with BMPs). There is the potential to investigate a coordinated enforcement protocol with all levels of government to respond to foreshore habitat impacts.

8. **Habitat losses and gains should be monitored to measure success.** This would include the development of indicators, actions and timelines and initiation of a detailed habitat monitoring program on Okanagan Lake. Results of the monitoring program should be compared to the original inventory data to determine compliance with best management practices and effectiveness of protection activities.

9. **Development and use of best practices for construction of bioengineered retaining walls is required.** Bioengineering has many different meanings. Concise guidelines and best management practices should be developed that is consistent with standard practices of bioengineering. During the assessment numerous examples of recently constructed walls that were not compliant with standard BMPs were observed.

10. **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**. Initially, it is recommended that notice of the availability of this report and associated products are available on the Community Mapping Network and the Okanagan Conservation Planning website atlas's. The outreach strategy is required because many people are not aware of the impacts of their activities and are also not fully aware of appropriate and governing legislation for development activities adjacent to shoreline areas. . Funding should be sought to address outreach activities and address local government implementation.

11. **Lake shore erosion hazard mapping should be conducted for private lands to identify areas at risk, which will stream line the review process and reverse the damaging trend of unnecessary hard armoring and construction of retaining walls along the shoreline.** 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 (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 to minimize impacts and use bioengineering techniques. It may be possible to utilize the existing FIM map base, plus other associated data (e.g., SEI or others) to identify areas more prone to shoreline erosion.

12. **Storm water management plans need to be more adequately considered in all development applications.** There are numerous examples of local storm water concerns from adjacent land development related impacts. Recent works conducted by the District of West Kelowna have indicated that the Smith Creek corridor is experiencing rapid erosion due to storm water discharge. Other examples include the accidental release of pollutants to Mill Creek during a fire at a commercial complex in the City of Kelowna. Each of these examples highlights how, even non adjacent storm water has the potential to influence water quality, fish and wildlife populations, and human health (because most storm water is associated with increased levels of fecal coliforms and potentially other contaminants). In urban areas, focus of storm water plans should be to correct historical systems that have little detention and result in direct release to either a stream or the lake.

13. **Local, provincial, and federal governments should only approve proposed developments with net neutral or net positive effects for biophysical resources.** Developments on Okanagan Lake have generally only been considered individually. This is likely the first assessment that has looked at development related impacts on a lake wide scale. The results indicate that cumulative impacts are measurable and that trends are pointing towards increased or further impacts if management is not revised. This is analogous to the saying "Death by a thousand cuts" and local governments should ensure that development proposals do not add to the ongoing impacts observed around the lake.

14. **Compensatory works resulting from projects or portions of projects that could result in harmful alterations, destruction, or disruption of fish habitat must follow the DFO Decision Framework for the Determination and Authorization of Harmful Alteration, Disruption or Destruction of Fish Habitat[5]. The works must be consistent with the "No Net Loss" guiding principle of The Department of Fisheries and Oceans Policy for the Management of Fish Habitat.**

15. **Habitat enhancements should not be considered in cases where incomplete or ineffective mitigation or compensation is proposed.**

[5] Note that the Riparian Areas Regulation does not address habitat compensation requirements because they fall under the jurisdiction of Fisheries and Oceans Canada.

16. **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 bonding amounts should be collected. These bonds will ensure performance objectives for the proposed works are met and that efforts are constructed to an acceptable standard.

17. **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.**

18. **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.

19. **Helical screw anchors should be utilized as a first choice for mooring buoy anchors.** The significant numbers of 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.

20. **A lakeshore management plan developed jointly by all three levels government and First Nations is required to ensure an integrated shoreline management approach across jurisdictions is achieved.** There has been a dramatic increase in the desire to live and recreate on or near Okanagan Lake. The increased development pressure is resulting in a significant number of moorage applications (either public or private) and development proposals to increase density along the shoreline. The analysis of historical data indicates that change is occurring and in some cases at a fairly fast pace. Local, provincial, and federal agencies need to identify what the maximum proposed build out for Okanagan Lake will be and develop a cross jurisdictional plan to achieve this goal. The management plan should incorporate the clear set of objectives recommended above to provide guidance on whether management measures are achieving success. The development of this document 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. Although the specific rates of changes cannot be accurately predicted at this time using data currently available, nearly all metrics for rates of change (e.g., Percent Natural Shoreline, Number of Modifications, etc.) indicated that the state of the shoreline is declining. If the build out on the lake does not occur with coordination at all levels of government, the impacts identified in this report cannot be effectively mitigated (i.e., it is better to work as part of a larger regional initiative than as solitary jurisdiction). Further, if the build out occurs without implementation of appropriate measures, it is possible that some of

the rates of change documented here could occur on similar orders of magnitude. Items to consider when developing more long term management objectives include:

a. addressing substrate alteration occurring around the lake to prevent further degradation of important kokanee spawning habitats, remaining wetland areas, and important floodplains. Substrate modification occurred along 47% of the shoreline and was, by far, the most significant impact observed around the lake;

b. implementing sufficient measures, including ensuring adequate budget, to provide for a long term watershed management approach. The Okanagan Basin Water Board is currently an agency that has taken a leadership role in this aspect and is developing valuable tools for better water management;

c. addressing construction of moorages in Very High and High value areas by identifying areas where moorage is not appropriate. Appropriate alternatives should be developed to address moorage shortages that may arise in areas deemed unsuitable for moorage. Ultimately, a moorage plan for the lake as a whole should be developed that considers habitat sensitivity, recreational carrying capacity, and other identified factors;

d. adjusting terms of occupation to ensure foreshore protection measures are incorporated (e.g., shorter moorage tenure terms with renewal based upon foreshore condition) and that public resources are appropriately protected (e.g., kokanee stocks).

e. providing sufficient moorage and boat access (e.g., boat ramps, parking, etc.) in appropriate locations to offset concerns in Very High and High value areas;

f. incorporate on land storage facilities for boats with good boat access facilities;

g. consideration should be given to inclusion of public moorage in all private moorage facilities as a mechanism to offset demands in areas where moorage is not favoured;

h. identifying and preserving key linkages to areas identified as Core Conservation Areas, Wildlife Corridors, or Other Important terrestrial areas;

i. addressing the presence of critical kokanee spawning areas;

j. addressing the presence of important waterfowl, including identifying appropriate boating and recreational best use practices that will help avoid impacts to Western Grebe nesting areas in the North Arm;

k. ensuring that the lakeshore management plan considers the Biodiversity Conservation Strategy currently being developed for the Okanagan Basin;

l. identifying important drinking water intakes and incorporating appropriate buffers to avoid potential impacts with associated land development activities;

m. include allowances to address known data gaps (some have been identified in this report), including identification of other key habitat elements around the shorelines of Okanagan that are not included in this analysis. Key linkages not considered include herptile access locations, rare plant communities, etc.; and,

n. identifying the most appropriate mechanisms for compliance and enforcement monitoring. Consistent and easily enforceable compliance mechanisms are required because it is apparent that substantial works have occurred that are not in compliance with standard best practices;
o. include regulations and guidelines for new development, re-development and management of existing development;
p. designate protection of critical areas;
q. explore a memorandum of understanding with all levels of government regarding foreshore management roles and responsibilities;
r. consider other shoreline development guidelines and foreshore plans completed or currently being developed for Okanagan Lake.

7.2 Future Data Management

Future data management is extremely important to ensure that data collected during this survey is available, accurate, and up to date. Future data collection should be integrated into this concise GIS dataset. The following are recommendations for future use of the FIM dataset:

1. **One agency should take the lead role in data management and upkeep**. This agency should be responsible for holding 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 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 as there becomes more datasets costs of management will increase. Formal data management may however, be best achieved by the Okanagan Basin Water Board, which has funded most of the GIS inventory works. Another possibly more feasible, local option is the OCCP through the Okanagan Habitat Atlas program. Again however, sufficient funding needs to be in place to appropriately manage and keep the data.

2. **A summary column(s) should be added to FIM GIS dataset that flags new GIS datasets as they become available.** Examples of this include new location maps for rare species, fish, etc. Other examples include the addition of appropriate wildlife data. Where feasible, these new data sets should reference the shore segment number (see below).

3. **The Segment Number is the unique identifier. Any new shoreline information that is provided should reference and be linked to the shore segment number.**

4. **Review and update of FIM/AHI and mapping should occur on a 5 year cycle.** Review and update of the FIM will be required to determine if shore line goals and objectives are being achieved. The analysis within this report have identified that 6 years is a sufficient period of time to document change. For this reason, the timing of inventory cycles should be around 5 years. In a perfect world, changes to the FIM data set would be done as projects are approved (i.e., real time). However, at this time, it is unlikely that capacity exists to establish such a system.

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 spawning locations for resident fish species is limited.** Numerous resident fish species, including burbot, lake whitefish, and rainbow trout have been identified within the lake system. In our review, there is only limited data regarding shore or stream spawning locations for these fish species. Future inventory of important areas for these species should be conducted. This is one of the operational management recommendations for Okanagan Lake (Redfish Consulting, 2007).

2. **The Juvenile Rearing Suitability Index should be field confirmed**. The rearing index that was developed for this project is based upon surveys in Shuswap Lake and a rearing index developed for Mabel Lake. There are differences between the Mable Lake and Okanagan Lake and the index utilized for this assessment should be adjusted according to results of a field program that samples different shore line 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.

3. **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 Okanagan 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.

4. **In addition to the Western Ridged Mussel mentioned in this assessment, other bivalves are present in Okanagan Lake and should be inventoried to identify any species of significance and their importance with the lake system.** Bivalves are good species to use as indicators. By mapping known locations, and identifying their spatial extents, it will be much easier to monitor future change in the populations. Further, monitoring of these populations may point to early warnings if the lake system is not functioning properly.

5. **The Sensitive Habitat Inventory and Mapping (SHIM) is a GIS based stream mapping protocol that provides substantial information regarding streams and watercourses and should be conducted on all watercourses around the lake**. Most of the streams in the Central Okanagan have been mapped using the SHIM protocol. However, there are still numerous important waterways that have not been mapped. These include some of the important source water streams. Continued mapping should focus on significant salmonid rivers and streams first, on smaller tributaries containing less fish habitat, followed by non fish bearing waters. This mapping protocol provides useful information for fisheries and wildlife managers, municipal engineering departments (e.g., engineering staff responsible for drainage), and others. This information is also extremely useful for Source Water Protection initiatives because it identifies potential contaminant sources in an inventory.

6. **Future shore spawning enumerations should identify the spatial locations of spawning activity for other fish species in a spatial fashion.** Shore areas are critical habitat features necessary to the maintenance of healthy populations. Spatial data regarding the locations and numbers of individuals will allow for species other than kokanee and will help managers to track changes over time and better relate changes in the watershed to changes in fish production. GIS enumeration will be a key component of any successful, long term fisheries management project. This is one of the operational management recommendations for Mable Lake (Redfish Consulting, 2007).

7. **Wetlands are extremely productive and important components of our ecosystems and these features should be inventoried**. Numerous low flood and mid flood benches and shore marshes were mapped during this survey. Detailed Wetland Inventory and Mapping (WIM) of these features are recommended. Detailed mapping of terrestrial wetlands is also important to ensure that linkages between foreshore and upland areas are achieved.

8. **An inventory of high value habitat islands in urbanized areas should be conducted in areas of concentrated settlement.** In many cases, small sections of higher habitat quality were observed in segments ranked Moderate to Low. These areas were typically areas that had well-established native vegetation or relatively natural shorelines. Development applications proposed in these "islands" of higher habitat quality should avoid disturbance to these "islands" as much as possible. A survey of these small "islands" would clarify which segments contain "islands" and would help aid planning objectives. This could form part of a riparian mapping exercise, where all shoreline vegetation is mapped and coded appropriately (e.g., coded and lawn, landscaped, coniferous, riparian, etc.).

9. **A carrying capacity analysis of the lake should be completed.** In this case, the carrying capacity refer's to a lakes ability to accommodate recreational use (e.g., boating) and residential occupation without compromising adjacent upland areas, biological resources, aesthetic values, safety, and other factors. Biological systems are extremely difficult to predict and manage. Currently, these fish and wildlife ecosystems are experiencing rapid changes due to a variety of factors including, but not limited to land development (e.g., water consumption may be exceeding the capacity of some streams, etc.) and climate change. At this point, it appears that the significant biological resources around the lake are maintaining viable populations. Determining the threshold upon which cumulative effects will have measurable and noticeable impacts is very difficult and therefore a conservative or precautionary approach is required. Determining carrying capacities on our large, interior lake systems is currently one of the most significant challenges to lakeshore management because it impacts many cultural, social, and environmental values of residents.

10. **A survey should be conducted on a home by home basis 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 assist 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.

11. **The addition of new segment breaks in long segments should be assessed in the future.** Some segments, predominantly in more natural areas, are quite long. Future mapping updates may wish to assess some new segment breaks on longer segments as more information is collected. Features should be considered as part of more detailed segment mapping include the locations of small tributaries, seepages, streams in natural areas, etc.

12. **Native beds of submergent and floating vegetation should be mapped in detail.** Native beds of submergent and floating vegetation were extremely rare on Okanagan Lake. More detailed mapping, maybe as part of a Wetland Inventory and Mapping project, would help better classify and described these rare, sensitive features. A good example of these communities is located in *Segments 93 and 84.*

13. **Conduct a more detailed analysis of habitat restoration opportunities, including riparian restoration.** An Aquatic Restoration potential analysis (AHI_POT) which was 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*. A more detailed analysis of habitat restoration opportunities, including riparian restoration is advised in the future because riparian restoration activities will provide substantial habitat benefits to the lake.

14. **Further research on the extents and magnitude of AHI devaluation due to construction of modifications is required.** The common modifications that were observed that could be easily quantified were added to the habitat index. The devaluing effects of modifications were determined through a series of iterations and are consistent with other large lakes. Further research is needed to confirm the approach taken and the weightings applied to different factors in the analysis.

8.0 CONCLUSIONS

The following report documents the current condition of 289 km of shoreline on Okanagan Lake. The assessment provides substantial background information summarizing the current condition of the upland and terrestrial zones and foreshores of Okanagan Lake. An Aquatic Habitat Index (AHI) was developed that used biophysical information collected during the survey to rank the relative environmental sensitivity of the shore zone areas around the lakes. Recommendations are presented to help integrate this information into local land use planning initiatives.

Approximately 43% of the shoreline that remains in natural condition and represents approximately 125 km of shoreline. In total, 30% of the shoreline is ranked as Very High Value and these very high habitat value areas tended to occur stream confluences, or their associated floodplains, or on gravel and rocky shores with suitable kokanee spawning habitats. Approximately 1.1% is ranked very low value and these areas tended to be on low gradient gravel and sand areas that have been severely impacted.

The most notable shoreline modifications that were observed were docks, retaining walls and groynes. In total, approximately 47% of the shoreline has had substantial substrate modification from groynes, beach grooming or construction of retaining walls. These impacts, along with riparian vegetation disturbance, are considered the most significant habitat degradations observed around the lake.

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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. For example, the Ministry of Environment have been recently creating documents containing guidelines for work in and around water.

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 lake corridors and was performed by the Regional District of Central Okanagan and partners. A full discussion of this mapping can be found in Regional District of Central Okanagan (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.