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.