PART TWO – DATA AND DATABASES

3.0 PART TWO OVERVIEW

Part Two of the Summary Report summarizes the various datasets, databases, and technical studies completed during Phase 2 of the Okanagan Water Supply and Demand Project. Figure 3.1 is a schematic diagram that illustrates the various studies and the links between them.

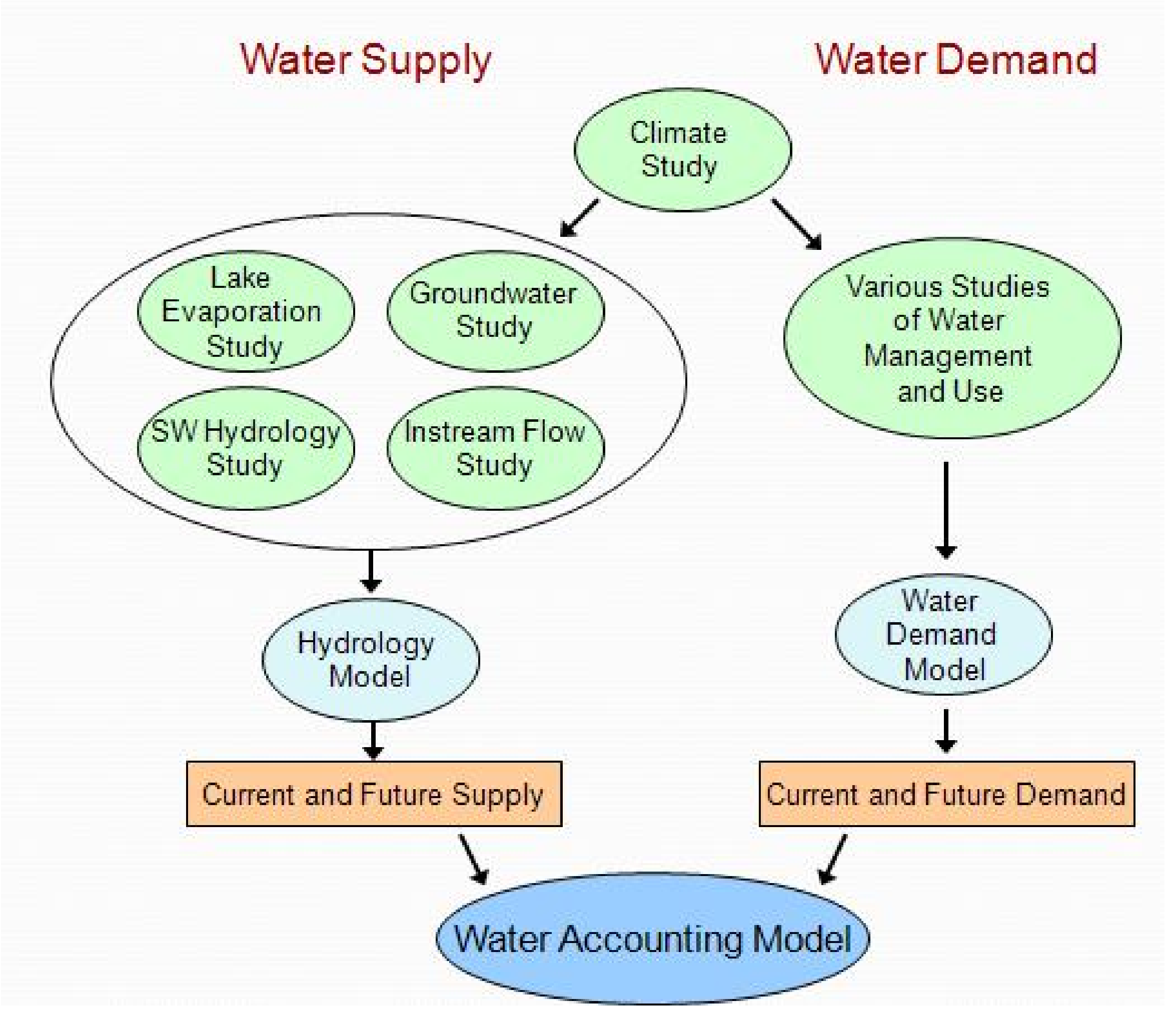

Figure 3.1 Interactions between the various Phase 2 technical studies and models.

4.0 BASIC TECHNICAL CONCEPTS

Three map layers were developed during Phase 2:

- A surface water layer (Attachment 1);
- A groundwater layer (Attachment 2) ; and
- A water use area layer (Attachment 3).

A separate climate layer consisting of a 500 m by 500 m grid was developed by Environment Canada (EC), AAFC, and the University of Lethbridge (U. Leth.) prior to the start of Phase 2 for water demand modelling and other applications. The development of the climate datasets is explained in Section 5.0. In addition to these layers, the Okanagan Water Demand Model has used several other data layers covering the developed areas of the Basin, including soil, cadastral, irrigation systems, and crop types. These layers are described in Section 14.0.

The surface water layer consists of 81 nodes (i.e. "points-of-interest) which are tributaries, residual land areas, mainstem lakes (i.e. Kalamalka, Okanagan, Skaha, Vaseaux, and Osoyoos), and mainstem Okanagan River locations.

The groundwater layer consists of 324 aquifers underlying the Okanagan Basin - 245 bedrock aquifers and 79 alluvial aquifers. The bedrock aquifers are found in the upper elevation areas of the Basin, and the alluvial aquifers are found along the main valley, and along the larger tributary valleys.

Water extracted from surface sources and groundwater wells is used for many purposes. Attachment 3 is a map of water use areas in the Basin. Each of these areas is linked to one or more water sources (surface or groundwater). After calculating the water used on each water use area, the Okanagan Water Demand Model calculates the required withdrawal from each water source to satisfy that demand.

The various possible ways in which water can move on the surface and below ground surface within the Basin are illustrated schematically on Figure 2.1 in Appendix B.

The scientific studies undertaken in support of the Project were designed to:

- Provide the current (1996-2006) and best available information on water resources in the Basin; and
- Provide relevant information to calibrate the Okanagan Basin Hydrology Model and the Okanagan Basin Water Accounting Model.

The 1996-2006 (11-year) period was selected as the “base case” for three reasons:

- It reasonably reflects the current population, climate, land use, irrigation practices, and water distribution systems;
- It includes three Canada Census years (1996, 2001, and 2006); and
- It specifically includes the year 2006, which represents a reasonably average year for water supply and use for which data from water suppliers was available.

The Census data facilitated analyses of per capita water use during the water use studies.

The Okanagan Basin Hydrology Model and the Okanagan Basin Water Accounting Model were calibrated using 1996 – 2006 data. Since this period includes a mix of average years, drier than average years, and wetter than average years, it is ideal for model calibration over a wide range of natural conditions.

5.0 DEVELOPMENT OF CLIMATE DATA SETS

A climate layer consisting of a 500 m by 500 m grid was developed by EC, AAFC, and U. Leth. for use in water demand modelling and other applications (Appendix N). Estimates of daily maximum and minimum temperature and daily precipitation have been generated for each cell in this climate grid using a number of methods. First, for the 1996-2006 calibration period, a network of 154 climate stations provided observed information to allow Environment Canada to populate the grid with daily maximum temperature, daily minimum temperature, and daily precipitation values. This dataset contains the best estimates of actual climate data available, and was used to calibrate both the Okanagan Water Demand Model and the Okanagan Basin Hydrology Model for the 1996 – 2006 period. Second, using the outputs of six General Circulation Models (GCMs), with outputs downscaled to the Okanagan climate grid, daily values of temperature and precipitation for each day from 1961 to 2100 were estimated.

The Working Group chose to use the Canadian General Circulation Model Version 2 (CGCM2) model (with the A2 CO_2 emission scenario) for examining the impact of future climates on Okanagan water resources (Sections 17.0 and 18.0). To ensure a clear comparison between future climates and the 1996-2006 calibration period climate, precipitation and temperature in the 1996-2006 “observed” dataset were compared with the 1996-2006 CGCM2A2-generated dataset. Differences in means and variances were corrected (see Appendix N), so that clear comparisons can be made between scenario results and 1996-2006 results.

6.0 WATER MANAGEMENT AND USE

Overview

In the Okanagan Basin water is extracted from many streams, lakes, and groundwater aquifers to support a growing population (approximately 294,000 in 2006) and a multitude of water-reliant activities. A number of investigations were completed during Phase 2 to understand how water is used and managed throughout the Basin. These investigations (which are documented in Appendix C), supported the development of the Okanagan Water Demand Model (the model is described Section 14.0). The output of that model provides an updated picture of how much water is presently[1] extracted from water sources and used in the Basin. A summary of the key technical findings is provided in this section.

Annual water balances

The overall water balance for the Basin is shown in Figure 6.1. This figure summarizes the information presented in the present section of the report, as well as information presented in subsequent sections. The values on the figure are annual totals, but they are averaged over time for the period 1996-2006, and across the entire area of the Basin. The figure does not indicate the variability which characterizes both water supply and water demand. Decision-making must consider the seasonal variability in both supply and demand, the differences that exist from place to place within the Basin, and the annual variability in both supply and demand.

The average annual water balance for Okanagan Lake is shown in Figure 6.2. As for Figure 6.1, this figure summarizes information presented in the present section of the report, as well as information presented in later sections.

Water rights for extraction and use of water in the Okanagan Basin

Within the Basin there are 101 known water suppliers and a total of nearly 4,000 active water licences[2] which have been issued by the Province to store or use surface water[3]. Approximately 443,000 megalitres[4] (ML) of surface water is licensed annually for offstream use while 351,000 ML is licensed for in-stream (conservation) and other "non-consumptive"

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[1] A period between 1996 and 2006 was analyzed to define current conditions.

[2] Water licences issued by the Province identify the volume of water that suppliers or users are legally entitled to extract from surface water sources for beneficial use. The volume of water allocated with water licences does not necessarily indicate the volume of water *actually* extracted and used.

[3] Surface water includes water from streams, lakes, and springs. It does not include groundwater, which currently does not require licensing.

[4] 1 megalitre (ML) is equal to 1 dam^3 (cubic decametre) or 1,000,000 litres. For reference, the volume of an Olympic-sized swimming pool is 2.5 ML, while the approximate volumes for the main lakes in the Okanagan Basin are as follows: Ellison (Duck) Lake (5,400 ML), Vaseux Lake (18,000 ML), Wood Lake (157,000 ML), Osoyoos Lake (325,000 ML), Skaha Lake (500,000 ML), Kalamalka Lake (1,560,000 ML), and Okanagan Lake (24,600,000 ML).

uses[5]. These uses are supported by 163,000 ML of water licensed for storage, typically within upland reservoirs. The operation of storage reservoirs is critical to the management of surface water in the Basin since most surface runoff occurs during a short period each spring when snowmelt occurs. However, most demand for water occurs later in the summer. The 36 major storage reservoirs in the Basin have a combined capacity of 133,000 ML, or about 82% of the total volume licensed for storage.

Volume of water actually used in the Okanagan Basin

Based on the technical studies and on the Okanagan Water Demand Model, the average annual water use in the Basin totals an estimated 219,000 ML. However, between 1996 and 2006, total annual water use has ranged from about 187,000 ML in 1997 (a relatively wet year) to 247,000 ML in 2003 (an extremely dry year) (Figure 6.3).

Sources of Water in the Okanagan Basin

Of the 219,000 ML of water actually used annually in the Basin, an estimated 147,000 ML (67%) is obtained from surface sources in the Basin (Figure 6.4). The rate of surface water extraction varies throughout the year in response to demands by water users. During the late fall and winter, when irrigation is not occurring, surface water extraction in the Basin is steady at about 500 ML/week. However, with the onset of irrigation in spring, water extraction rates increase until they peak in late July to mid-August at about 8,500 to 10,000 ML/week. While water is extracted from many locations in the Basin, about 32% of the total surface water used is obtained from the three (3) largest sources: Okanagan Lake, Mission Creek and Kalamalka/Wood Lake (Table 9.2 in Appendix C).

Although less groundwater than surface water is used, groundwater is becoming an increasingly important source of water. There are now 23 known water suppliers (with 74 active wells) that pump a combined total of 49,000 ML of groundwater each year in the Basin. This represents 22% of the total water use in the Basin (Figure 6.4). As with surface water, the rates of groundwater extraction vary with demand through the year, from about 100 ML/week in late fall and winter to about 3,000 to 4,000 ML/week in late-summer.

There are eight (8) known water suppliers that import water from outside the Basin to supplement existing water supplies (Table 7.1 in Appendix C). On average, the volume of water imported annually is approximately 17,000 ML, or 8% of the total use in the Basin (Figure 6.4).

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[5] See Table 5.2 in Appendix C for a complete description of licensed end-uses.

Several water suppliers (including Greater Vernon Water, Town of Oliver, City of Armstrong, and Town of Osoyoos) are supplementing their water supply by using WTP effluent to irrigate agricultural lands. On average between 1996 and 2006, 7,000 ML of this “recycled” wastewater was used for this purpose each year, which represents 3% of the total water use in the Basin.

The study evaluated two means by which humans “return” water to groundwater: the operation of septic systems and over-irrigation. The latter is also known as *deep percolation*, and represents a volume of water that is not used by vegetation but rather infiltrates beyond the root zone to groundwater. On average, septic systems in the Basin “return” about 10,000 ML of water per year to groundwater, while deep percolation supplies about 25,000 ML per year.

Four (4) of the ten (10) known wastewater treatment plants (WTPs) in the Basin (namely City of Kelowna, City of Penticton, District of West Kelowna, and District of Summerland) discharge or “return” water to surface waterbodies, namely Okanagan Lake and Okanagan River. Combined, these four (4) WTPs discharge a total of 17,000 ML of effluent on average each year. Approximately 75% of this volume is discharged to Okanagan Lake while 25% is discharged to Okanagan River near Penticton.

Distribution of water between end-uses in the Okanagan Basin

Year-to-year distribution of water use among the end-uses is relatively consistent, with the greatest proportion (55%) typically used for agriculture (Figure 6.5). This is followed by domestic outdoor (24%), domestic indoor (7%), golf courses (5%), commercial (4%), parks and open spaces (2%), industrial (2%) and institutional (1%) water use.

On average, 120,000 ML (or 55% of the total Basin water use) is used to irrigate an agricultural area in the Basin of approximately 18,300 ha. This represents a Basin-wide average application of 660 mm of water over the irrigation season. Locally, however water application rates vary by crop, irrigation system, soil and climate.

Within the Basin there are 41 known golf courses that irrigate an estimated 1,060 ha of land. An estimated total of 10,000 ML of water is typically used by golf courses during the irrigation season. This represents an average application of 960 mm per season. Irrigated park lands and other “green” spaces in the Basin, totalling approximately 590 ha require an additional 5,000 ML each irrigation season. This equates to an average application of 920 mm per season.

In the Basin, total domestic water use averages 68,000 ML per year, or 31% of the total water use in the Basin (Figure 6.5). Approximately 22% of this total is used indoors, while 78% is used outdoors. Between 1996 and 2006, the average year-round combined indoor and outdoor water use in the Basin was 675 L/person/day. Indoor use is relatively constant throughout the year at 150 L/person/day. Outdoor use is nearly zero for 6 months of the year, but averages over 1,000 L/person/day in the other 6 months.

Institutional, commercial, and industrial (ICI) water users include schools, hospitals, care facilities, businesses, and industry. In most cases, the main use of water is for indoor domestic-type purposes (e.g. drinking, toilet flushing, and washing). Over 5,000 ICI users were identified in the Basin, together using an average of 15,000 ML (or 7% of the Basin total) annually. Of this total, approximately 2,000 ML is associated with institutional users, 8,000 ML is associated with commercial users, and 5,000 ML is associated with industry (Figure 6.5).

Losses from the managed system and “unaccounted for water” (UFW) include water lost to deep percolation through over-watering, irrigation system inefficiencies, leakage in the water suppliers’ distribution systems or at the point-of-use, and water theft. The term “loss” is used relative to the managed system – the water is not lost from the groundwater system or the Basin as a whole. Based on limited records, distribution system losses for all end-use categories were assumed to be 5% of the total volumes conveyed through water supplier systems. Losses are included in all the quoted water use values above. Total losses from all end-uses average an estimated 51,000 ML.

Summary

These investigations of water use and management are the result of a major effort to understand current water management and use patterns throughout the Basin. This summary provides Basin-wide information, and information for specific areas is provided in Appendix C.

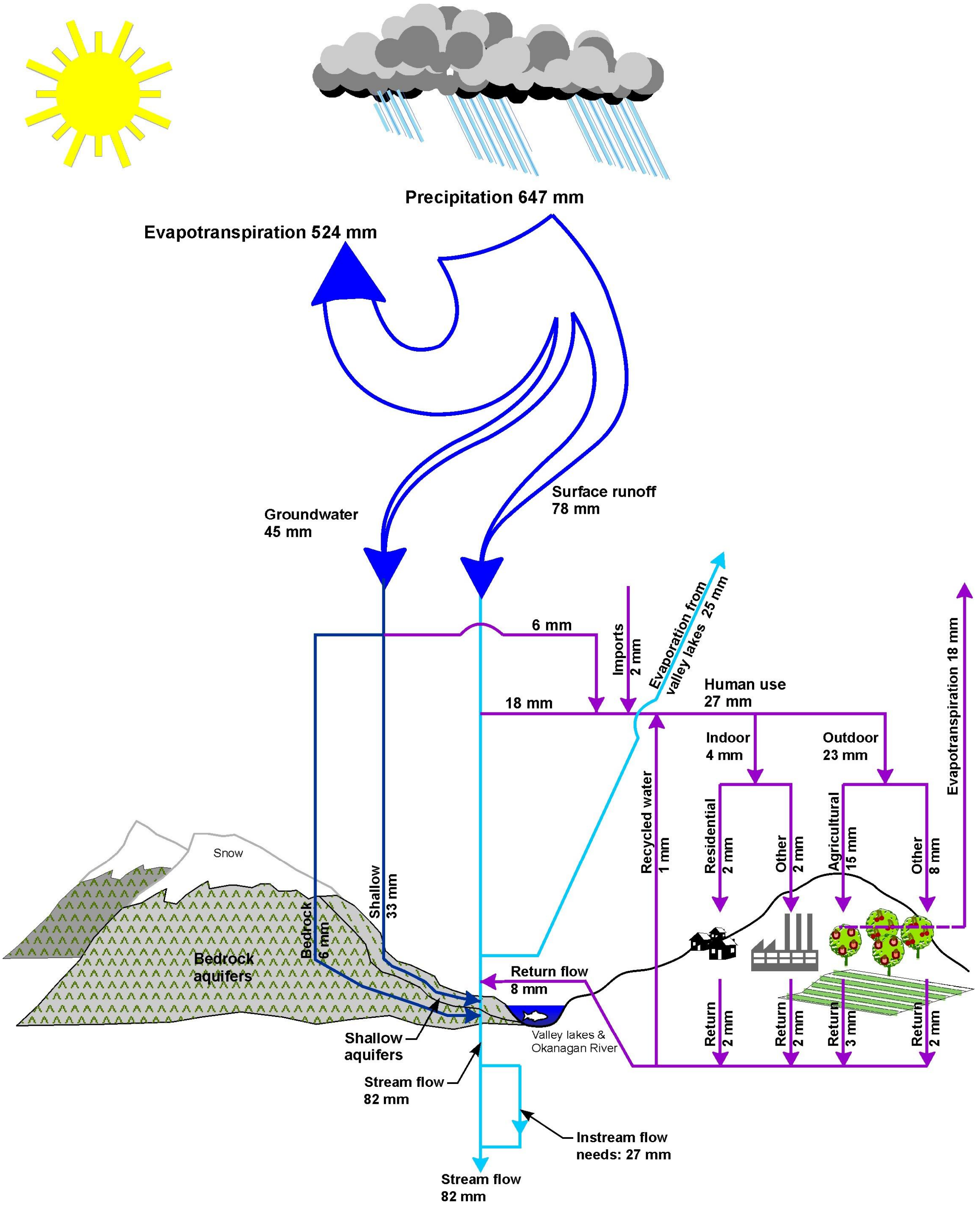

Figure 6.1 Average annual water balance for the Okanagan Basin.

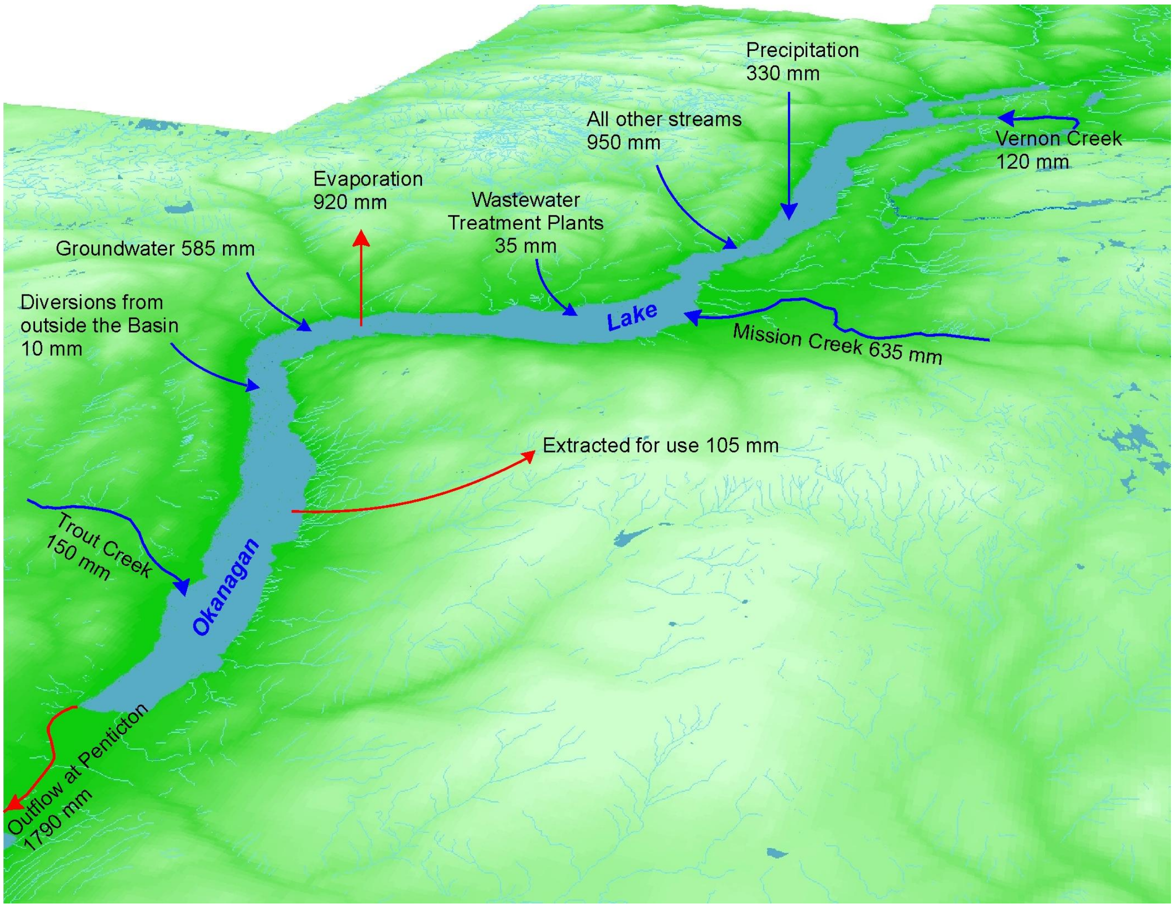

Figure 6.2 Average annual water balance for Okanagan Lake.

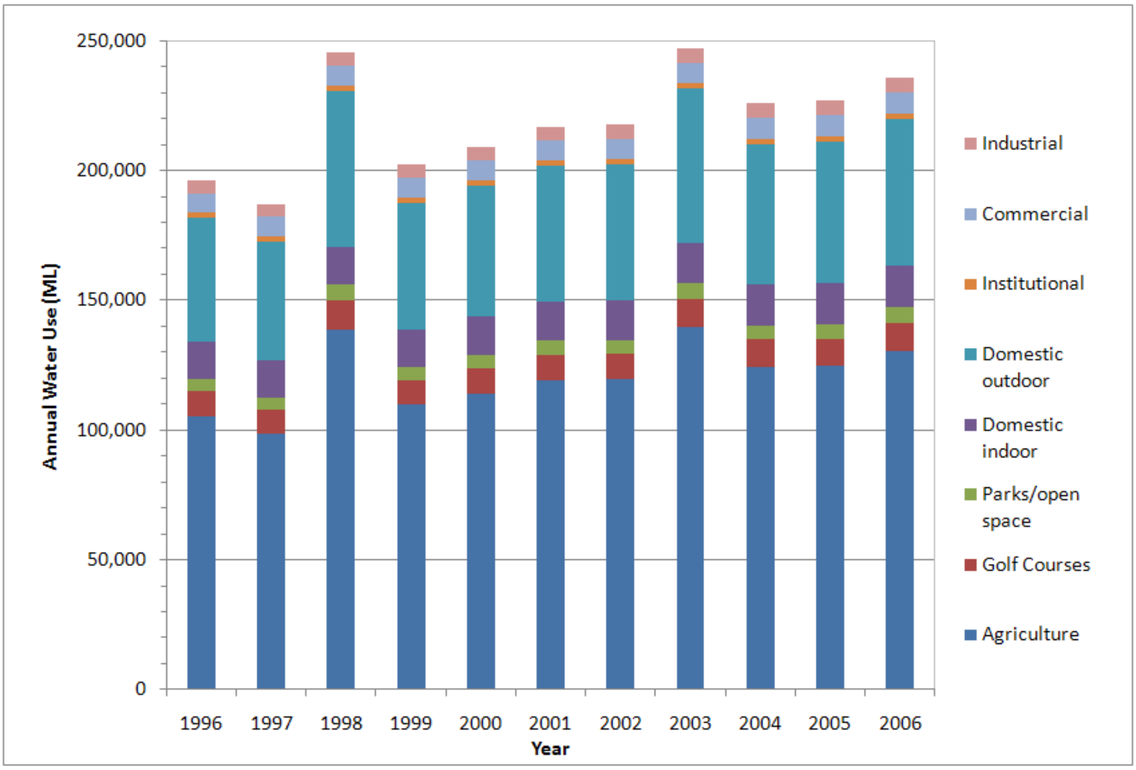

Figure 6.3 Estimated volume of water used in the Okanagan Basin between 1996 and 2006 by end-use.

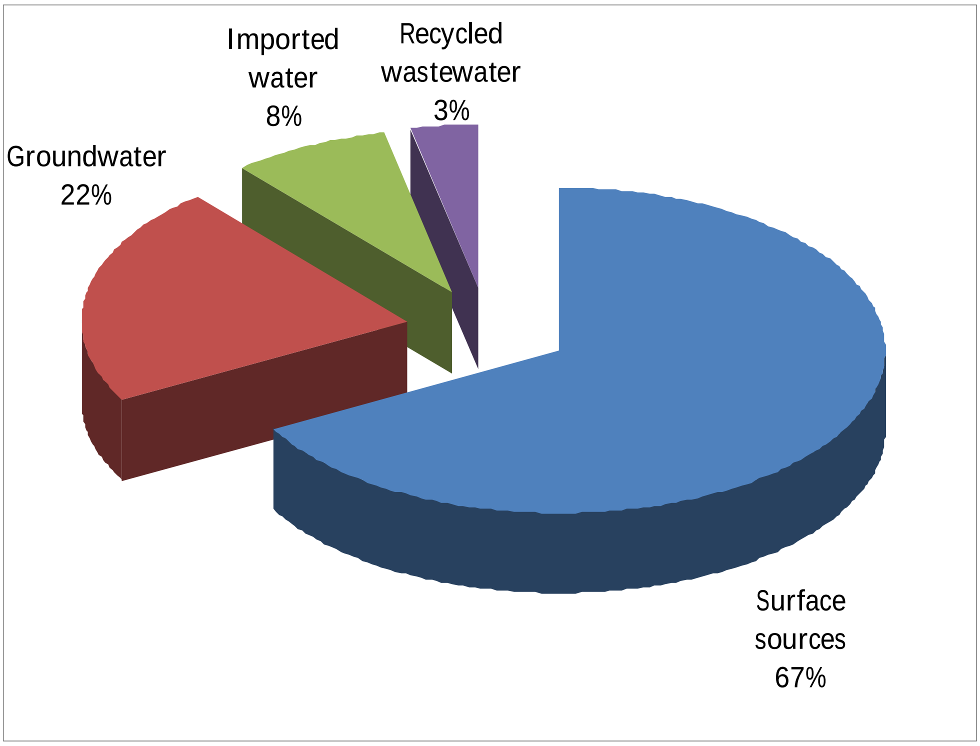

Figure 6.4 Typical distribution of total water use in the Okanagan Basin by source (based on data for 1996 to 2006).

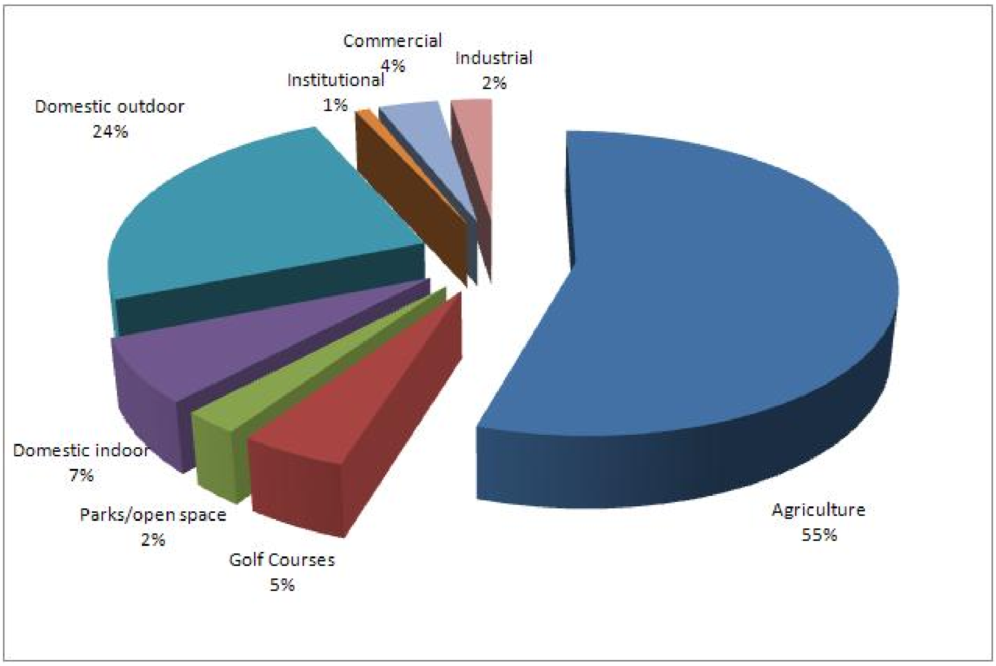

Figure 6.5 Typical distribution of water use amongst water users.

7.0 GROUNDWATER RESOURCES

Introduction

Three groundwater study objectives were met during Phase 2 - they are listed below along with the primary deliverables:

Groundwater Study Objectives	Main Deliverable(s) and Authors
1. To develop a comprehensive State-of-the-Basin report to synthesize the current state of knowledge of groundwater in the Okanagan Basin and document sources of information on groundwater.	*Groundwater and Hydrogeological Conditions in the Okanagan Basin of British Columbia – a State-of-the-Basin report.* **Appendix D**
2. To develop as thorough a series of conceptual models of the groundwater systems throughout the Okanagan Basin as is possible with existing information.	*Groundwater Study Objectives 2 and 3: Phase 2 Okanagan Water Supply and Demand Project – Final Report* **Appendix E**
3. To represent Okanagan groundwater systems in the format required by a water balance model of the basin.	Completed 1996-2006 monthly water balances for 79 unconsolidated aquifers. **Appendix K**

This summary focusses on the conceptual groundwater flow model developed in Appendix E. That model was based primarily on the information identified in Appendix D.

The methodology developed for the water balance modelling used a spreadsheet tool custom-designed for this Project (Groundwater Balance Analysis Tool - GWBAT). The water balance (GWBAT) model is based on upland areas recharging valley-bottom aquifers. The concept underlying the model is that a significant portion of the recharge in the upland areas of the Basin reports to a shallow bedrock flow system and that this flow, along with infiltration of some streamflow along the edges of the Okanagan Valley is conveyed to the Valley bottom unconsolidated aquifers.

Two upland groundwater flow systems exist within the conceptual model: i) a shallow upland flow system consisting of relatively thin and localized surface deposits overlying weathered upper bedrock formations; and ii) flow through deeper-seated bedrock fractures. The model assumes that upland recharge mainly supplies the shallow upland aquifer zone, not the deeper zone. Groundwater within this system stays within the boundaries of the overlying surface catchment area, and is recharged, stored and discharged to lower-lying unconsolidated aquifers and streams on a timeframe of years to decades. The model assumes that groundwater flow patterns are determined by local surface topography.

Upland recharge to fracture-flow systems in deep-seated bedrock is thought to be small as a percentage of total groundwater recharge, but occurs across a broad area and over a very long timeframe (hundreds to thousands of years). The deep-seated system may hold large amounts of water in storage, but due to the physical constraints of deep-seated fracture flow much of this water remains in storage and moves through the system on a timeframe that far exceeds the weekly/monthly time steps of the water balance analysis. It is possible that higher-permeability geological structures such as faults and fracture zones may exist in the deep-seated bedrock flow system, but the basin-wide scale of this study does not provide sufficient resolution to identify and quantify such features.

Recharge from bedrock to the lower-lying unconsolidated aquifers is assumed to be constant, whereas recharge from stream losses to unconsolidated aquifers is seasonally variable and proportional to surface water runoff, with the majority occurring immediately following snowmelt-generated peak streamflows in spring. In general, annual water level fluctuations in representative observation wells in valley-bottom unconsolidated aquifers are relatively small, ranging from less than 1 m to about 2 m. Larger water level fluctuations may be observed near pumping wells and in upland areas.

A total of 79 distinct unconsolidated aquifers were identified (Attachment 2), located primarily in the valley bottom. Characteristics of these aquifers are described in Section 5.0 and Appendix III of the main groundwater report (Appendix E).

Three areas of the Basin contain connected aquifer systems of regional importance (Section 7.3 of Appendix E):

- North Okanagan: Coldstream-Vernon and Spallumcheen unconsolidated aquifers;
- Central Okanagan: Greater Kelowna aquifers; and
- South Okanagan: Vaseux Lake to Osoyoos Lake aquifers.

Detailed analysis was applied to each aquifer, and the resulting models are applicable to a Basin-scale estimation of groundwater balance. Different results can be expected from other studies conducted at the local, sub-basin or catchment scale. The information from the Phase 2 work provides a useful starting point for gathering the quantitative groundwater and hydrologic/hydrogeologic information that would be needed for a local-scale study.

Monthly water balances were computed for the 79 unconsolidated aquifers delineated in this study. The spreadsheet-based water balance tool (GWBAT) allows for the determination of water balances for individual aquifers based on an approximate analytical solution, rather than a complex numerical solution. The tool used data from several sources that form part of the Phase 2 work, including gridded climate data, regional surface water runoff data, calculated bedrock recharge values, predicted groundwater use, and predicted irrigation return flow. In addition, the groundwater study team developed estimates of stream loss, recharge, physical aquifer properties, and water table evaporation for selected aquifers.

The estimated mean annual flow (total discharge to the valley-bottom rivers/lakes) in all 79 unconsolidated aquifers for the 11-year period 1996-2006 is 943,000 ML/yr. The year 2003 had the lowest annual flow (928,000 ML), while the highest annual flow was 956,000 ML in 1997 and 2000. The difference between the largest and smallest estimated annual flow is only 28,000 ML.

The mean annual groundwater discharge into Okanagan Lake is estimated to be 296,000 ML (40 percent of mean annual (total) inflow to the Lake, as reported in the Surface Water Hydrology report (Appendix G)), with Aquifer 234 (Summerland) contributing approximately 25 percent of this amount. Based on the water balance results, it can be inferred that 92 percent of the mean annual groundwater flow to the Lake occurs through the unconsolidated systems (many of which receive recharge from the shallow bedrock flow system), with many of these systems surrounded by large catchments. By comparison, the 11-year mean annual groundwater discharge to Okanagan Lake, calculated in Appendix G is only 41,300 ML. This is only 5.7 percent of the mean annual lake inflow (compared with 40% as calculated in the groundwater study). That these two independent methods give such different results is a reflection of the quantity and quality of the available groundwater data; and different approaches to accounting for groundwater-surface water interaction (e.g. aquifers can contribute baseflow to streams and streams can act as sources of recharge to groundwater – different accounting methods will account for these source/sink terms differently and could result in some of the groundwater being accounted for as surface water and vice versa). The actual volume of groundwater discharge reporting to Okanagan Lake, on a long-term annual basis likely lies between the two estimates and should be refined on a smaller scale (i.e. within specific sub-basins) once better groundwater data, streamflow data and baseflow separation analysis are available to support more detailed groundwater-surface water accounting.

Figure 7.1 provides a summary assessment of groundwater aquifer recharge in the Okanagan Basin. It should be emphasized that the red areas (areas of minimal recharge) may contain significant volumes of groundwater stored in bedrock aquifers. However, natural recharge to such aquifers appears to be very low, and more detailed study is warranted in these areas before significant groundwater development occurs. Most of the bedrock aquifers surrounding the mainstem lakes are denoted red on Figure 7.1 and are recharge-limited. Further development of groundwater resources in these recharge limited areas may not prove sustainable.

Recommended investigations to improve understanding of groundwater resources (Section 9, Appendix E) include:

- Surface water-groundwater interaction assessments - collecting and mapping streamflow data in creeks crossing alluvial fans and monitoring water levels in aquifers near the creeks to identify and quantify areas where streams may be losing or gaining with respect to groundwater;
- Adding more provincial groundwater observation wells in aquifers currently not monitored;
- Conducting studies to confirm the conceptual model of groundwater flow in bedrock areas; and
- Refining evapotranspiration values as this affects upland aquifer recharge, which has a large influence on Valley-bottom groundwater balances.

Ultimately, (as more data become available) it may be possible to use more sophisticated modelling approaches than those used in this basin-scale analysis to develop or refine aquifer water balance estimates.

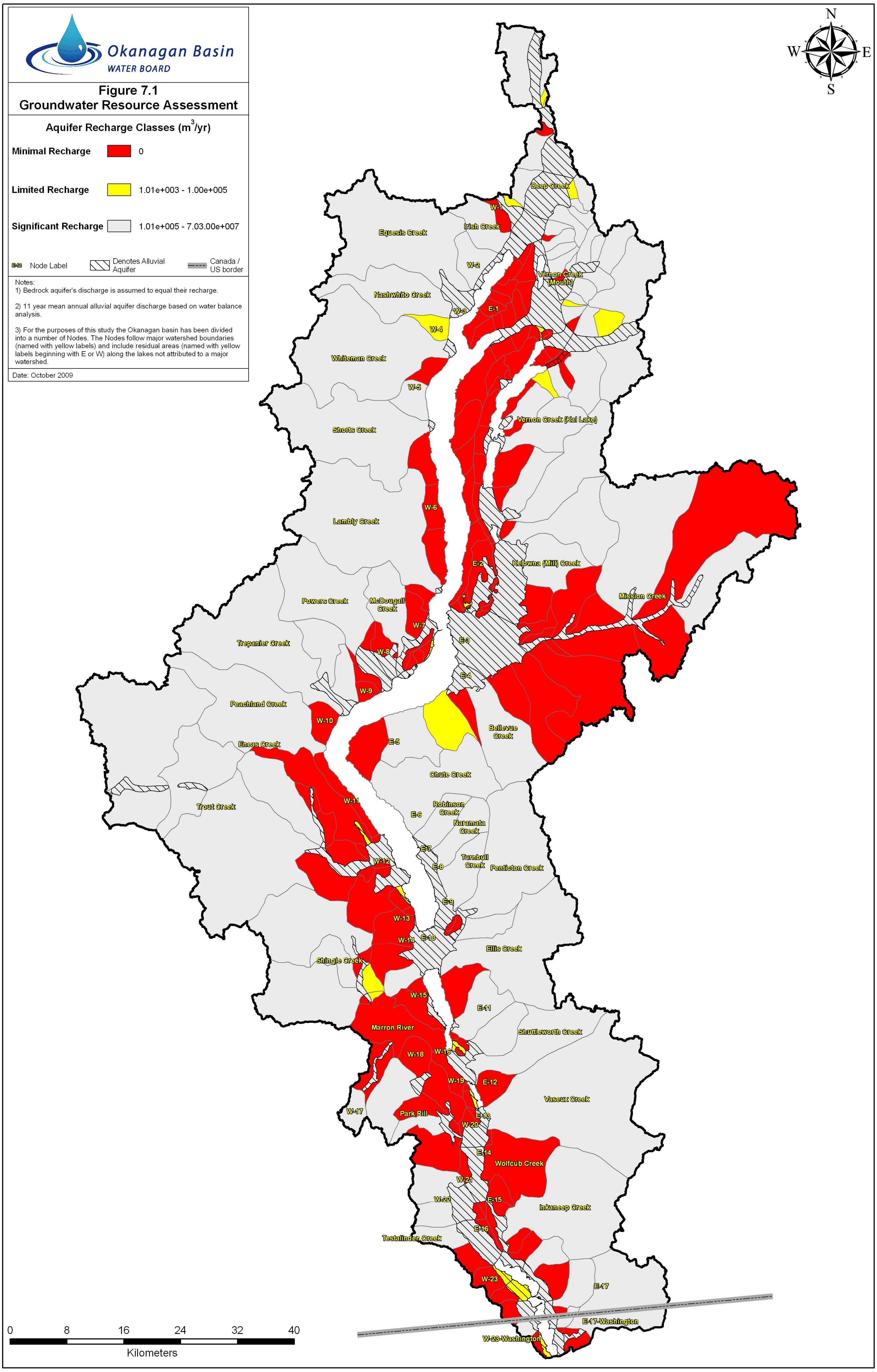

Figure 7.1 Groundwater resource assessment.

8.0 LAKE EVAPORATION

Little previous research has been done to quantify the amount of water lost to evaporation from the main valley lakes in the Okanagan. Accordingly, as part of this Project, Environment Canada undertook a study of lake evaporation, with the goal of identifying a model (or suite of models) most suitable for estimating lake evaporation in the Okanagan. Environment Canada also recommended a method for estimating evaporation from the upland lakes and reservoirs in the Basin. A summary of the Environment Canada report is presented in Appendix F1 of this Summary Report, and the full report is presented as Appendix F2.

Environment Canada evaluated 19 potentially relevant models for estimating lake evaporation in the Okanagan. According to these 19 models, estimates of average annual evaporation from Okanagan Lake range from 271 mm/year to 1,227 mm/year. Environment Canada stated a preference for the Trivett (1984) method, because the data used to make the evaporation estimates was considered slightly more reliable than the data underlying the other models. The Working Group chose the Penman-Monteith method for the purposes of Phase 2, because the advantage of slightly stronger data for the Trivett method was outweighed by problems integrating these results with other models used in Phase 2. The Penman-Monteith model is the same model used for estimating evapotranspiration in the Okanagan Water Demand Model. Lake evaporation estimates derived using the Penman-Monteith method are discussed in Appendix J, and summarized in Table 8.1. Average annual evaporation from the five mainstem lakes is 972 mm. For Kalamalka and Okanagan Lakes, the volume lost to evaporation is approximately 90% and 50%, respectively, of the net inflow to these lakes.

Table 8.1 Evaporation from the five Okanagan mainstem lakes.

Lake	Area (km^2)	Average annual evaporation (mm)	Average annual volume lost to evaporation (1996-2006) (ML)	Average annual net inflow (1996-2006) (ML)
Kalamalka	35.6	905	32,200	34,900
Okanagan	348	918	320,000	609,000
Skaha	20.1	963	19,400	651,000
Vaseaux	2.75	1008	2,800	660,000
Osoyoos	15	1068	16,000	696,000

Note: Evaporation values are estimated using the Penman-Monteith model. Average annual net inflow is taken from Appendix G.

Environment Canada also proposed a method for computing lake evaporation for upland reservoirs based on air temperature. The method was illustrated with evaporation data calculated using the Trivett method. One of the key advantages of this method is that daily air temperature data are available throughout the Basin from the 500 m by 500 m climate grid (Section 5.0). In future updates of the Phase 2 work, it is recommended that a simple air temperature-based method such as this be adopted for the purpose of estimating lake evaporation from upland reservoirs.

Further meteorological and limnological data collection and studies should be undertaken to determine the magnitude and timing of evaporation from Okanagan Lake and other mainstem lakes, and the upland Basin lakes. This would allow more detailed lake evaporation modelling and indicate the optimal model(s) for these lakes. With improved knowledge of evaporation volumes and timing, the accuracy of the water budget for the lakes and for the Basin as a whole would be improved.

9.0 SURFACE WATER RESOURCES

Introduction

The Surface Water Hydrology and Hydrologic Modelling Study consisted of three main parts. The overall objectives of Part One were to summarize existing information on surface water flows and develop a solid understanding of the natural surface water supply in the Okanagan Basin. The baseline data developed in Part One were used in Part Two (Appendix J) to calibrate and check the performance of the Okanagan Basin Hydrologic Model (OBHM) (Section 15.0). Once calibrated, the OBHM was used to run future water supply scenarios in Part Three in order to support the Okanagan Basin Water Accounting Model (Section 16.0).

This section summarizes the results of Part One – the "State of the Basin", which refers to the state of the current understanding of surface flows, climate and other biophysical factors that influence surface water flow, and the development of estimates of natural flow (i.e. streamflow in the absence of storage and diversions). Data were compiled and summarized for 81 points-of-interest or "nodes" in the Basin (Attachment 1) and naturalized flows were developed for 73 nodes for an 11-year period (1996-2006) that was adopted for modelling. This period is referred to as the "standard period" or the "calibration period" in this report. Flows were not naturalized for the mainstem lakes and the nodes on the Okanagan River because flows through the lakes and river have been regulated by dams and other control structures for many decades.

Methodology

Most Okanagan streams and lakes have been developed for surface water storage and withdrawals, thus the majority of streamflow records are considered *regulated* (i.e. affected by the storage and diversion of water). Determining natural streamflows using data from regulated watercourses is accomplished by a process of *streamflow naturalization* which removes the effects of human management from the data. Streamflow naturalization therefore requires information on water use and management, which was provided to the study team through the water management and use investigations (Section 6.0 and Appendix C). Streamflow estimates derived in this way are referred to as naturalized streamflows.

Although a reasonable number of streamflow measurement stations have existed or currently exist in the Basin, several streams have never had direct measurements of flow. For these locations, several estimation approaches for naturalized streamflow were used, depending on the available data.

Natural Streamflow Results and Patterns

The pattern of natural runoff in the Basin varies not only by elevation but also geographically in response to precipitation type and amount, evapotranspiration, and other factors such as soil type, vegetation, and the distribution of wetlands and ponds in catchment areas. For the 1996-2006 standard period, total natural streamflow from all tributaries and residual areas in the Okanagan Basin averaged 884,000 ML per year. If spread evenly over the entire Basin, this volume would cover the landscape to a depth of 117 mm. Approximately 83% of this total flowed into Okanagan Lake, while 17% of the total flowed into Okanagan River and the mainstem lakes downstream of Okanagan Lake. Upstream of Penticton, the runoff averages 130 mm, while downstream of Penticton, it averages 78 mm. Furthermore, runoff on the east side of the Basin tends to be higher than on the west side. This is because the prevailing winds are generally from the west – these winds are forced to ascend the east side of the valley, causing more precipitation on that side due to orographic effects. Total annual flow from the west side of the Okanagan Valley averaged approximately 371,000 ML over the 1996-2006 period (equivalent to 99 mm of runoff), while flow from the east side averaged 513,000 ML (or 134 mm of runoff).

Average annual discharge and runoff were calculated for the 1996-2006 standard period at each node, with averages presented in Table 5.3 and Figure 5.4 of Appendix G. Mission Creek is the largest tributary, delivering 28% of the total flow in the Basin. Trout and Vernon Creeks are the second and third largest contributors, each delivering about 7% of the total. Although the residual areas[6] cover 17% of the Basin, they contribute only about 5% of the annual flow because of high actual evapotranspiration rates at lower elevations.

Over the period 1996-2006, total flow varied considerably from a peak in 1997 to a low in 2001. In seven of the 11 years, runoff was above normal, while in four of the 11 years it was below normal. Because it captures extremes, and includes a mix of “wet” and “dry” years, the 11-year standard period is appropriate for calibrating the Okanagan Basin Hydrology Model (OBHM).

On an annual basis, streamflow during the low flow months of August to February accounts for only 14% of the Basin total, while flows in March to July account for 86%. The August to February total streamflow averages about 18,200 ML per month, which is being contributed by groundwater as there is virtually no surface runoff during this period. This volume is a small fraction of the 334,147 ML in the peak month of May.

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[6] Residual areas are land areas in the watershed that do not have a major stream network.

Accuracy of Natural Flow Data

The natural and naturalized flow data was given a rating to indicate the estimated error and quality of the data (Table 6.5, Appendix G). Of the 73 nodes addressed in this study (including node "00" - inflows to Kalamalka Lake), 12 have uncertainty ratings of "2" (indicating uncertainties between 10% and 25%). A total of 18 nodes have uncertainty ratings of "3" (uncertainty between 25% and 50%) and the remaining 43 nodes have uncertainty ratings of "4" (uncertainty between 50% and 100%). However, 40 of the 43 nodes with ratings of "4" are residual areas, which have no major streams, and in total produce only about 5% of the runoff in the Basin. Therefore, high uncertainty in these minor flows has very little impact on the overall strong confidence in the results outlined in the study.

Recommendations:

The following recommendations are made for future studies to refine the estimates of natural flows in the Basin:

- Obtain improved water use and management information from the Basin water suppliers to improve naturalized flow estimates. The priority sub-basins are Kelowna (Mill) Creek, Powers Creek, Penticton Creek, Ellis Creek, Shuttleworth Creek, and Inkaneep Creek.
- Implement the recommendations of Dobson and Letvak (2008) to improve the existing Okanagan Basin hydrometric network and obtain better flow records for important streams.
- A key information gap identified in this study is data on streamflow-groundwater interactions where streams flow across alluvial fans and other unconsolidated deposits. Although there are ongoing modelling studies on this process, a field-based investigation should be undertaken that targets a select number of locations on critical streams.
- To provide further insight to streamflow–groundwater interactions, the groundwater regime should be assessed in areas of interest by establishing test wells and obtaining field measurements of groundwater levels. This program will increase our understanding of the spatial and temporal variability of streamflow gains and losses across alluvial fans in the Basin, which will further improve the Okanagan Basin Hydrology Model.
- Further investigation and monitoring is recommended to improve the flow estimates of small streams during low flow (or no flow) periods (late summer through winter). This would include obtaining flow information from local residents, conducting field surveys and discharge measurements, and incorporating this data into the surface water – groundwater interaction investigations.
- Consider the potential impacts of land use changes on runoff and infiltration over time.

10.0 INSTREAM FLOW NEEDS FOR THE OKANAGAN

The Working Group completed a study to determine the most appropriate office-based method(s) to apply in the Okanagan to identify instream flow regimes needed to both minimally sustain, and optimize conditions for, aquatic biota and their ecosystems. That study is presented in Appendix H.

The study describes the distribution of six (6) species of salmonid fishes that utilize the lakes and tributaries in the Okanagan (Table 2.2 of Appendix H). Extensive datasets on salmonids were assembled from studies relevant to the Okanagan region, and ranges of optimal spawning and rearing flows for these fish species in each of 36 Okanagan tributaries were identified (Figures B.1 to B.36 of Appendix H). The authors found that naturalized flows (i.e. flows that would exist without human use or management) are sufficient in most years to achieve optimal spawning flows for spring-spawning salmonids (i.e. rainbow trout and steelhead); however, naturalized flows usually fail to provide recommended flows for fall-spawning species (i.e. kokanee and sockeye). Optimal rearing conditions are mostly rare in the late summer to mid-winter for resident salmonids (Section 3.2 of Appendix H). Thus, estimates of naturalized flows suggest that most Okanagan streams historically provided suboptimal habitat for salmonid fishes and associated biota in late summer through mid-winter.

The study team recommended use of the BC Instream Flow Methodology (BCIFN) to identify instream flow regimes that protect aquatic life and sustain aquatic populations in individual tributaries. The minimum flow regime identified using this method is “conservative”, meaning that even when flows are lower than the BCIFN flows, there is a relatively low risk of acute damage or extirpation for salmonid populations. The authors also identified the lowest 25th percentile of flows as a low-flow reference level. Salmonid fishes are generally regarded as sensitive “sentinels” of aquatic ecosystem integrity, under the assumption that if they are adequately protected, then most other aquatic species and their habitats will be protected.

The final flow parameter considered in this study was a “watershed conservation flow” - a high flow which should occur in spring every few years to sustain physical and biological processes along streams and riparian zones. The results (from the minimum instream flow regime estimation methods and the watershed conservation flow) are illustrated for each of the 36 Okanagan tributaries on Figures B.1 to B.36 in Appendix H.

Eight additional sensitive species and ecological functions that could be affected by instream flows are briefly considered in Section 3.4 of Appendix H. These species include the chiselmouth chub (fish), Mexican mosquito fern, tiger salamander, Great Basin spadefoot toad, vivid dancer damselfly, western painted turtle and Rocky Mountain ridged mussel. It is not yet possible to model their habitat requirements directly in an instream flow analysis.

An analysis comparing regulated flows to naturalized flows found that at some locations the recommended BCIFN minimum risk flows were achieved more frequently in the late summer dry period with regulated flows than with naturalized flows. This is likely due to water storage in these watersheds during the spring freshet, with subsequent release of this stored water later in the summer. However, regulated flows generally met BCIFN minimum risk flow thresholds less often than naturalized flows during other critical time periods (e.g. mid-winter - Table 3.3). These findings indicate the importance of upland reservoirs as a potential source of instream flow in support of aquatic habitat.

The BCIFN guidelines provide standardized methods for setting operational ecosystem objectives, indicators and reference points to facilitate water management decisions that are responsive to the requirements of federal and provincial laws, regulations and policies to promote the maintenance of ecosystem integrity and healthy populations of specified aquatic biota. However, the current study has demonstrated some weaknesses for effective application of outputs from these guidelines. These include: (a) the observation that minimum flow recommendations in drought prone areas such as the Okanagan under BCIFN guidelines may be higher than estimates of historic, naturalized low flows for a given stream, (b) the omission of any consideration of maintenance of water quality characteristics such as suitable temperatures for aquatic biota that may be controlled by the influence of interactions among surface and groundwater flows on habitat or ecosystem integrity, and (c) the failure of BCIFN guidelines to explicitly consider that maintenance of healthy populations of aquatic biota and ecosystem integrity frequently depend on interdependent processes (e.g. mating, spawning, rearing, and overwintering), operating at spatial scales involving migration or dispersal of aquatic biota among multiple streams exhibiting a wider range of seasonal flow variations than recommended from application of BCIFN methods.

Recommendations:

The following recommendations are made for future studies to refine the approach to specifying instream flow needs to maintain aquatic biota and their ecosystems in the Basin:

- Conduct additional studies to assess the consequences of failure to meet particular low flow thresholds – e.g. increased risk of production losses or extirpation of specified aquatic biota (e.g. fish and SARA-listed species).
- Initiate tests of the key assumption that habitat requirements of a broad range of sensitive aquatic biota will be met if the requirements of sentinel species such as salmonid fishes are satisfied.

- Assess the importance of combinations of surface and groundwater flows and withdrawals in various streams of the Okanagan to the maintenance of suitable, seasonal, thermal conditions required to sustain healthy populations of salmonids and other sensitive species of aquatic biota.
- Initiate work to identify how to expand effective application of the BCIFN methodology to sets of streams by determining the consequences of annual to seasonal temperature and flow variations on migration, dispersal, recolonization and production of sentinel species of aquatic biota among streams that taken together comprise the ecosystem(s) of such species.

In the meantime, when an appropriate minimum instream flow regime must be identified on a particular stream, it is recommended that:

- Agreement on an acceptable minimum instream flow regime for a set of streams will likely require that the agencies with a responsibility for aquatic species agree in advance on an acceptable level of risk to these species.
- A preliminary evaluation of the instream flows required to sustain aquatic biota should be made using the BC Instream Flow Methodology, with consideration of the 25th flow percentile documented herein.
- These office-based studies should be supplemented by site-specific field evidence for the stream (or representative member of a characteristic set of streams).

11.0 OKANAGAN WATER DATABASE

Phase 2 of the Okanagan Water Supply and Demand Project involved many modelling and analysis exercises to produce time series datasets for various water balance variables. The purpose of the Okanagan Water Database (OkWater Database) is to standardize these datasets and provide a website for automating remote delivery into a central long-term storage system. The system uses a flexible design that allows for additions and potential modifications in the future.

The central database is web-enabled via a web browser that allows users to upload MS Access templates through a simple import interface. This interface also enforces an audit trail and requires standard metadata information so that the datasets can be appropriately referenced and combined to form complete water balance scenarios.

Supporting Documents

Two major documents support the OkWater Database:

- Okanagan Water Database System Documentation (v.1.0.000) (ESSA 2009; Appendix K); and
- OkWater Database Users Guide Version 2.0 (Abraham and Alexander 2009; Appendix K).

The System Documentation (ESSA 2009) provides a comprehensive description of the system, its design concepts, requirements, and installation steps along with a full listing of the tables in the database (Table 5.1 of Appendix K).

The OkWater Database Users Guide (Abraham and Alexander 2009 – Appendix K) focusses on how to work with the website, the data import template, and the upload manager software.

Database Design

The OkWater Database consists of four components:

- A centralized relational database (SQL Server 2005 format);
- A data import template (MS Access 2003);
- A web application for specifying metadata and uploading template files; and
- A data export tool.

The relational database houses all core water budget data, related metadata and database look-up tables, attributes and standards. This SQL Server 2005 database is maintained and administered on a web-accessible Windows server computer.

The data import template mirrors the structure of the master database allowing compatible, standardized datasets to be uploaded. The OkWater Database Users Guide provides step-by-step instructions on using the template.

The web application consists of four elements:

- An “Upload Manager” for reviewing existing uploads and launching a new upload;
- A tab “Upload Details” for entering and reviewing meta-data and attaching supporting documentation;
- A “Templates” tab to download a copy of the current MS Access data import template; and
- Links at the top right of the page for changing an account password, accessing the Users Guide, and signing off.

In version 1.0.000 of OkWater Database, a custom data export tool (the "MikeSHE Exporter") was created to format datasets required by the Okanagan Basin Water Accounting Model (OBWAM). This tool currently supports the time series data products required for calibration of the model to 1996-2006 conditions, as well as for examining 15 alternative scenarios defined as part of Phase 2. Details on configuration and operation of this tool are described in Section 4.3 of the System Documentation (Appendix K).

12.0 OKANAGAN WATER INFORMATION REFERENCE LIBRARY

Overview

A great deal of potentially relevant information on water supply and demand exists for the Okanagan Basin. Efforts to collect and review information in Phase 1 of the Project (Summit 2005) focussed on information relating to surface water supply, water use, and groundwater, as well as population, land use, recreation, and tourism. The Okanagan Water Information Reference Library is a web-accessible database designed to make this information readily available to researchers and the public. Each report in the database is accompanied by an expert review. Authors of technical reports in Phase 2 provided additional documents and reviews to the database. As of June 2010, there were over 300 records in the database, all accompanied by a link to the full document.

The database design is simple and includes a user-friendly interface with the ability to create customized summaries, including a data gap analysis. The information database is useful for summarizing the variety of data sources and identifying the most useful resources for a given topic or geographic area within the Basin. The database is reproduced in Appendix L of this Summary Report.

Database Design

The database consists of 3 main sections: Source, Content and Evaluation (Figure 12.1). The Source section contains the reference information, including the citation, the location and available format (hardcopy or digital) of the original document. Electronic versions of each of the documents in the database have been created, and a user can directly access the document through a link provided by the database.

The Content section includes information regarding:

- Information type (data, data interpretation, or other);
- Classification (surface water, groundwater, or other);
- Geographic scope (Basin-wide or specific area of the Basin);
- The name(s) of the Okanagan sub-basins for which the document is relevant; and

- Scientific focus of the document (e.g. hydrology, water quality, groundwater, instream flow).

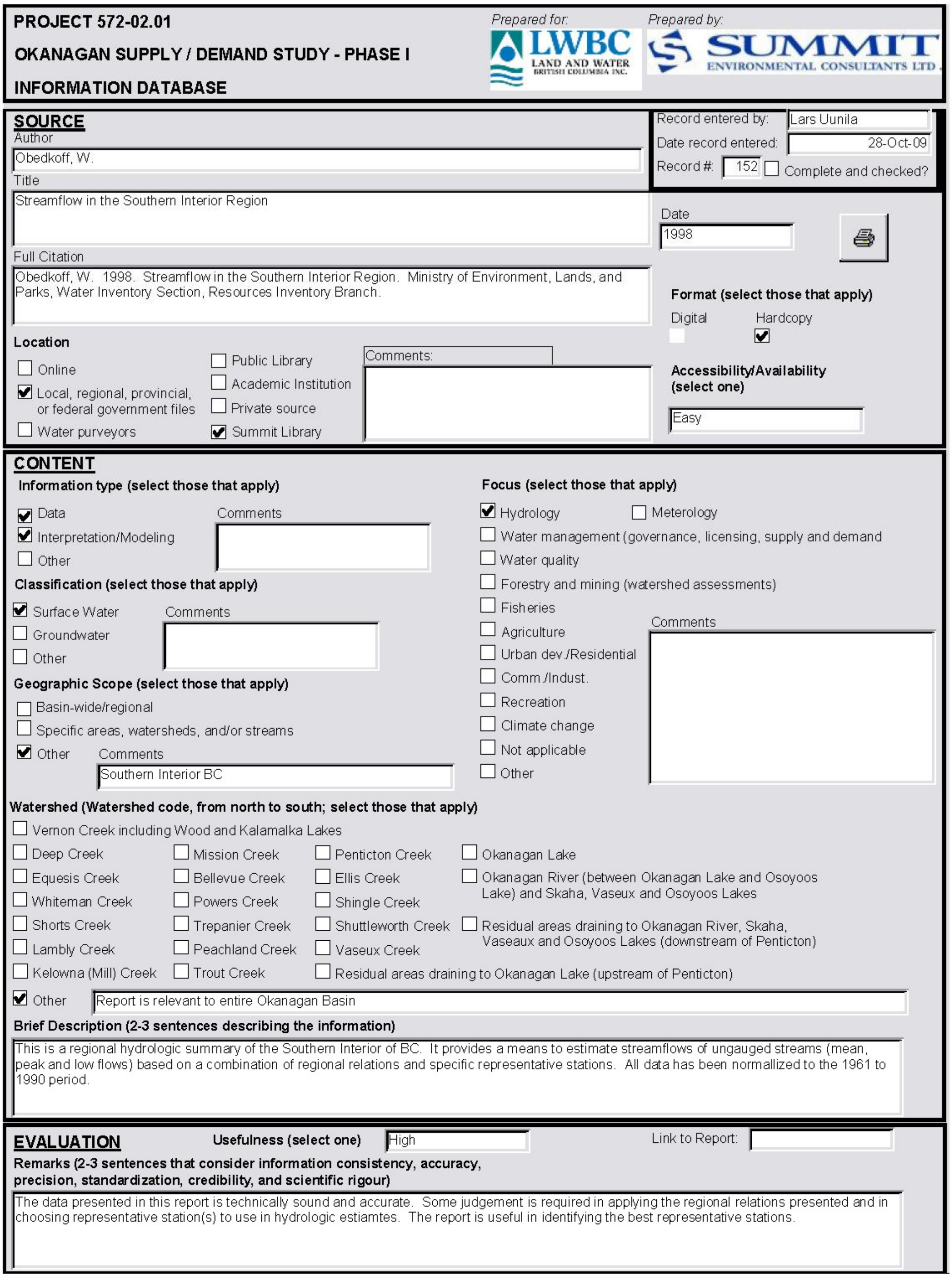
This section also includes a brief description of the information found in the source document.

The Evaluation section provides an evaluation of the document.

A database user can view, enter, search, filter or sort any of these fields through the interface.

Web Access

The interface of the database is available and searchable on the internet through the OBWB website: http://www.obwb.ca/obwrid/. This online tool also allows access to the digital documents.



PROJECT 572-02.01

OKANAGAN SUPPLY / DEMAND STUDY - PHASE I

INFORMATION DATABASE

Prepared for: LWBC LAND AND WATER BRITISH COLUMBIA INC.

Prepared by: SUMMIT ENVIRONMENTAL CONSULTANTS LTD.

SOURCE

Record entered by: Lars Uunila

Date record entered: 28-Oct-09

Record #: 152 ☐ Complete and checked?

Author: Obedkoff, W.

Title: Streamflow in the Southern Interior Region

Date: 1998

Full Citation: Obedkoff, W. 1998. Streamflow in the Southern Interior Region. Ministry of Environment, Lands, and Parks, Water Inventory Section, Resources Inventory Branch.

Format (select those that apply)

Digital ☐ Hardcopy ☑

Location

☐ Online

☑ Local, regional, provincial, or federal government files

☐ Water purveyors

☐ Public Library

☐ Academic Institution

☐ Private source

☑ Summit Library

Comments:

Accessibility/Availability (select one): Easy

CONTENT

Information type (select those that apply)

☑ Data

☑ Interpretation/Modeling

☐ Other

Comments

Classification (select those that apply)

☑ Surface Water

☐ Groundwater

☐ Other

Comments

Geographic Scope (select those that apply)

☐ Basin-wide/regional

☐ Specific areas, watersheds, and/or streams

☑ Other

Comments: Southern Interior BC

Focus (select those that apply)

☑ Hydrology ☐ Meterology

☐ Water management (governance, licensing, supply and demand

☐ Water quality

☐ Forestry and mining (watershed assessments)

☐ Fisheries

☐ Agriculture

☐ Urban dev./Residential

☐ Comm./Indust.

☐ Recreation

☐ Climate change

☐ Not applicable

☐ Other

Comments

Watershed (Watershed code, from north to south; select those that apply)

☐ Vernon Creek including Wood and Kalamalka Lakes

☐ Deep Creek

☐ Equesis Creek

☐ Whiteman Creek

☐ Shorts Creek

☐ Lambly Creek

☐ Kelowna (Mill) Creek

☐ Mission Creek

☐ Bellevue Creek

☐ Powers Creek

☐ Trepanier Creek

☐ Peachland Creek

☐ Trout Creek

☐ Penticton Creek

☐ Ellis Creek

☐ Shingle Creek

☐ Shuttleworth Creek

☐ Vaseux Creek

☐ Residual areas draining to Okanagan Lake (upstream of Penticton)

☐ Okanagan Lake

☐ Okanagan River (between Okanagan Lake and Osoyoos Lake) and Skaha, Vaseux and Osoyoos Lakes

☐ Residual areas draining to Okanagan River, Skaha, Vaseaux and Osoyoos Lakes (downstream of Penticton)

☑ Other: Report is relevant to entire Okanagan Basin

Brief Description (2-3 sentences describing the information)

This is a regional hydrologic summary of the Southern Interior of BC. It provides a means to estimate streamflows of ungauged streams (mean, peak and low flows) based on a combination of regional relations and specific representative stations. All data has been normallized to the 1961 to 1990 period.

EVALUATION

Usefulness (select one): High

Link to Report:

Remarks (2-3 sentences that consider information consistency, accuracy, precision, standardization, credibility, and scientific rigour)

The data presented in this report is technically sound and accurate. Some judgement is required in applying the regional relations presented and in choosing representative station(s) to use in hydrologic estiamtes. The report is useful in identifying the best representative stations.

Figure 12.1 Example form in the Water Information Reference Library Database. (Note that the online version has a slightly different format.)