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ENVIRONMENTAL CONSULTANTS INC.
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Final Report

Okanagan Basin Water Board

Okanagan Hydrologic Connectivity Model: Summary Report

Project: 2010-8005.000

May 2013

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Re: OKANAGAN HYDROLOGIC CONNECTIVITY MODEL

Summit Environmental Consultants Inc. (Summit) is pleased to provide this report on the Okanagan Hydrologic Connectivity Model (OHCM). The work was completed by a consulting team led by Summit that included DHI Inc, Polar Geoscience Ltd., and Agua Consulting Inc. The OHCM is built on the complex supply and demand models developed during Phase 2 of the Okanagan Water Supply and Demand Project. It is a flexible, user-friendly model that allows an individual to evaluate the implications of various water management choices.

The report outlines the development of the OHCM, and highlights key results for several major water utilities derived from an examination of several water demand scenarios. It also includes recommendations to enhance and extend the model. Other deliverables associated with the study include a schematic representation of the water demand system in the Okanagan Basin, a poster intended for communication purposes, and a Graphical User Interface that allows a user to easily view model output.

If you have any questions, please contact either the undersigned or Drew Lejbak at 250-545-3672.

Yours truly,

Summit Environmental Consultants Inc.

Submitted digitally

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Executive Summary

PURPOSE

The Okanagan Basin Water Board (OBWB) retained Summit Environmental Consultants Inc. (Summit) to develop a nimble and user-friendly model that can be used to demonstrate the hydrologic and legal linkages between water suppliers in the Okanagan Basin and to support water management decisions during drought conditions. Summit constructed the Okanagan Hydrologic Connectivity Model (OHCM) using the Water Evaluation and Planning software developed by the Stockholm Environment Institute. Three water supply and demand models developed in 2010 as part of the Okanagan Water Supply and Demand Project were also used in the creation of the OHCM.

In this study, the OHCM was used to run scenarios investigating how water users are impacted by changes in upland storage, increased water demands, in-stream flow needs, their location in the Basin (and associated stream catchment), and licence seniority in the “first in time, first in right” licensing system under the British Columbia *Water Act*. This report presents an overview of how the OHCM was developed and the key outcomes of the scenarios.

BACKGROUND

The Okanagan Basin (“the Basin”) covers 8,046 km^2 in B.C. It is a narrow watershed stretching from the City of Armstrong to the U.S. border that includes six main lakes – Okanagan, Kalamalka, Wood, Skaha, Vaseux and Osoyoos – and the surrounding mountains.

The Basin is experiencing a variety of pressures on its water resources. It has the highest ratio of population to water supply of any basin in Canada. Ongoing population growth, combined with a changing climate, suggests that water demand will continue to increase while water supply may decrease. Water supply in the Basin is dependent on rain and snowfall. The significant variation in the quantity of precipitation the Basin receives each year results in both water shortages and floods. Most of the annual water supply arrives between April and June as the winter snowpack melts. However this timing is not the same as the timing of water demands, which are highest during the summer months (July to September). This variability and timing of water supply makes the storage capacity of reservoirs and aquifers a critical factor in effective water management. There are 101 known water suppliers and nearly 4,000 active water licences issued by the Province of B.C. to store or use surface water (Summit 2010a).

Pressures on the water resource can have serious implications for the economy, environmental quality, and way of life in the Basin. To this end, the Okanagan Water Supply and Demand Project (OWSDP) was initiated in 2004 to improve the state of knowledge of the water resources of the Basin through a credible scientific study aimed at establishing current water availability, water use, and future potential influences on supply and demand (Summit 2010a). Three scientific models were developed as part of the OWSDP: a water demand model (Okanagan Water Demand Model - OWDM), a hydrologic model (Okanagan Basin Hydrology Model - OBHM), and a water accounting model that combines the demand and supply model information (the Okanagan Basin Water Accounting Model - OWAM).

The models are very useful in that they permit quantitative assessments of changes to water supply and demand due to climate and other drivers. However, they are complex and require special skills to operate, the simulation run times are long, and the output files require post-processing to distill information in a manner that is meaningful to most users. Accordingly, the OBWB initiated the development of a model (the OHCM) that makes use of the OWSDP models but is easier to operate, more nimble in its operation, capable of running many scenarios quickly, and capable of producing simple summaries of results.

DEVELOPMENT OF THE OHCM

The goals of the OHCM are to illustrate how water management actions are interconnected in the Basin, and to support the development of regional drought plans and watershed-specific management plans. The Water Evaluation and Planning (WEAP) modeling platform was selected as the base for the OHCM because it offers a Basin-wide priority function to allow a model user to assign a level of allocation priority for each water licence. This makes it suitable for investigating the "first-in-time, first-in-right" (FITFIR) principle used in the B.C. water licensing system.

The OHCM was developed using data for the same eleven year calibration period (1996-2006) used for development of the OWAM. This period includes wet, normal, and dry hydrologic conditions. The OHCM specifically used natural and net streamflows (i.e. streamflows that account for human effects), water demand, and instream flow requirements from the OWAM as input values.

The OHCM also required information on rivers and creeks, reservoirs, water demand, inter-basin diversions, instream flows, return flows, and water use priorities. The OHCM is intended to investigate key water users in the Basin. Accordingly, while the model domain covers the entire Basin, the OHCM provides explicit modeling only of those surface water sources that are directly involved in the supply and delivery of water to those key water users (i.e. the five mainstem lakes, the Okanagan River, and the major stream catchments where extractions and upland reservoirs are present). Forty-eight upland reservoirs and their physical properties and operational rules are included in the OHCM.

The OHCM was successfully developed to represent both natural processes and human influences on the water resources of the Okanagan Basin. Inflows to demand sites and reservoirs were extracted from the OWAM and used to drive the OHCM.

The OHCM was verified using a QA/QC process to establish whether the model results reflected the OWAM outputs and actual observations. The primary measure of model performance was a comparison of net streamflows calculated by the OHCM against net streamflows calculated by the OWAM at the outlets of the major stream catchments; and a comparison of lake levels and outflows calculated by the OHCM with both actual observations and OWAM estimates for the mainstem lakes. The comparisons of net streamflows indicated that the OHCM generally performed well for the major stream catchments and for Okanagan Lake levels.

OVERVIEW OF OHCM SCENARIOS

To understand and evaluate hydrologic and legal (i.e. B.C. *Water Act* and licence allocations) connectivity in the Okanagan Basin under a range of situations, eight scenarios were examined. Each scenario covered the same (1996-2006) time period. The scenarios allowed for an investigation of how water users and instream requirements would be impacted by changes in upland storage, water demands, and varying the priority given to meeting in-stream flow needs (IFN). Each scenario output included results for 21 major water users in the Okanagan Basin, as well as “other” relevant water users. This report highlights the results for six major water users: Black Mountain Irrigation District, South East Kelowna Irrigation District, District of Summerland, City of Penticton, City of Kelowna, and the Town of Oliver.

KEY FINDINGS

Prioritizing instream flow needs versus water withdrawals

Under present-day water demands, giving instream flow needs for fish and other environmental values a higher priority would not likely significantly affect the ability of water suppliers to continue to provide water to their customers. If water demands increase (approaching the amount of licensed volumes), either IFN are frequently not met; or water suppliers frequently run short of water (depending on the priority attached to meeting IFN. Since we chose to assign a high priority to meeting minimum flow releases out of mainstem lakes and IFN in the Okanagan River than to keeping Okanagan Lake within its usual elevation range (which reflects current practice), the instream flow needs of Okanagan River were not impacted under any scenario. However, different choices concerning priorities could create different results.

Dealing with the simultaneous use of licences

Each utility’s water intake is associated with one or more water licences – most utilities have several licences. In OHCM terms, each water licence is referred to as a “demand site”. We identified individual “demand sites” in order to incorporate and evaluate water licence priorities (using the FITFIR principle) when running demand-supply scenarios.

Water utilities consider that their water allocation is the sum of their individual licences, and they generally manage their allocation as a single unit – they don’t manage extractions on the basis of individual licences. One of the biggest challenges during development of the OHCM was to assign the surface water demand at each intake and each time step to each of the licences. This was accomplished through a demand calculator tool developed for this purpose, which assumes that the licensed volume is spread out across the licensed usage period in the year, and that each licence is used at each time step until it is exhausted. This method appears satisfactory, in that it does not appear to cause conflicts with the current water management regime in the Basin. However, under future scenarios of increased demands and potentially a drier climate, water regulators could specify rules or guidelines for the way in which water use is assigned to licences. Various approaches to applying water withdrawals against licences could be simulated in a future version of the OHCM, such as specifying the use of junior licences before more senior licences.

Water storage

For some water suppliers, increasing storage in upland reservoirs would help to reduce the frequency with which their customer demands and IFN are not met. Since we chose to assign higher priority to meeting water users' demands than to maintaining lakes and reservoirs within their normal operating ranges in this version of the OHCM; none of the water users that withdraw water from mainstem lakes or the Okanagan River (e.g. City of Kelowna, Town of Oliver) were found to be limited by supply. However, in a future model application, other priority choices could be made, which could influence these results.

Drawdown of Okanagan Lake

Because of our priority-setting choices in the current version of the model, the model satisfies all water demands from Okanagan Lake and the Okanagan River downstream of the lake at the cost of the lake's useable storage. This occurs because water users and IFN requirements were assigned higher priority than meeting lake level targets. Under maximum demand scenarios (i.e., scenarios 5-8), Okanagan Lake becomes depleted during drier years and lake levels begin to approach the sill elevation of the dam (339.75 m GSC) at Penticton. Under this framework (which appears to reflect the actual practices and priorities of the provincial water managers who manage the mainstem lakes), FITFIR does not seem to influence water users that withdraw water from Okanagan Lake (or the other mainstem lakes) or the Okanagan River, since all higher priority demands are supplied at the cost of mainstem lake levels. However, the results of these scenarios could have been different if maintaining Okanagan Lake within its normal operating range had been assigned a higher priority in the model. The impact of choosing different priorities could be investigated further in future model applications.

LIMITATIONS OF THE OHCM

OHCM output should be interpreted carefully, recognizing the assumptions and limitations associated with the input data and the choices made in model development. These choices include the method of associating water use with water licences, the way water licences are prioritized to represent the FITFIR principle, and the methods used to represent IFN and reservoir operations. Finally, the OHCM is limited to datasets available from the OWAM; and results therefore reflect the assumptions made and limitations associated with Phase 2 of the OWSDP.

OTHER PROJECT DELIVERABLES

To display the significant volume of data that the OHCM produces, a web-based Graphical User Interface (GUI) – Results Viewer was developed. The Results Viewer, which is available through the OBWB, simplifies review of the results produced by the OHCM for each of the eight scenarios. In addition, a conceptual OHCM schematic diagram and a poster were developed. The OHCM schematic diagram provides a top-down representation of the Okanagan Basin, which reflects the flow of water into mainstem lakes from stream catchments (and associated upland reservoirs), the connectivity of mainstem lakes to one another, and the role of the water purveyors in storing and withdrawing water. The poster highlights the results of the OHCM, and was designed to provide a way to communicate the OHCM and its applicability to a broader audience.

RECOMMENDATIONS

Technical Improvements

The OHCM is currently limited to datasets available from the OWAM and assumptions developed during Phase 2 of the OWSDP. Results are constrained by the accuracy of this information and these assumptions.

Several technical improvements are suggested in Section 5.2.1, including:

1. Update the spatial extent of the OWAM to include water that is imported into the Okanagan from stream catchments outside of the Basin (e.g. Duteau Creek watershed).
2. Investigate other approaches to allocating water use against individual water licences, such as using junior licences before more senior licences.
3. Update all reservoir operations in the OHCM to reflect actual water utility management operations and strategies.
4. Update the OHCM to consider flow percentiles other than the 25th naturalized flow percentile (e.g. 5th, 10th, 15th percentiles).
5. Further explore the possibility of changing the priority of the mainstem lakes to a higher priority than given to water users (as might happen if the lake was drawn down below its operating range) so the lakes are not mined under some maximum demand scenarios.
6. Update the OHCM to include an improved representation of Osoyoos Lake's operations and hydraulic constraints.

Future Applications

Recommendations are made in Section 5.2.2 to extend the work completed herein to make the model more suitable for potential future applications. The recommendations include:

1. Include additional datasets developed during Phases 2 and 3 of the OWSDP (such as future climates) to provide more scenario applications in the OHCM and to allow for future predictions.

2. Change the OHCM time-step to monthly for future applications. This will help to minimize run times, represent groundwater information at the appropriate resolution and improve the robustness of the model.
3. Use the licensed storage volume instead of the physical reservoir volume to provide a more legally appropriate representation of licensed supply capabilities. This could help in the identification of those water users that may not have enough licensed storage to meet actual or maximum licensed demands.
4. Separate agricultural irrigation licences from other irrigation licences so that a model user can assign a higher priority to the agricultural licences, which will assist in investigating a potential water reserve for agricultural use.
5. Include groundwater processes and withdrawals in the OHCM.
6. Complete a detailed investigation of IFN throughout the Basin and incorporate this knowledge in an updated version of the OHCM.
7. Extend the OHCM to explicitly represent all catchments modelled by the OWAM.

Once recommendations 5, 6, and 7 are complete, the OHCM will be a comprehensive and easy to use gaming tool for water allocation decision makers.

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1 INTRODUCTION

This report presents the results of a study to develop a customized version of the Water Evaluation and Planning model to demonstrate the hydrologic and legal linkages between water suppliers in the Okanagan Basin. The custom model, referred to as the Okanagan Hydrologic Connectivity Model (OHCM), has been used to examine the consequences of the first-in-time, first-in-right (FITFIR) principle contained in the British Columbia *Water Act*, and of applying other water management choices, such as giving instream flows a higher priority than meeting requirements for withdrawals from streams.

1.1 PROJECT BACKGROUND

The Okanagan Basin ("the Basin") covers 8,046 km^2 in British Columbia (B.C.) and has the highest ratio of population to water supply of any basin in Canada. Ongoing population growth, combined with a changing climate, suggests water demand will continue to increase while water supply may decrease. Pressures on the water resource can have serious implications for the economy, environmental quality, and way of life in the Basin. To address these issues, the Okanagan Water Supply and Demand Project (OWSDP) was initiated in 2004. The goal of the OWSDP is to provide a strong scientific basis for water and land use planning in the Basin for years to come.

The OWSDP is a multi-phase work program focussed on improving the state of knowledge of the water resources of the Basin through a credible scientific study aimed at establishing current water availability, water use, and future potential influences on supply and demand (Summit 2010a). Phase 1 of the project was completed in 2005, providing a report that compiled relevant data and reports, identified and prioritized information gaps, and outlined a strategy for completing the second phase. Phase 2 of the project was completed in 2010 and provided estimates of the current supply of and demand for water throughout the Basin. Phase 2 included the development of three scientific models: a water demand model (Okanagan Water Demand Model - OWDM), a hydrologic model (Okanagan Basin Hydrology Model - OBHM), and a water accounting model that combines the demand and supply model information (the Okanagan Basin Water Accounting Model - OWAM). The OBHM and OWAM are based on DHI's MIKE SHE and MIKE 11 modeling platforms, and can be used to examine water management alternatives and to identify potential future changes in both supply and demand (Summit 2010a). Phase 2 of the OWSDP was completed under the direction of a steering committee of key stakeholders and a technical working groups that included several government agencies and other stakeholders.

To continue to build on the OWSDP, in September 2010, the Okanagan Basin Water Board (OBWB) issued a request for the development of an Okanagan Hydrologic Connectivity Model (OHCM). The OHCM is intended to illustrate how water management actions are interconnected within the Basin and to help the OBWB and major water purveyors investigate how water is stored, licensed and flows through the Basin. The OHCM is also intended to support the development of regional drought plans and watershed specific management plans.

1.2 PROJECT UNDERSTANDING

As a major water user, the agricultural sector in the Okanagan shares water resources with urban centres, industries, and a growing tourism and recreation sector that is attracted to many lakes and to water-dependent recreational developments (e.g. golf courses). Water resource management in the Okanagan is challenging, requiring detailed information on current and future domestic and industrial water demand, ecological requirements for water flow and quality, and a realistic understanding of how water supply and demand will change in a future with climate warming.

Adding to the complexity of water resource management within the Basin, there are 101 known water suppliers and nearly 4,000 active water licences issued by the Province to store or use surface water (Summit 2010a). This translates to approximately 443,000 megalitres[1] (ML) of surface water licensed for extraction (i.e. offstream use) and approximately 351,000 ML licensed for in-stream (conservation) and other non-consumptive uses (Summit 2010a).

Most major water users do not use their full allocation, in fact most use only 1/3 or 1/2 of their allocation. Accordingly, it is rare that a water user requires more water than their allocation. Each water licence in B.C. has a priority date, such that if a conflict arose between two or more licensed users, the user with the earliest licence would prevail. The only formal legal mechanism available for limiting water use between two or more conflicting users when demand exceeds supply is to invoke the *Water Act*, in particular the Act's first-in-time, first-in-right (FITFIR) principle.

Notwithstanding the above, much of the water licensed in the Okanagan is licensed to municipalities or Irrigation Districts. The managers of these systems deliver water to their customers and have system-specific means of limiting water use when there is a risk that water supply will not meet demands.

There have been long-standing concerns that the Basin is over allocated – as a whole or within specific drainages, yet a categorical determination of over-allocation is related to the risk of shortages, which has not been well-defined in the past and is changing as a result of climate warming. Wide-spread conflicts over water have not been present in the Basin to-date. However, it is important that all water managers have a sound understanding of the hydrologic connectivity between various water suppliers; of the priority dates assigned to water licences; and of the legal implications of the FITFIR doctrine of the B.C. *Water Act*.

Since water supply is dependent on rain and snowfall, and the storage capacity of reservoirs and aquifers, water shortages could very possibly escalate in the future. As indicated above, during dry years, water suppliers may impose conservation measures to ensure both human and environmental requirements are being met. However, with increased water demand, water suppliers will likely need to augment this demand-side approach through additional reservoir storage and management. Increasing storage in

[1] 1 megalitre (ML) is equal to 1 dam^3 (cubic decametre) or 1,000,000 litres.

upland reservoirs could impact in-stream flows for environmental requirements, downstream water licences, and inflows into the mainstem lakes; and continue to make water management challenging. These observations highlight the ongoing need to have a widespread and detailed understanding of hydrologic and water licence/supplier connectivity, both watershed-specific and Basin wide.

The OHCM project was completed by an integrated team of professionals with detailed knowledge of the Okanagan Basin, the OWSDP, and the three key Phase 2 models (OWDM, OBHM, and OWAM). This integrated team consisted of members from Summit Environmental Consultants Inc., DHI Inc., Polar Geoscience Ltd., and Agua Consulting Inc.

1.3 PROJECT OBJECTIVES

The objectives of this study were to:

1. Explore how local water utilities are connected within the Okanagan's hydrologic context (upstream and downstream flows), and through the provincial water licensing system (priority ranking of water access under FITFER);
2. Develop a useable tool (the OHCM) to build upon the completed Phase 2 models of the OWSDP, and support water management decisions during drought conditions; and
3. Use the OHCM to model how specific water users (i.e. Greater Vernon Water, City of Kelowna, Black Mountain Irrigation District, District of Summerland, South East Kelowna Irrigation District, City of Penticton, and Town of Oliver) are connected within the Basin, and how their interactions – expressed by relative water shortage or availability – change in a variety of situations (scenarios). These scenario outcomes are intended to aid in:
    a. Improving the understanding of how the Okanagan water supply is influenced by climate, hydrology, environmental flow, and anthropogenic use;
    b. Supporting drought policy development and decision models;
    c. Describing how communities are connected to upstream and downstream water users by water licensing seniority as described by the Provincial FITFIR legislation; and
    d. Describing how water users are impacted by changes in storage, use and conservation (upstream and downstream) by other users, in-stream flow needs, and their location within the Okanagan basin and licence seniority within the FITFIR licensing system.

This document represents the final deliverable of the OHCM study and summarizes the OHCM development and water user investigations.

2 OHCM MODEL DEVELOPMENT

The development of the OHCM is outlined in this section. A detailed description of the model development is provided in the OHCM Model Development report in Appendix A.

2.1 MODEL SELECTION

During Phase 2 of the OWSDP, three custom models were developed for simulating water supply and demand in the Okanagan (OWDM, OBHM, and OWAM). The OWDM was developed to compute irrigation and non-irrigation water use for discrete parcels of land (i.e. "water use areas") and link the water use in each water use area to its water source (Summit 2010a). The OBHM is a hydrologic model that computes naturalized streamflow (i.e. streamflow in the absence of human effects), while the OWAM is a water accounting model that assesses the demand and supply information in an effort to represent the state of the Okanagan's water resources under a number of land-use and climate scenarios. The three Phase 2 models are important elements of the OWSDP because they permit quantitative assessments of changes in water supply and demand due to climate and other drivers. However, they are complex models requiring specialized skills to operate, the simulation run times are quite long, and the output files require post-processing to distill information into something meaningful and understandable to most users and to the general public. Accordingly, the OBWB initiated the development of the OHCM to provide a model that makes use of the Phase 2 models, but is easier to operate, more nimble in operation, and capable of producing simple summaries of results.

The OHCM was constructed using the Water Evaluation and Planning (WEAP) software tool developed by the Stockholm Environment Institute. The WEAP platform is a water management and allocation tool that has a graphical user interface to guide model input and output. WEAP uses an integrated approach to simulate both natural processes (e.g. evapotranspiration demands, runoff, baseflow) and human influences (e.g. water extraction and reservoir management). Since the user has the ability to adjust a broad range of factors that influence water supply and demand, the WEAP platform is useful for scenario analyses. Within the OHCM, separate datasets are used to impose different conditions within the Okanagan Basin using the WEAP platform's flexibility.

In addition, the WEAP platform allows the user to set priority levels amongst water users (i.e. who gets water first in the case of limited supply) and a supply source preference. The allocation of water in WEAP uses a linear programming algorithm to maximize the ability to meet demand-site and user-specified in-stream flow requirements (subject to demand priorities, supply preferences, mass balance, and other constraints). The application of the FITFIR water allocation policy was modeled within the Okanagan Basin though this function.

2.2 MODEL DEVELOPMENT

The OHCM was developed using the Phase 2 data for the same eleven year calibration period (1996-2006) used for development of the OWAM. This 11-year period includes wet, normal, and dry hydrologic conditions. The OHCM specifically used natural and net streamflows (i.e. streamflows that account for human effects), water demand, and instream flow requirements from the OWAM as input values.

The OHCM required information on: rivers and creeks, reservoirs, water demand, inter-basin diversions, instream flows, return flows, and water use priorities. The following sections briefly summarize each component. More detail is provided in Appendix A.

2.2.1 Rivers and Creeks

The OWSDP divided the Okanagan Basin into 32 watersheds (i.e. stream catchments), 40 residual areas (i.e. areas of interest, but not stream catchments), five mainstem lakes, and four points of interest on the Okanagan River (Summit 2009). These collectively represent 81 “nodes” of interest in the Okanagan Basin. However, for this specific project the OHCM was intended to investigate only a few key water users in the Basin, so it explicitly modeled only those surface water sources that are directly involved in the supply and delivery of water to these users. The OHCM explicitly represents the mainstem lakes (Kalamalka, Okanagan, Skaha, Vaseux, and Osoyoos Lakes), the Okanagan River, and the major stream catchments where extractions and upland reservoirs are present. All other stream catchments and residual areas are accounted for, not individually, but rather as lumped inputs to mainstem lakes or to a river segment. A summary of the major and lumped watersheds included in the OHCM is presented in Figure 2-1 and summarized in Table 2-1.

Natural streamflow data was extracted from the OWAM at water intake and upland reservoir locations and net streamflows were extracted at the outlets of watersheds not explicitly modeled in the OHCM. All streamflow data (natural and net) was extracted from the OWAM result files containing data at 6 hour time-steps and converted to one-week time-steps for application within the OHCM. The details of the extraction process are technically complex and are described further in Appendices A and B.

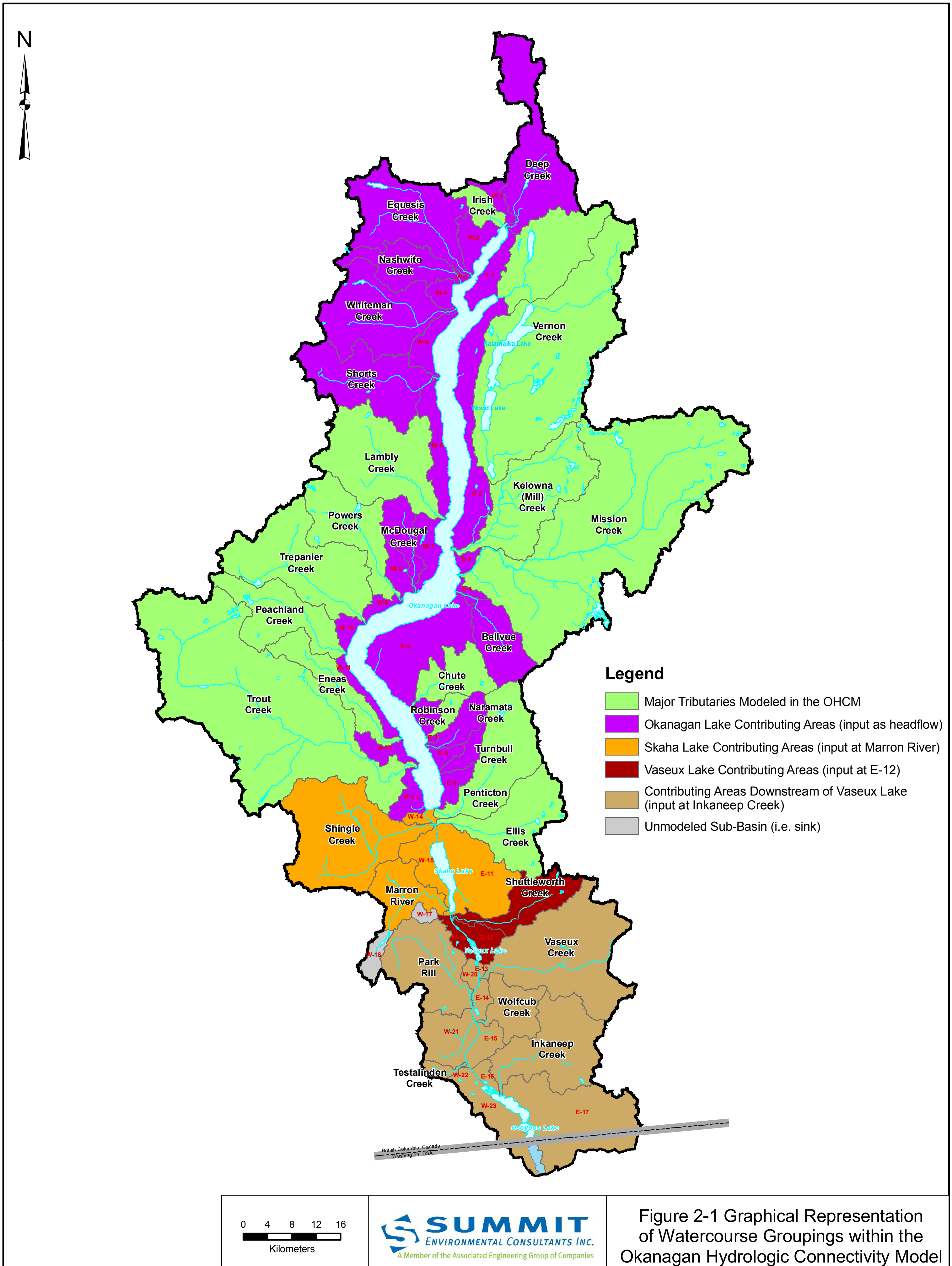

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Figure 2-1 Graphical Representation of Watercourse Groupings within the Okanagan Hydrologic Connectivity Model

Table 2-1 Summary of watercourses in the Okanagan Hydrologic Connectivity Model.

Watercourse Feature in OHCM	Watershed Modeled	
Okanagan River	n/a	
Main Tributary (Individual)	• Irish Creek • Vernon Creek • Lambly Creek • Kelowna (Mill) Creek • Mission Creek • Powers Creek • Robinson Creek	• Trepanier Creek • Peachland Creek • Eneas Creek • Trout Creek • Penticton Creek • Ellis Creek • Chute Creek
Okanagan Lake Tributaries (Lumped as Okanagan Lake Headflows)	• Equesis Creek • Nashwito Creek • Whiteman Creek • Shorts Creek • McDougall Creek • Deep Creek	• Bellevue Creek • Turnbull Creek • Naramata Creek • Residual Area W1-13 • Residual Area E1-9
Skaha Lake Tributaries (Lumped as Marron River)	• Shingle Creek • Marron River	• Residual Area W14-16 • Residual Area E10-11
Vaseux Lake Tributaries (Lumped as E12 Reach)	• Shuttleworth Creek • Residual Area W-19	• Residual Area E12
Tributaries downstream of Vaseux Lake (lumped as Inkaneep Creek)	• Vaseux Creek • Park Rill • Wolfcub Creek • Testalinden Creek	• Inkaneep Creek • Residual Area W20-23 • Residual Area E13-17

Note:

1. Residual areas W-17 and W-18 were not included in the OHCM as they have no surface outlet and are considered sinks.

2.2.2 Reservoirs

Five (5) mainstem lakes (Kalamalka, Okanagan, Skaha, Vaseux, and Osoyoos) and 48 upland reservoirs are included in the OHCM (Table 2-2). For each reservoir, both physical properties and operational rules were included. The physical properties and operational rules incorporated in the OHCM included: storage – elevation curves, maximum storage capacity, assumed initial storage, maximum hydraulic outflow, net evaporation, monthly target elevations (top of inactive zone and top of conservation zone) and the basin-wide priority level. Appendix A includes a description of these parameters.

Storage – elevation curves for the mainstem lakes were developed using bathymetric data from the OWAM, while those for the upland reservoirs were obtained from bathymetric mapping completed by the B.C. Ministry of Environment and the Ministry of Lands, Forests, and Water Resources in the 1970s and 1980s (including identification of dead, live, and potential storage levels).

Reservoir operations followed the rules documented in the Okanagan Lake Regulation System Operating Plan (Okanagan Basin Implementation Board 1982) for Kalamalka, Okanagan, Skaha, and Vaseux lakes. For Osoyoos Lake, the lake operations followed the rules outlined by the International Joint Commission's (IJC) Orders of Approval (IJC 1982; 1985), which identify separate summer and winter operating ranges and timing, as well as summer normal and drought operating ranges based on inflow forecasts for Okanagan Lake and the Similkameen River. However, since flow forecasting is not an available function in the WEAP modeling platform, a synthesized time series representing the normal upper and lower operating limits of Osoyoos Lake was developed following the actual 1996-2006 management operations. Finally, maximum hydraulic outflows were specific for Kalamalka, Okanagan, Skaha, and Vaseux Lakes, but not Osoyoos Lake[2]. These maxima exert an upper constraint on the rate of outflow from the lakes.

Table 2-2 Reservoirs included in the Okanagan Hydrologic Connectivity Model.

Watershed	Reservoir/Lake
Mainstem Lakes	• Kalamalka-Wood Lake • Skaha Lake • Osoyoos Lake • Okanagan Lake • Vaseux Lake
Vernon Creek	• Swalwell Lake • Ellison Lake • Goose Lake • Swan Lake • Crooked Creek • King Edward Lake • Oyama Lake
Kelowna Creek	• James Lake • Moore (Bulman) Lake • Postill Lake • South Lake
Mission Creek	• Ideal Lake • Loch Long Lake • Browne Lake • Long Meadow Lake • Graystoke Lake • Mission Lake • Fish Hawk Lake • McCulloch Reservoir • Fish Lake
Lambly Creek	• Big Horn Lake • Rose Valley Lake • Tadpole Lake
Powers Creek	• Dobbin Lake • West Lake • Jackpine Lake • Islaht Lake • Paynter Lake • Lambly Lake
Peachland Creek	• Peachland Lake
Eneas Creek	• Eneas Lakes • Garnet Lake
Trout Creek	• Munro Lake • Tsuh Lake • Isintok Lake • Crescent Lake • Headwaters Lake #2 • Headwaters Lake #4 • Darke Lake • Thirsk Lake • Whitehead Lake • Headwaters Lake #1 • Headwaters Lake #3
Penticton Creek	• Greyback Lake
Ellis Creek	• Ellis Lake #4
Chute Creek	• Chute Lake
Robinson Creek	• Naramata Lake • Big Meadow Lake

For the upland reservoirs, the elevation of the normal maximum operating level was set equal to the reservoir's maximum live storage elevation (or potential storage elevation), while the lower limit elevation

[2] Maximum hydraulic outflows were not included for Osoyoos Lake due to the instability of the lake levels and lake outflows that were caused by including the hydraulic constraints. In addition, backwater conditions caused by high Similkameen River flows at the outlet of Osoyoos Lake naturally restrict the maximum hydraulic outflows from the lake, which could not be included under this phase of the OHCM.

was set to the "top of dead storage" elevation. Due to limited information on upland reservoir operations, monthly (or weekly) reservoir level targets were not included in the OHCM. Similarly, due to the lack of information on channel capacities downstream of individual upland reservoirs, limitations on the maximum hydraulic outflows were also not implemented for upland reservoirs.

The net evaporation (i.e. Net Evaporation = Evaporation – Precipitation) from each mainstem lake and upland reservoir was estimated by extracting the daily potential evapotranspiration and precipitation data available from the gridded climate datasets developed by Environment Canada for Phase 2 of the OWSDP.

2.2.3 Water Demand

Water Users

The OHCM is intended to be a tool for investigating the major water uses in the Okanagan Basin. Accordingly, 21 of the largest water users were represented individually (Table 2-3) while the remainder of the water users and licence holders in each sub-basin were lumped together according to their water source (Table 2-4). In the context of the OHCM, a water user is an organization or utility that is extracting water from a surface waterbody. Only surface water sources are considered in this phase of the project because groundwater use is not regulated under FITFER and the B.C. *Water Act*. In the OWSDP, water use areas were aggregated for each major water user and estimates of off-stream water demands by the OWDM provide a means to estimate water withdrawals from a specific water source to supply a specific water use area.

Each water user generally has one or more intakes where they extract water from a surface waterbody. The volume of extraction is legally limited by the water licences held by the water user. In the OHCM, water licences are organized based on the intake that is associated with it, and each licence associated with that intake is represented as a specific node called a "demand site" (Figure 2-2). Due to the number of water licences and the complexity of managing the annual demands from each water user throughout the year, some simplification of the data was required to accommodate the requirements and limitations of the WEAP modeling platform.

Table 2-3 Water users included in the Okanagan Hydrologic Connectivity Model.

No.	Water User	Water Use Area[1]	1996-2006 Mean Annual Water Use (ML)[2]
1	Greater Vernon Water Utility (GVW)	466, 467	26,009
2	City of Kelowna (COK)	433	14,255
3	South East Kelowna Irrigation District (SEKID)	559	11,614
4	District of Lake Country (DLC)	490, 491, 492, 494	10,326
5	District of Summerland (DOS)	442, 443	10,301
6	City of Penticton (COP)	436, 437, 439	9,764
7	Black Mountain Irrigation District (BMID)	410	9,306
8	Town of Oliver (OLIV)	568, 569, 570, 571, 572, 573	8,093
9	Glenmore Ellison Improvement District (GEID)	457, 458, 459	6,341
10	Town of Osoyoos (OSO)	576, 577	4,215
11	Westbank Irrigation District (WID)	586	4,098
12	Lakeview Irrigation District (LID)	483	2,966
13	District of Peachland (DOS)	495, 497	2,402
14	Regional District of Okanagan-Similkameen (former Naramata Irrigation District) (RDOS)	453, 454, 455	2,327
15	Bylaw 1083 – Sunnyside (SUL)	418	1,499
16	Kaleden Irrigation District (KID)	477	985
17	Meadow Valley Irrigation District (MVID)	488	643
18	Bylaw 597 – West Kelowna Estates (WKEWU)	422	487
19	Grandview Irrigation District (GID)	463	482
20	City of Armstrong (COA)	432	420
21	Bylaw 793 – Pritchard/Shanboolard (SWUL)	424	243

Note:
[1] Water use areas as defined by Phase 2 of the OWSDP; and
[2] Mean annual water use does not include groundwater use (data source OWDM (Summit 2010b)).

Table 2-4 Other water user groupings included in the Okanagan Hydrologic Connectivity Model.

Watershed	Water User	Water Use Area[1]	1996-2006 Mean Annual Water Use (ML)[2]
Ellis Creek	Ellis Creek – Other Users	642	15
Eneas Creek	Eneas Creek – Other Users	628	864
Irish Creek	Irish Creek – Other Users	513, 597	1.2
Kelowna Creek	Kelowna Creek – Other Users	612	160
Lambly Creek	Lambly Creek – Other Users	610	57
Mission Creek	Mission Creek – Other Users	614	1,631
Peachland Creek	Peachland Creek – Other Users	624	101
Penticton Creek	Penticton Creek – Other Users	638	29
Powers Creek	Powers Creek – Other Users	620	98
Trepanier Creek	Trepanier Creek – Other Users	421, 622	197
Trout Creek	Trout Creek – Other Users	634	381
Vernon Creek	Lower Vernon Creek – Other Users	604	2,085
Okanagan River	Okanagan River – Other Users	417, 444, 487, 518, 520	4,237
Okanagan Lake	Okanagan Lake – Other Users	420, 427, 429, 430, 448, 451, 465, 470, 479, 511, 554, 584, 585, 590, 598, 599, 603, 605, 607, 609, 611, 613, 615, 617, 619, 621, 623, 625, 627, 629, 631, 633, 635, 637, 640	8,832
Osoyoos Lake	Osoyoos Lake – Other Users	415, 522, 545, 662, 663, 665	8,257
Kalamalka Lake	Kalamalka Lake – Other Users	481, 593, 594	5,691
Skaha Lake	Skaha Lake – Other Users	482, 558, 643, 644, 646	995
Vaseux Lake	Vaseux Lake – Other Users	651, 652	1,420

Note:
[1] Water use areas as defined by Phase 2 of the OWSDP; and
[2] Mean annual water use does not include groundwater use (data source OWDM (Summit 2010b)).

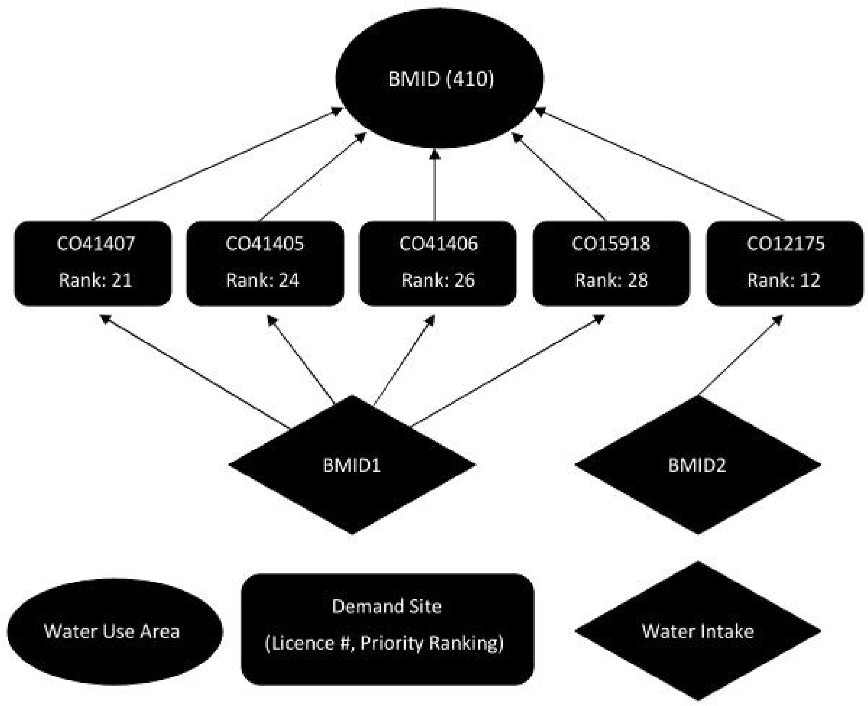

Figure 2-2 Example schematic of a water user, intakes, and demand sites within the Okanagan Hydrologic Connectivity Model.

In the Okanagan Basin there are more than 4,000 individual water licences, with each licence having an annual volume and a priority based on the date when the licence was issued. Since the WEAP modeling platform is restricted to only 99 individual demand priority rankings, the total number of licences for each of the included water users (177) needed to be reduced in order to be able to account for water licence priorities in the OHCM. Therefore, a ranking scheme was developed whereby the period during which licences have been issued (1871-2002) was subdivided into 2-year increments (Table 2-5). In addition, in order to reduce the number of demand sites in the OHCM, all water licences for offstream purposes were classified either as “irrigation” or “waterworks”. Those licences classified as waterworks include all non-irrigation-related offstream purposes. To simplify the model, licences with the same purpose and ranking at a given intake were combined. For the OHCM, the ranking of water licences ranges from 11-76 (senior to junior in priority). This provides the user some flexibility to adjust the rankings, if scenarios involving different priority rankings are desired. In addition, all other water users not specifically modeled in a major stream catchment or lake in the OHCM (e.g. all water licences in the Mission Creek watershed not held by BMID or SEKID) were assigned a priority ranking of 77. All water licences located on waterbodies not modeled by the OHCM (e.g. Shorts Creek, Inkaneep Creek) were accounted for indirectly by the net streamflow data and were not assigned a priority ranking.

Table 2-5 Water licence priority ranking scheme utilized in the Okanagan Hydrologic Connectivity Model.

Rank	Priority Date
1-10	Available for other uses
11	1871-1872
12	1873-1874
13	1875-1876
14	1877-1878
15	1879-1880
16	1881-1882
17	1883-1884
18	1885-1886
19	1887-1888
20	1889-1890
21	1891-1892
22	1893-1894
23	1895-1896
24	1897-1898
25	1899-1900
26	1901-1902
27	1903-1904
28	1905-1906
29	1907-1908
30	1909-1910
31	1911-1912
32	1913-1914
33	1915-1916
34	1917-1918
35	1919-1920
36	1921-1922
37	1923-1924
38	1925-1926
39	1927-1928
40	1929-1930
41	1931-1932
42	1933-1934
43	1935-1936
44	1937-1938
45	1939-1940
46	1941-1942
47	1943-1944
48	1945-1946
49	1947-1948
50	1949-1950
51	1951-1952
52	1953-1954
53	1955-1956
54	1957-1958
55	1959-1960
56	1961-1962
57	1963-1964
58	1965-1966
59	1967-1968
60	1969-1970
61	1971-1972
62	1973-1974
63	1975-1976
64	1977-1978
65	1979-1980
66	1981-1982
67	1983-1984
68	1985-1986
69	1987-1988
70	1989-1990
71	1991-1992
72	1993-1994
73	1995-1996
74	1997-1998
75	1999-2000
76	2001-2002
77	Other water users
78-99	Available for other uses

Water Demand Separation

A key step in developing the OHCM was to identify and link the intake(s), water licence(s), and water use (i.e. distribution) areas for each of the 21 water utilities examined in this study. Most water utilities have more than one water licence. In OHCM language, each water licence is referred to as a "demand site" (Figure 2-2). The identification of individual "demand sites" reflecting each of a utility's water licences was required in order to incorporate and evaluate water licence priorities (using the FITFIR principle) when running demand-supply scenarios.

The total water use from surface sources in each utility's water use area was obtained from the OWDM (Table 2-3)[3]. These volumes were partitioned (where necessary) between the utility's various intakes (using information developed during Phase 2) and then among its water licences. Water utilities generally manage their water allocation at each intake as a single unit, rather than managing based on the individual licences that make up that allocation. One of the biggest challenges during development of the OHCM was to assign the surface water demand at each intake and each time step to each of the licences. To accomplish this, a demand calculator tool was developed using Microsoft Excel. The Demand Calculator accounts for the total volume of water allocated to each licence, the priority of each licence held, and the weekly distribution of water use during the year (both for irrigation and for waterworks uses). This last item is based on the demand patterns for each year in the 1996 to 2006 period, as estimated by the OWDM. Further description of the water demand partitioning process is provided in Appendix A.

For scenarios involving water users using their maximum licensed volume, the same data processing steps were completed as noted above; however, the total demand volume is assumed equal to the total licensed volume, but with the same weekly distribution pattern (through the year) as the actual demand values.

2.2.4 Inter-Basin Transfers

Two types of inter-basin diversions are included: transfers of water between watersheds in the Okanagan Basin and imports of water from outside the Basin. Both of these transfers represent additions or removal of water between identified watersheds.

Inter-Basin Transfers

- Lambly Creek – Lambly Creek diversion into Rose Valley Lake; and
- Peachland Creek – Macdonald Creek (Trepanier Creek watershed) into Peachland Creek.

Water Imports

- Alocin Diversion – Nicola River watershed into Powers Creek watershed;
- Stirling Creek Diversion – West Kettle River watershed into Mission Creek watershed;
- Duteau Creek Diversion – Duteau Creek watershed into Vernon Creek watershed; and

[3] Water demands provided by the OWDM include those supplied by both surface water and groundwater sources. For the purpose of this investigation, the groundwater component of the demand was first removed using estimates identified during Phase 2 of the OWSDP.

- Fortune Creek Diversion – Fortune Creek watershed into Deep Creek watershed.

The volume of water transferred between watersheds was provided by inter-basin transfer volumes calculated during Phase 2 of the OWSDP and from water demand estimates provided by the OWDM.

2.2.5 In-Stream Flows

Water licences in the Okanagan Basin have been issued for “conservation purposes” on only a few streams: Mission Creek, Powers Creek, Kelowna Creek, Eneas Creek, Peachland Creek, and the Okanagan River. In addition, minimum flow release requirements at the outlets of each mainstem lake are documented by the Okanagan Fish Water Management Tool and the Lake Operating Plan.

To investigate the effects of in-stream flow needs (IFN) on the main water users, an IFN level was included at the mouth of all the major streams and outlets of the mainstem lakes regardless of whether conservation licences were present. In practice, fisheries regulators can require licence holders to supply water for fish in the absence of conservation licences.

The 25th percentile of the naturalized flow was selected as a surrogate for IFN’s within the major tributaries (excluding Mission and Trout Creeks that follow the specific IFN relationships defined in their respective watershed water use plans), while minimum flow releases from the mainstem lakes followed the Lake Operating Plans and the Okanagan Fish Water Management Tool. The 25th flow percentiles were calculated from the natural flow estimates included within the OWAM.

2.2.6 Return Flows

Two types of return flows are included: wastewater treatment plant (WWTP) discharges and reclaimed water use. WWTP discharge represents a return of water directly back into a waterbody, while reclaimed water is recycled for use as irrigation in certain areas. In the Okanagan Basin, water users that contribute return flows and the receiving waterbody include:

Wastewater Treatment Plants

- City of Kelowna – Okanagan Lake;
- District of West Kelowna – Okanagan Lake;
- District of Summerland – Okanagan Lake; and
- City of Penticton – Okanagan River.

Reclaimed Water

- City of Armstrong;
- City of Penticton;
- Greater Vernon Water; and
- Town of Osoyoos.

The volume of return flows by each water user was estimated during Phase 2 of the OWSDP and from water demand estimates by the OWDM for water use areas using a reclaimed water source.

2.2.7 Water Use Priority

The WEAP modeling platform uses a linear programming (LP) algorithm to attempt to satisfy the requirements for all the demand sites, IFN's, reservoir operations, and other uses, subject to demand priorities, supply preferences, mass balance and other constraints. As discussed in Section 2.2.3, a priority ranking scheme was developed to apply FITFIR to water licences within the Okanagan Basin (Table 2-5). Following that ranking scheme, IFN's were given a rank of either 1 or 80 based on the scenario under evaluation (i.e. either higher or lower priority than all extractive demands). In addition, minimum outflows from each mainstem lake were given a priority ranking of 1 to ensure minimum flow releases were always met within the Okanagan River.

Significant effort was made to optimize reservoir operations, as it was observed during the model development phase that the assigned priority significantly impacts the results. The priority scheme for reservoir operations that provides the best match to the way reservoirs are operated in practice was found to be as follows:

- Upland Reservoirs – Priority 94;
- Kalamalka Lake – Priority 95;
- Okanagan Lake – Priority 96;
- Skaha – Priority 97;
- Vaseux Lake – Priority 98; and
- Osoyoos Lake – Priority 99.

Under the priority ranking adopted for the OHCM, water users are not influenced by reservoir operations, since water demands have a higher priority. However, each reservoir (upland or mainstem) is restricted in a "top-down manner" (i.e. upstream-to-downstream). This means that the further upstream in the Okanagan system the reservoir is located, the higher the priority its reservoir operation is. For example, reservoir operations within Kalamalka Lake have a higher priority than those on Okanagan Lake, which means that the OHCM will try to meet the operational targets for Kalamalka Lake first before releasing any water downstream into Okanagan Lake. This priority ranking is considered to be generally representative of reservoir management strategies within the Okanagan Basin. However, this approach ensures that all water demands are met first (if water is available) at the possible cost of the upland reservoirs and mainstem lakes moving out of their preferred operating ranges. This approach represents a worst case scenario for the Basin, as water utilities and water managers would likely impose water restrictions to limit water demands prior to reservoirs being drained. The priority ranking scheme used in the present version of the OHCM would require adjustment if a different Okanagan Basin management approach is considered (e.g. Okanagan Lake levels and operational targets have a higher priority than downstream water demands).

Also, as only 21 major water users were specifically included within the OHCM, only those 21 have assigned licence priorities that actually reflect the true application of FITFIR. The rest of the licences were grouped into “other users”, or not specified in the non-modeled stream catchments (e.g. Shorts Creek and Inkaneep Creek). As such, the results are specific to the influence of these 21 major water users. However, since the 21 major water users in the OHCM represent the largest users of water within the Basin, the inclusion of other licensed users would likely not change the results significantly.

2.3 MODEL SCENARIOS

Currently, most major water utilities in the Okanagan Basin extract approximately one-third of their licensed volume, and water availability conflicts generally arise only during times of drought. However, as the population in the Okanagan Valley continues to grow, utilities are likely to face increased demands for water. Accordingly, they are faced with upgrades to existing infrastructure and long-term water supply and drought planning. For many utilities, drought planning includes recommending increases to upland reservoir storage and/or utilizing other water sources (surface or groundwater). However, before provincial water allocation officials award new offstream or storage licences, they generally complete investigations that include a review of impacts to the aquatic ecosystems and an estimation of the natural hydrology of the particular waterbody. In addition, although a practical application of the FITFIR legislation has not occurred in the Okanagan Basin to-date; as water demands continue to increase and water utilities use more of their licensed volumes and/or increase their licensed capacity, FITFIR could become more of a focal point.

In an effort to evaluate hydrologic connectivity in the Basin, eight (8) separate modeling scenarios were identified. Each scenario encompasses the same 1996-2006 period and fundamentally contains the same building blocks of the OHCM. A summary of each of the scenarios is provided in Table 2-6.

Table 2-6 Okanagan Hydrologic Connectivity Model Scenarios.

Scenario	Period of Investigation	Demand	Upland Storage	In-stream Flow Needs
1	1996-2006	1996-2006 Water Demands	Existing Storage	Highest Priority
2	1996-2006	1996-2006 Water Demands	Existing Storage	Lowest Priority
3	1996-2006	1996-2006 Water Demands	Potential Storage	Highest Priority
4	1996-2006	1996-2006 Water Demands	Potential Storage	Lowest Priority
5	1996-2006	Maximum Licensed Volume	Existing Storage	Highest Priority
6	1996-2006	Maximum Licensed Volume	Existing Storage	Lowest Priority
7	1996-2006	Maximum Licensed Volume	Potential Storage	Highest Priority
8	1996-2006	Maximum Licensed Volume	Potential Storage	Lowest Priority

The 8 scenarios include variations in water demands, upland reservoir storage capacities, and the priority of IFN. The water demand scenarios contrast estimated “actual” water demands (for 1996-2006) as identified in the OWDM, versus extractions at maximum licensed volume. As the climate changes and population grows, previous studies have suggested that water utilities will utilize more of their licensed water allocation, and the maximum licensed allocation scenarios (scenarios 5 – 8) represent a worst-case situation. With respect to upland reservoirs, storage capacities for the scenarios ranged between current and potential capacities (i.e. if dams were raised to a reasonable physical limit), while the IFN scenarios contrasted scenarios where the IFN has a higher or lower priority than water demands within that watershed.

2.4 MODEL VERIFICATION

The naturalized streamflows used in the OHCM were based on the hydrologic modeling results from the Phase 2 OWAM. The OWAM was calibrated for snow water equivalent, streamflows, lake levels, and lake evaporation over the 1996-2006 baseline period (summarized by DHI Inc. (2010)). Since the OHCM utilizes the OWAM hydrologic modeling results, the verification of the OHCM was an exercise in quality assurance and quality control (QA/QC) to ensure the various components of the OHCM were properly assembled and produce reasonable results. The QA/QC procedure compared the net flows of the selected major watersheds and the Okanagan River calculated by the OHCM with the net flows calculated by the OWAM at the outlets of the selected stream catchments and at strategic locations along the Okanagan River. In addition, the QA/QC procedure also compared actual mainstem lake levels with the lake levels calculated by the OHCM and OWAM. It is important to note that this QA/QC was completed to identify significant variations between the two models only.

The stream catchments included in the QA/QC procedure were Mission Creek, Kelowna Creek, Trout Creek, Powers Creek, Trepanier Creek, Lambly Creek, Ellis Creek, Penticton Creek, Peachland Creek, Eneas Creek, Irish Creek, and Vernon Creek. The results suggested that for most streams the OHCM was comparable to the OWAM. However, for Kelowna, Vernon, and Eneas Creeks, the results indicated poor agreement between the OHCM and the OWAM. On average, the OHCM underestimates the annual net flows in most streams, with Eneas, Kelowna, Peachland, Penticton, and Vernon Creeks indicating the largest annual variability between the two models. This underestimation is associated to the natural and net flow extraction process from the OWAM and the differences in water demand extraction locations between the two models (i.e. OWAM removes water demands at the mouth of the watershed, while the OHCM removes water demands at water supplier intake locations). A detailed review of the model verification results for these streams is provided in Appendix A.

All five mainstem lakes were included in the QA/QC procedure. For Okanagan Lake there was generally a good agreement in lake levels between the OHCM and OWAM. However, for Kalamalka Lake levels and outflows and Okanagan Lake outflows, the OWAM and OHCM were quite dissimilar at a weekly time-step. Additionally, for Skaha, Vaseux, and Osoyoos Lakes, the results suggested a poor match between the two models. Finally, the OHCM lake level and Okanagan River results were also compared to actual values; the results were similar to the OWAM comparison, with the lake levels represented slightly better. A detailed review of the model verification results for the mainstem lakes is provided in Appendix A.

Note that this QA/QC procedure is only specific to this phase of model development and the representation and assumptions of the selected 21 water users, the partitioning of water demand to water licences, the application of FITFIR and the adopted priority ranking scheme for water licences, IFN, and reservoir operations. As such, the OHCM is subject to various limitations that a user should be aware of before utilizing the model for water management decisions. The limitations and reliability of the OHCM are discussed further in Section 4.1 and Appendix A.

3 OHCM RESULTS

Study outcomes are summarized in this section, including a review of an OHCM schematic, an assessment of the impact of each scenario on key water users, and a review of an OHCM graphical user interface.

3.1 OHCM SCHEMATIC

A conceptual OHCM schematic was developed to visually reflect the hydrologic connectivity of the Okanagan Basin and among the water users selected for the study. The OHCM schematic is provided in Appendix A1 of Appendix A. The schematic highlights the 12 major stream catchments (including upland reservoirs) and 5 mainstem lakes included in the OHCM, and identifies the water users, the water users' intakes and locations, and licences and priorities associated with each intake, as well as the location of the IFN for each water source.

The OHCM schematic gives a top-down representation of the Basin, with the contribution of water into mainstem lakes by stream catchments (and upland reservoirs), and the connectivity of the mainstem lakes to one another. Through this representation of the Okanagan Basin, the OHCM schematic allows individuals to visually relate the connectivity of water users at the stream catchment or basin-wide level.

3.2 MODEL RESULTS

In an effort to understand and evaluate hydrologic connectivity in the Basin, OHCM scenarios investigate how water users are impacted by changes in upland storage, increased water demands, in-stream flow needs, their location in the Basin (and associated stream catchment), and licence seniority in the FITFIR licensing system (Section 2.3).

Water users supply water to distribution areas – in the OHCM this is represented by an intake extracting water to meet a water demand at a demand site. The influence of a scenario (e.g. where an IFN has higher priority than a water extraction) on a water supplier is seen by the occurrence of water shortages at a demand site. In the OHCM, water shortages are represented by "unmet" demands at the demand site. Unmet demands are defined as the amount of the demand site's requirement that is not being met. Similarly, "unmet" in-stream flow requirements can also be investigated – an unmet IFN is the difference between the in-stream flow requirement and the amount actually flowing past the IFN location. By focusing on the occurrence and size of the unmet demands, information can be gleaned about the influence of each scenario on individual water suppliers, and on the instream environment.

Each scenario includes results for all 21 water suppliers selected for the study, as well as the "other" water users included in the OHCM. To illustrate the results, outcomes for six major water users are presented in this report:

- Black Mountain Irrigation District (BMID);

- South East Kelowna Irrigation District (SEKID);
- City of Penticton (COP);
- District of Summerland (DOS);
- City of Kelowna (COK); and
- Town of Oliver (OLIV).

These water utilities extract water from Penticton, Kelowna, Mission, Eneas, and Trout Creeks, as well as Okanagan Lake and the Okanagan River. All figures referenced in the following sections are provided in Appendix C.

3.2.1 Black Mountain Irrigation District (BMID)

General Review

BMID operates six upland reservoirs (Fish Hawk, Graystoke, Mission, Loch Long, Ideal, and James Lakes) and has two water supply intakes: one on Mission Creek (i.e. BMID1)[4] and one on Scotty Creek (i.e. BMID2). The two intakes are located in separate watersheds (Mission and Kelowna Creeks) and approximately 90% of BMID's water supply is supplied by the Mission Creek intake. The BMID holds fourteen (14) surface water licences (for extraction) for an annual total of 27,779 ML (5,010 ML for waterworks and 22,769 ML for irrigation) and only one of these licences is for the Scotty Creek intake. The priority dates of the licences range from 1873 to 1970 (i.e. they have an OHCM priority range of 12-60) and the most senior licence is associated with the Scotty Creek intake. A summary of individual water licences for BMID is presented in Table A1-1 and on the OHCM schematic; both located in Appendix A1 of Appendix A.

No other major water users are located upstream of either intake; however, there are "other" water users (see defined groupings in Section 2.2.3) located further downstream. Also, there are other major water utilities in the Kelowna and Mission Creek watersheds: SEKID (in Mission Creek watershed) and Glenmore Ellison Improvement District (GEID – in Kelowna Creek watershed) (see OHCM schematic). Neither of these major water utilities are hydrologically connected to BMID since their intakes are located on other creeks in the watershed; however, due to the presence of IFN requirements at the mouth of both creeks, FITFIR could influence the release of water at some intakes to meet IFN requirements.

Summary of OHCM Results

A summary of unmet demands for BMID and unmet in-stream flow requirements for Mission and Kelowna Creeks for the entire 1996-2006 baseline period is presented in Figures C-1[5] and C-2, while the unreliability of the supply to the BMID's demand sites is provided in Figure C-3. The unreliability is defined as the average number of days per year for which the total water demand at a demand site is not satisfied. Figure C-2 shows the unreliability for each of the water licence groupings at each demand site.

[4] Intakes have been assigned an arbitrary identification for the OHCM.
[5] Note that the unmet demand figures in Appendix C indicate the presence of water shortages only, but do not indicate how severe the shortages are.

The key findings for BMID include:

1. Unmet demand is present for BMID for numerous weeks over the course of the baseline period (Figure C-1). For scenarios 1 and 2 (i.e. actual demands and existing storage versus high and low IFN priorities, respectively), the unmet demand is mainly a result of insufficient water supply to the Scotty Creek intake, since the water supply to the BMID2 demand site is unreliable for only 3 to 4 weeks every year (Figure C-3)[6]. In addition, since the percentage of weeks with unmet demand does not significantly change between scenarios 1 and 2, the IFN priority downstream is insignificant. However, keeping water demands and IFN priorities the same, but increasing reservoir storage to the maximum potential storage volumes (i.e. scenarios 3 and 4), unmet demand will decrease at the Scotty Creek intake (Figures C-1 and C-3). The increase in reservoir storage also likely contributes to a reduction in the number of weeks with unmet in-stream flow requirements in Kelowna Creek (Figure C-2).
2. If BMID's demand is increased to its maximum licensed volume (i.e. scenarios 5-8), the number of weeks with unmet demand significantly increases, as compared to the actual demand scenarios (Figure C-1). In addition, under the maximum demand scenarios, the unmet demand is associated with both BMID intakes (Figure C-2). The unmet demand is a function of both insufficient supply to the intakes, as well as downstream IFN requirements, based on the observed unmet in-stream flow requirements on Mission and Kelowna Creeks (Figures C-1 and C-2). In addition, under the maximum demand scenarios, the results indicate that an increase in storage to the upland reservoirs will only slightly reduce the frequency of BMID unmet demands in both watersheds (Figures C-1 and C-3);
3. The majority of unmet demand occurs during the late summer and early fall in all scenarios.
4. Under maximum demand scenarios, the more junior BMID licences become more unreliable (Figure C-3). In addition, the amount unmet demand associated with senior licences decreases as the priority of IFN requirements decreases.
5. Unmet in-stream flow requirements are also a function of the cumulative impacts of maximum demands. From a comparison of scenarios 1 and 5 (i.e. high IFN priority and existing storage versus actual and maximum demands, respectively), unmet in-stream flow requirements increase as the maximum demands increase. However, since the IFN priority stays the same between these scenarios (i.e. highest priority), the unmet in-stream flow requirement is a function of upland reservoirs being drained during previous time-steps. The results are slightly improved by increasing reservoir storage (i.e. scenarios 3 and 7), but due to the large demands required for the maximum scenarios, the cumulative impact of the large demands impacts the IFN requirements negatively.

In summary, key observations for BMID include:

[6] Note that during Phase 2 of the OWSDP, it was estimated that 10% of BMID's water supply was provided by the Scotty Creek intake. This assumption also applies to the OHCM, and is a potential source of error, as the distribution estimate is an average for the baseline period and might not reflect individual years accurately.

- IFN priority is not particularly important under actual demand scenarios, but the priority becomes more important under maximum demand scenarios.
- The addition of potential storage does not help to significantly reduce the frequency with which demands are unmet or the frequency of unmet instream flow requirements under maximum demand scenarios (although it may reduce the severity of these conditions).
- The demand (maximum versus actual) makes a significant difference in the frequency of unmet demands and unmet instream flow requirements.
- The unreliability of water supply to BMID intakes significantly increases under maximum demand scenarios.

3.2.2 South East Kelowna Irrigation District (SEKID)

General Review

SEKID operates four upland reservoirs (McCulloch, Long Meadow, Browne, and Fish Lakes) and has a single water supply intake on Hydraulic Creek, a tributary of Mission Creek. SEKID holds ten (10) surface water licences (for offstream purposes) for a total of 26,335 ML (1,825 ML for waterworks and 24,510 ML for irrigation) and their priority dates range from 1907 to 1970 (i.e. they have an OHCM priority range of 29-60). A summary of individual water licences for SEKID is presented in Table A1-1 and on the OHCM schematic; both are located in Appendix A1 of Appendix A.

There are no other major water users located upstream of the intake; however, there are “other” water users (groupings) located further downstream on Mission Creek. Within the Mission Creek watershed, BMID is the only other major water user, but it is not hydrologically connected to SEKID since Hydraulic Creek’s confluence with Mission Creek is downstream of BMID’s intake. However, their ability to extract water may be affected by IFN downstream, as well as other licencees (i.e. residential landowners) in the watershed with higher seniority licence priorities.

Summary of OHCM Results

A summary of unmet demands for SEKID and unmet in-stream flow requirements for Mission Creek for the entire 1996-2006 baseline period is presented in Figures C-4 and C-1, respectively, while the unreliability of supply to SEKID’s demand sites is provided in Figure C-5.

The key findings for SEKID include:

1. Unmet demand is present for SEKID for numerous weeks over the course of the baseline period (Figure C-4). For scenarios 1 and 2 (actual demands and existing storage versus high and low IFN priorities, respectively), the unmet demand is a result of insufficient water to the SEKID intake only, since the percentage of weeks with unmet demand does not change between scenarios 1 and 2. In addition, there are almost no unmet in-stream flow requirements (i.e. only one single week) on Mission Creek for scenarios 1 and 2 (Figure C-1), which suggests that SEKID’s unmet demand is a function of supply availability. However, keeping water demands and IFN priorities the same, but increasing reservoir storage to the maximum potential storage volumes (i.e. scenarios 3 and 4),

unmet demand is eliminated at the SEKID intake (Figures C-4 and C-5) and likely helps to ensure that all in-stream flow requirements are met.

2. By increasing SEKID's demand to its maximum licensed volume (i.e. scenarios 5-8), the number of weeks with unmet demand significantly increases, as compared to the actual demand scenarios (Figures C-4 and C-5). The unmet demand is a function of both insufficient supply to the intake, as well as the downstream IFN requirements (Figure C-1). In addition, under the maximum demand scenarios, the results indicate that an increase in storage to the upland reservoirs will only slightly reduce SEKID's unmet demands (Figures C-4 and C-5).
3. The majority of unmet demand occurs during the late summer and fall for all scenarios, which is similar to the period of unmet in-stream flow requirements in Mission Creek.
4. The unmet demands in scenarios 1 and 2 are associated with the most senior demand site (Figure C-5), which is a result of the demand site solely fulfilling irrigation demands for these scenarios. However, as the demands increase (e.g. scenarios 5-8), the unreliability of all demand sites increases and the more junior the demand site is, the more unreliable it becomes (Figure C-5).
5. Unmet in-stream flow requirements are also a function of the cumulative impacts of maximum demands. From the comparison of scenarios 1 and 5 (i.e. high IFN priority and existing storage versus actual and maximum demands, respectively), unmet in-stream flow requirements increase as the maximum demands increase. However, since the IFN priority stays the same between these scenarios (i.e. highest priority), the unmet in-stream flow requirement is a function of upland reservoirs being drained during previous time-steps. The results are slightly improved by increasing reservoir storage (i.e. scenarios 3 and 7), but due to the large demands required for the maximum scenarios, the cumulative impact of the large demands impacts the IFN requirements negatively.

In summary, key observations for SEKID include:

- IFN priority is not particularly important under actual demand scenarios, but the priority becomes more important under maximum demand scenarios.
- The potential storage helps to reduce the frequency of unmet demands and unmet instream flow requirements under actual demands, but does not significantly help under maximum demands.
- The demand (maximum versus actual) makes a significant difference in the freqeuncy of unmet demands and unmet instream flow requirements.
- The unreliability of water supply to SEKID significantly increases under maximum demand scenarios.

3.2.3 City of Penticton (COP)

General Review

COP operates two upland reservoirs (Greyback Lake and Ellis Creek Reservoir) and has three water supply intakes: two watershed intakes (one in Penticton Creek watershed (i.e. COP1) and one in Ellis Creek watershed (i.e. COP3)) and one Okanagan Lake intake (i.e. COP2). The Penticton Creek and Okanagan Lake intakes are both used to supply COP's main water use area, while COP's intake on Ellis Creek supplies a separate water use area. COP has eleven (11) surface water licences (for offstream purposes) for a total of 25,352 ML (17,396 ML for waterworks and 7,956 ML for irrigation) and their priority dates range from 1891 to 1982 (i.e. they have an OHCM priority range of 21-66). A summary of individual water licences for COP is presented in Table A1-1 and on the OHCM schematic; both are located in Appendix A1 of Appendix A.

For COP, there are no other major water users upstream of either watershed intake location; however, there are “other” water users (groupings) located further downstream on both Ellis and Penticton Creeks, and there are numerous water users that make withdrawals from Okanagan Lake. There are also IFN requirements at the mouths of both Penticton and Ellis Creeks specified in the OHCM.

Summary of OHCM Results

A summary of unmet demands for COP and unmet in-stream flow requirements for Penticton and Ellis Creeks for the entire 1996-2006 baseline period is presented in Figures C-6 and C-7, while the unreliability of the supply to COP’s demand sites is provided in Figure C-8.

The key findings for COP include:

1. Unmet demand is present in COP’s supply systems (Figures C-6 and C-7). For the Penticton Creek and Okanagan Lake supply system (i.e. COP1 and COP2), the unmet demand only occurs at the Penticton Creek intake (i.e. COP1 21) (Figures C-6 and C-8). For scenarios 1 and 2 (i.e. actual demands and existing storage versus high and low IFN priority), the unmet demand at the Penticton Creek intake is a result of insufficient water supply, since there are unmet in-stream flow requirements on Penticton Creek when the IFN has the highest priority and there is no change in unmet demands when the IFN priority is the lowest. In addition, an increase in reservoir storage on Greyback Lake (i.e. scenarios 3 and 4) does not appear to help reduce unmet demands.
2. By increasing COP’s demand to the maximum demand (i.e. scenarios 5-8) for the Penticton Creek and Okanagan Lake supply system, the number of time-steps with unmet demand slightly increases, as compared to the actual demand scenarios (Figure C-7). The unmet demand is a function of both insufficient natural water supply at the intake, as well as the downstream IFN requirement, which is based on the observed unmet in-stream flow requirement on Penticton Creek (Figure C-7). In addition, under the maximum demand scenarios, the results indicate that an increase in storage to Greyback Lake will only slightly reduce COP’s unmet demands (Figure C-7).
3. For the Ellis Creek supply system (i.e. COP3) unmet demand is present under all maximum demand scenarios (i.e. scenarios 5-8), but is only present for actual demand scenarios 1 and 2 (Figure C-7). This suggests that the increase in storage on Ellis Creek Reservoir (i.e. scenarios 3 and 4) helps to reduce the unmet demand at the Ellis Creek intake (Figure C-8). The increase in reservoir storage is also observed to reduce the number of time-steps with unmet demand when the maximum demand is occurring. The increase in storage on the Ellis Creek Reservoir also helps to reduce the number of time-steps with unmet in-stream flow requirements in Ellis Creek under actual and maximum demand scenarios (Figure C-8).

4. Unmet demand occurs throughout the year for all scenarios for the Penticton Creek watershed and Okanagan Lake supply system, which is similar to the period of unmet in-stream flow requirements in Penticton Creek. Unmet demand for the Ellis Creek supply system occurs throughout the year under the maximum demand scenarios, which is similar to the period of unmet in-stream flow requirements in Ellis Creek.
5. COP's demand sites that utilize Okanagan Lake are not impacted under any scenario (Figure C-8).

In summary, key observations for COP include:

- IFN priority is not particularly important under actual demand scenarios, but the priority becomes more important under maximum demand scenarios.
- The potential storage does not help to reduce the frequency of unmet demands and unmet instream flow requirements for the Penticton Creek and Okanagan Lake supply system (although it may reduce the severity of these conditions). Increasing storage in the Ellis Creek Reservoir does help reduce the frequency of unmet demands and unmet in-stream flow requirements for the Ellis Creek supply system.
- The demand (maximum versus actual) makes a significant difference in the frequency of unmet demands and unmet instream flow requirements for COP's supply systems, except for demand sites supplied by Okanagan Lake, as unmet demand was not present under all scenarios.
- The unreliability of water supply of COP's supply systems significantly increases under maximum demand scenarios.

3.2.4 District of Summerland (DOS)

General Review

DOS operates twelve (12) upland reservoirs: nine on Trout Creek, one on Darke Creek (a Trout Creek tributary) and two on Eneas Creek. DOS also operates two water supply intakes: one on Trout Creek (i.e. DOS1) and one on Eneas Creek (i.e. DOS2). DOS holds twelve (12) surface water licences (for offstream purposes) for a total of 22,326 ML (8,378 ML for waterworks and 13,948 ML for irrigation) and their priority dates range from 1889 to 1988 (i.e. they have an OHCM priority range of 20-69). A summary of individual water licences for DOS is presented in Table A1-1 and on the OHCM schematic; both are located in Appendix A1 of Appendix A.

There are no other major water users above the Eneas Creek intake, but on Trout Creek, Meadow Valley Irrigation District (MVID) is located upstream of the DOS intake. The MVID is located on Darke Creek and has three (3) surface water licences (for irrigation purposes only) for a total of 1,661 ML with priority dates that range from 1891 to 1964 (i.e. an OHCM range of 21-57). There are also "other" water users downstream of the DOS intakes on both creeks, as well as IFN requirements.

Summary of OHCM Results

A summary of unmet demands for DOS and unmet in-stream flow requirements for Trout and Eneas Creeks for the entire 1996-2006 baseline period is presented in Figures C-9 to C-10, while the unreliability of the supply to the DOS's demand sites is provided in Figure C-11.

The key findings for DOS include:

1. Unmet demand is present for both of DOS's supply systems (Figures C-9 and C-10). For the Trout Creek intake unmet demand occurs in all scenarios (Figure C-9). For scenarios 1 and 2 (i.e. actual demands and existing storage versus high and low IFN priority), the unmet demand at the Trout Creek intake is a result of insufficient water supply, since there are unmet in-stream flow requirements on Trout Creek when the IFN has the highest priority and similar unmet demand when the IFN has the lowest priority. In addition, an increase in storage in the upland reservoirs does not appear to significantly reduce the frequency of unmet demands under the actual demand scenarios (i.e. scenarios 3 and 4).
2. By increasing DOS's demand to the maximum demand (i.e. scenarios 5-8) at the Trout Creek intake, the number of weeks with unmet demand increases, as compared to the actual demand scenarios (Figure C-9). The unmet demand is again a function of both insufficient supplies to the intake, as well as the downstream unmet IFN requirement (Figure C-9). Similar to the actual demand scenarios, the maximum demand results indicate that an increase in upland reservoir storage will only slightly reduce the frequency of unmet demands (Figures C-9 and C-11).
3. Similar to the results at the Trout Creek intake, unmet demands at the Eneas Creek intake are a result of insufficient water supply at the intake under actual demands, existing storages, and alternating high and low IFN priorities (i.e. scenarios 1 and 2) (Figure C-10). However, these results indicate that if the upland reservoir storages were increased, the unmet demands and unmet in-stream flow requirements would be eliminated under actual demand scenarios (i.e. scenarios 3 and 4).
4. By increasing the DOS's demand to the maximum demand (i.e. scenarios 5-8) at the Eneas Creek intake, the number of time-steps with unmet demand increases, as compared to the actual demand scenarios (Figure C-10). Similar to Trout Creek, the unmet demand is again a function of both insufficient supplies to the intake, as well as the downstream IFN requirement (Figure C-10). However, these results indicate that if the upland reservoir storages were increased, the frequency of unmet demands and unmet in-stream flow requirements would not be significantly reduced (Figure C-11).
5. Unmet demand occurs in the late summer and early fall under actual demand scenarios for the Trout Creek supply system, but increases to throughout the year under maximum demand scenarios. The majority of unmet demand for the Eneas Creek supply system occurs in the late summer and fall under actual demand scenarios, but increases to the entire period of irrigation use (i.e. April to September) under maximum demand scenarios.

In summary, key observations for DOS include:

- IFN priority is not particularly important under actual demand scenarios, but the priority becomes more important under maximum demand scenarios;
- The potential storage does not help to reduce the frequency of unmet demands and unmet instream flow requirements for the Trout Creek supply system (although it may reduce the severity of the conditions). Increasing storage in Eneas Creek watershed does help to reduce the frequency of unmet demands and unmet in-stream flow requirements under actual demands, but not maximum demand scenarios;
- The demand (maximum versus actual) makes a significant difference in the frequency of unmet demands and unmet instream flow requirements for both of DOS's supply systems; and
- The unreliability of water supply to both of DOS's supply systems significantly increases under maximum demand scenarios.

3.2.5 City of Kelowna (COK)

General Review

The COK withdraws water from Okanagan Lake and holds thirteen (13) surface water licences (for offstream purposes) for a total of 47,119 ML (47,087 ML for waterworks and 32 ML for irrigation) with priority dates ranging from 1913 to 1980 (i.e. they have an OHCM priority of 32-65). A summary of individual licences for COK is presented in the OHCM schematic, as well as in Appendix A1 of Appendix A.

There are several major and other water users that also withdraw from Okanagan Lake, as well as upstream in all the stream catchments that drain into Okanagan Lake. There is also a minimum flow release at the outlet of Okanagan Lake in the OHCM.

Summary of OHCM Results

A summary of unmet demands for COK and unmet minimum flow releases at the outlet of Okanagan Lake for the entire 1996-2006 baseline period is presented in Figure C-12, while the unreliability of the supply to the COK's demand sites is provided in Figure C-13.

The key findings for COK include:

1. No unmet demands were observed for the COK over the entire baseline period under any of the scenarios and there were no unmet minimum flow releases at the outlet of Okanagan Lake (Figures C-12 and C-13). This suggests that the available supply in Okanagan Lake, under actual and maximum demand scenarios, is sufficient to meet all of COK's demands without impacting water demands and in-stream flow requirements downstream of Okanagan Lake. However, this is at the cost of having Okanagan Lake levels fall below normal operating ranges in some years, which may not be allowed by provincial regulators (see Section 3.2.7).

In summary, key observations for COK include:

- The minimum flow release priority for Okanagan Lake was always met, which is a result of the minimum flow release having the highest priority under each scenario.

- The demand (maximum versus actual) does not make a difference in the frequency of unmet demands or unmet in-stream flow requirements; or the ability to meet specified minimum flow releases downstream of Okanagan Lake. However, this occurs at the cost of Okanagan Lake levels – which deviate from normal operating ranges under maximum demand scenarios.

3.2.6 Town of Oliver (OLIV)

General Review

The OLIV withdrawals water from the Okanagan River for waterworks and irrigation purposes, which is represented in the OHCM by a single intake. The OLIV holds four surface water licences (for offstream purposes) for a total of 51,403 ML (553 ML for waterworks and 50,850 for irrigation) and their priority dates range from 1907 to 2000 (i.e. an OHCM priority range of 29-75). A summary of individual licences for OLIV is presented in the OHCM schematic, as well as in Appendix A1 of Appendix A.

There are no other major water users on the Okanagan River below the OLIV intake; however, the Town of Osoyoos and Osoyoos Lake "other" water users are located downstream, and withdraw water from Osoyoos Lake. Since the OLIV withdrawals water from the Okanagan River, all upstream withdrawal points are hydrologically connected to OLIV, which suggests that FITFIR could potentially influence the release of water at some of the upstream intakes in order to meet OLIV demands.

Summary of OHCM Results

A summary of unmet demands for the OLIV and unmet in-stream flow requirements on the Okanagan River downstream of the OLIV intake, for the entire 1996-2006 baseline period, are presented in Figure C-14, while the unreliability of the supply to OLIV's demand sites is provided in Figure C-15.

The key findings for OLIV include:

1. No unmet demands were observed for the OLIV over the entire baseline period under any of the scenarios, and there were no unmet in-stream flow requirement demands on the Okanagan River (Figures C-14 and C-15). This suggests that the available storage in the mainstem lakes, and Okanagan River releases (under actual and maximum demand scenarios) are sufficient enough to meet the Okanagan River in-stream flow requirement downstream of the OLIV intake, as well as meet all of OLIV's demands;
2. With all water demands at each of the OLIV's demand sites met for every week and the Okanagan River's IFN requirement met downstream of the OLIV intake, the results suggest that OLIV's water demands are not impacted by upstream water users. In particular, OLIV's most junior demand site (i.e. OLIV 75) represents one of the most junior licences in the Okanagan Basin (i.e. with a priority date of 2000) yet its water demands are consistently met under all scenarios (Figure C-15). In addition, due to the numerous water users in the mainstem lakes with no unmet demands upstream of the OLIV intake (e.g. COP and COK), the results suggest that the OLIV's water demands (actual and maximum) are not negatively influencing upstream water users. As noted earlier, however, this outcome is related to the arbitrary assignment of relatively low priority to maintaining the mainstem

lakes within their normal operating range; and the high priority given to meeting IFN in the Okanagan River.

In summary, key observations for OLIV include:

- The minimum flow requirement in the Okanagan River downstream of the OLIV intake was always met, which was a result of the IFN having the highest priority under each scenario.
- The demand (maximum versus actual) does not make a difference in the frequency of unmet demands for OLIV or unmet in-stream flow requirements for the Okanagan River.
- The reliability of water supply is high for OLIV, since no unmet demands occur over the 11-year baseline period.
- The reliability of water supply is based on the assumption that the Okanagan Lake can be drawn down indefinitely, which may not be valid under extreme conditions.

3.2.7 Okanagan Lake

The use of the OHCM has highlighted an interesting result for Okanagan Lake. In the current version of the OHCM, the useable storage volume of Okanagan Lake is available to all water users and is available to meet downstream Okanagan River IFN requirements; since water users and the Okanagan River IFN have been assigned higher priorities than keeping the lake within its usual operating range (Section 2.2.7). Accordingly, all water demands from Okanagan Lake or from the Okanagan River downstream of the lake are met by the model at the cost of Okanagan Lake's useable storage (Figure C-16). In particular, under maximum demand scenarios (i.e. scenarios 5-8), Okanagan Lake becomes depleted during drier years and lake levels begin to approach the sill elevation of the dam (339.75 m GSC) at Penticton (Figure C-16). With this choice of priorities (which appear to reflect the actual practices and priorities of the provincial water managers who manage the mainstem lakes), FITFIR does not appear to influence water users that withdraw water from Okanagan Lake (or the other mainstem lakes) or the Okanagan River, since all higher priority demands are met at the cost of maintaining the levels of the mainstem lakes. However, the results of these scenarios could have been different if maintaining Okanagan Lake within its normal operating range had been assigned a higher priority in the model.

3.2.8 Summary of Selected Results

The key findings for the six water utilities are summarized in Table 3-1. Using the unmet demand and unmet in-stream flow requirement information from the OHCM, a ranking scheme was developed to visually compare the scenario results. The ranking scheme uses colors (green, yellow, and red) to identify the frequency with which unmet demands or unmet in-stream flow requirements.

The representation of the results shown in Table 3-1 visually demonstrate how the IFN priority becomes more important under maximum demand scenarios for some water utilities, and how increasing storage reduces the frequency of unmet demand and unmet in-stream flow requirements.

Table 3-1 Summary of results for selected water utilities under various Okanagan Hydrologic Connectivity Model Scenarios.

Water Utility	Intake ID	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7		Scenario 8	
		Unmet Water Demand	Unmet IFN	Unmet Water Demand	Unmet IFN	Unmet Water Demand	Unmet IFN	Unmet Water Demand	Unmet IFN	Unmet Water Demand	Unmet IFN	Unmet Water Demand	Unmet IFN	Unmet Water Demand	Unmet IFN	Unmet Water Demand	Unmet IFN
Black Mountain Irrigation District	BMID1	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	10-25%	0-10%	0-10%	10-25%	10-25%	0-10%	0-10%	10-25%
	BMID2	0-10%	0-10%	0-10%	10-25%	0-10%	0-10%	0-10%	0-10%	>25%	10-25%	>25%	>25%	>25%	10-25%	10-25%	>25%
Southeast Kelowna Irrigation District	SEKID	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	10-25%	0-10%	10-25%	10-25%	10-25%	0-10%	10-25%	10-25%
City of Penticton	COP1, 2	10-25%	10-25%	10-25%	10-25%	10-25%	0-10%	10-25%	10-25%	>25%	10-25%	>25%	>25%	>25%	10-25%	>25%	>25%
	COP3	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	>25%	10-25%	>25%	>25%	10-25%	10-25%	10-25%	>25%
District of Summerland	DOS1	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	10-25%	10-25%	0-10%	10-25%	10-25%	0-10%	0-10%	10-25%
	DOS2	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	10-25%	10-25%	10-25%	10-25%	10-25%	0-10%	10-25%	10-25%
City of Kelowna	COK	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%
Town of Oliver	OLIV	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%

Scenario Legend:

- Current Demand
- Maximum Demand
- IFN Highest Pirority
- IFN Lowest Pirority
- Existing Reservoir Storage
- Potential Reservoir Storage

Results Legend:

- Unmet Water Demand
- Unmet IFN

Percentage of time water demands and IFN requirements are unmet over the 11-year simulation period (i.e. 1996-2006 or 572 weeks)

- 0-10%
- 10-25%
- >25%

3.3 OHCM GRAPHICAL USER INTERFACE – RESULTS VIEWER

A Graphical User Interface (GUI) – Results Viewer was developed to help simplify the review of the results produced by the OHCM. The OHCM GUI – Results Viewer is a web-based tool that was developed using the conceptual OHCM schematic.

The purpose of the GUI is to allow users to interact, investigate, compare, and understand the large amount of results and information generated from the eight OHCM scenarios. The results include inflows and water elevations for the upland reservoirs and mainstem lakes, demand and unmet demand for a water user's demand site, required and unmet in-stream flow requirements for a stream catchment, and net streamflows at the mouths of the major stream catchments included in the OHCM. It can be easily used without having any knowledge of the OHCM.

A summary of the OHCM GUI – Results Viewer is provided in Appendix D and the GUI can be viewed on the OBWB's website (www.obwb.ca).

3.4 OHCM POSTER

In addition to the GUI, a poster that illustrates the key findings of the study was produced. The poster was designed to provide a simple way to communicate the OHCM and its applicability to a broad audience. The poster is provided in Appendix E.

4 OHCM LIMITATIONS

4.1 MODEL LIMITATIONS

The results obtained in the present study are specific to the present version of the OHCM, and the representation and assumptions related to the selected 21 water utilities, the partitioning of water demand to water licences, the application of FITFIR and the adopted priority ranking scheme for water licences, IFN, and reservoir operations. However insightful the results might be for the Basin or a stream catchment, the user must understand the limitations of the OHCM before using it to make management or planning decisions.

Individual limitations of available datasets are described within the "*Okanagan Hydrologic Connectivity Model: Model Development Report*" in Appendix A. Based on the model verification results, the OHCM produces reasonable results for Okanagan Lake and its major tributaries and generally reflects the results produced by the Okanagan Water Accounting Model. However, the results from the OHCM scenario evaluations underscore the challenges in modelling a complex hydrologic system such as Okanagan Basin, particularly one where human influences, such as lake regulation, are difficult to quantify and reliably predict.

In addition, it is difficult to replicate the actual operations of the mainstem lakes and lake outflows due to human decisions and operational choices based on forecasts. Consequently, without forecasting abilities embedded within the OHCM and an improved understanding or description of actual lake management operations, mainstem lake levels and outflows will continue to deviate from OWAM and actual observations. However, mainstem lake operations in the OHCM currently represent as closely as possible the lake operating plans. And, although lake levels in the mainstem lakes downstream of the Penticton Dam deviate from the OWAM and actual records, the total volume of water being released down the Okanagan River is generally consistent with the OWAM. This suggests that all of the water within the Basin is accounted for within the OHCM, but some of the timing and volume of flows within the Okanagan River and stream catchments might not match the OWAM or actual records for water users downstream of Okanagan Lake.

Also, in the present version of the OHCM, all water demands are given a higher priority than mainstem lake levels or upland reservoir operations, which results in the "mining" of reservoirs under some maximum demand scenarios. This generally reflects present-day practice, but does not necessarily reflect how the mainstem lake or upland reservoirs would be managed under extreme water shortages. A model user must be aware of this limitation before using the OHCM to make management or planning decisions. Similarly, for all water users using a mainstem lake source, the depth of water supply intakes is not considered in the OHCM; therefore, the water supply to a mainstem lake water user is not restricted. In the model, therefore, a mainstem lake water user has access to the entire lake volume, rather than being limited to the lake volume above the elevation of their intake.

Finally, the partitioning of a water utility's total demand amongst several individual licences held by that utility can be approached in different ways. For the current version of the model, we developed a method of allocating water use to each licence simultaneously. This method appears satisfactory, in that it does not appear to cause conflicts with the current water management regime in the Basin. However, under future scenarios of increased demands and potentially drier climate, water regulators could specify rules or guidelines for the way in which water use is assigned to licences. Various approaches to applying water withdrawals against licences could be simulated in a future version of the OHCM, such as specifying the use of junior licences before more senior licences.

5 CONCLUSIONS AND RECOMMENDATIONS

An Okanagan Hydrologic Connectivity Model (OHCM) has been developed based on the WEAP modelling platform, driven by the models developed in Phase 2 of the OWSDP. Other deliverables of the study are a poster describing water flow and water use in the Okanagan Basin; an easy-to-read schematic diagram of the Basin's natural and managed water systems; and a Graphical User Interface – Results Viewer that allows a user to visualize outputs without knowing how to use the model. Conclusions and recommendations of the study are listed in this section.

5.1 CONCLUSIONS

The conclusions for the OHCM study include:

1. The OHCM is able to represent hydrological and water management processes in the Okanagan Basin, and is well suited to rapid evaluation of scenarios.
2. Its accuracy is limited by the quantity and quality of the data available to the Phase 2 models that provide input data to the OHCM.
3. Under present-day water demands, giving instream flow need (IFN) for fish and other environmental values a higher priority would not likely significantly affect the ability of water suppliers to continue to provide water to their customers.
4. If water demands increase (approaching the amount of licensed volumes), either IFN are frequently not met; or water suppliers frequently run short of water (depending on the priority attached to meeting IFN).
5. Increasing upland storage can reduce the frequency with which water suppliers and streams run short of water in some watersheds under current water demands. However, under maximum demand scenarios, increasing storage does not help to significantly reduce the frequency with which demands are unmet or the frequency of unmet instream flow requirements.
6. In a high water demand scenario, if a model user assigns a higher priority to meeting downstream flows than to keeping Okanagan Lake within its acceptable range of levels, the model will satisfy Okanagan River flow requirements while allowing Okanagan Lake to drop below its acceptable range. Alternatively, if a model user reverses the priority, the model will keep the lake level within the acceptable range at the expense of meeting downstream flow requirements. Using a priority ranking scheme which appears to reflect the priorities of the provincial water managers who manage the mainstem lakes, FITFIR does not appear to influence water users that withdraw water from Okanagan Lake (or the other mainstem lakes) or the Okanagan River, since withdrawal demands are met at the cost of mainstem lake levels.
7. The WEAP platform is well-suited to the OHCM application and to future studies intended to extend the Phase 2 OWSDP results.

5.2 RECOMMENDATIONS

The OHCM is currently limited to datasets available from the OWAM and assumptions developed during Phase 2 of the OWSDP. Therefore, results are constrained by the accuracy of this information and these assumptions. To move ahead with the use of the OHCM as a tool for water management decisions, the following technical recommendations and future applications are proposed.

5.2.1 Technical Recommendations

Technical recommendations for the OHCM include:

1. The spatial extent of the OWAM currently includes the entire Okanagan Basin. However, water is imported into the Okanagan from stream catchments outside the Okanagan Basin (e.g. Duteau Creek watershed). Without including these stream catchments within the OWAM's spatial extent, the OHCM's representation of water users that rely on these imports under future climatic conditions is limited. By updating the spatial extent of the OWAM to include the necessary stream catchments outside of the Okanagan Basin, specific water user (e.g. Vernon Greater Water, City of Armstrong) investigations could be improved;
2. The partitioning of total demand amongst individual licences can be approached in different ways. In the present version of the model, water use is allocated against all licences simultaneously. Under future scenarios of increased demands and potentially drier climate, water regulators could specify the use of junior licences before senior licences, or another method of assigning water use to licences. Future applications of the model should investigate the impact of such choices.
3. Many assumptions have been made regarding upland reservoir operations in the OWAM and the OHCM. Reservoir release and fill patterns have been assumed (or set equal to demands downstream), and minimum flow releases from the reservoirs (if applicable) have not been included. To better reflect management operations within a stream catchment, all reservoir operations should be updated to match actual water utility management operations and strategies. This would provide a better reflection of reality, which would be carried into future applications.
4. In the OHCM, the 25th naturalized flow percentile was selected as a surrogate for IFN in the major tributaries (excluding Mission and Trout creeks), while minimum flow releases from the mainstem lakes followed the Lake Operating Plans and the Okanagan Fish Water Management Tool. Given the current level of uncertainty that exists in the Okanagan Basin over the most appropriate way to identify IFN, in order to glean more information about the sensitivity of the major tributaries to IFN, it is recommended that additional flow percentiles be considered (e.g. 5th, 10th, 15th percentiles). This will provide OHCM users more flexibility when they are using the model with different scenarios.
5. In the current version of the OHCM, all water demands have a higher priority than mainstem lakes or upland reservoir operations, which results in the "mining" of lakes and reservoirs under some maximum demand scenarios. This does not necessarily reflect how the mainstem lake

or upland reservoir operations would be handled under extreme conditions. Accordingly, it is recommended that OHCM further explore the priorities associated with the mainstem lakes, particularly Okanagan Lake. By changing the priority of the mainstem lakes to higher priorities than given to water users (as might happen if the lake was drawn down below its operating range), the impacts to downstream users could be investigated further and compared with the current OHCM scenarios.

6. Maximum hydraulic outflows were not included for Osoyoos Lake due to the instability of the lake levels and lake outflows that were caused by including the hydraulic constraints. In addition, backwater conditions (caused by high Similkameen River flows) at the outlet of Osoyoos Lake naturally restrict the maximum hydraulic outflows from the lake. Therefore, it is recommended that the OHCM be updated to include an improved representation of Osoyoos Lake's operations and hydraulic constraints.

5.2.2 Future Applications

Some potential future applications of the OHCM include:

1. The current OHCM framework was developed using the Phase 2 1996-2006 baseline dataset; however, additional datasets (such as for future climates) developed during Phases 2 and 3 of the OWSDP could be included to provide more scenario applications within the OHCM and to allow for future predictions.
2. To minimize run times, represent groundwater information at the appropriate resolution, and improve the robustness of the model, future applications of the OHCM should consider changing the model time-step to monthly.
3. Within the version of the OHCM, only surface water licences for extraction are considered. However, many of the surface water licences are supported by storage licences on upland reservoirs. Future applications could consider using the licensed storage volume instead of the physical reservoir volume in order to provide a more legally appropriate representation of licensed supply capabilities. This could help in the identification of those water users that may not have enough licensed storage to meet actual or maximum licensed demands.
4. The model could be used to investigate the implications of various approaches to reserving water for agricultural land in the Okanagan Basin. In this application, the assignment of a "water reserve" to agricultural land could be accomplished by assigning a high priority to agricultural licences. In the current version of the OHCM, various kinds of irrigation licences are lumped together; therefore, future applications should consider separating agricultural irrigation licences from other irrigation licences.
5. Groundwater processes and withdrawals are not included in this version of the OHCM. However, with the continued and growing dependence on groundwater sources in the Basin (and water licensing discussions considering groundwater licensing in British Columbia), groundwater use and its impacts on aquifers and nearby surface water resources needs to be considered. Therefore, it is recommended that groundwater be considered, in order to use the OHCM as a full water allocation tool. Significant groundwater information was developed in

Phase 2 of the OWSDP and the inclusion of groundwater processes and withdrawals could be included in future applications of the OHCM without significant additional data development.

6. IFN understanding is currently limited to the information developed in Phase 2 of the OWSDP. It is recommended to complete a detailed investigation of IFN throughout the Basin, and to incorporate this knowledge in an updated version of the OHCM.
7. The OHCM could be extended to explicitly represent all catchments modelled by the OWAM.
8. By combining a spatially-extended model with new IFN knowledge and explicit representation of the effects of groundwater withdrawals, it would be possible to build a comprehensive and easy to use gaming tool for water allocation decision-makers.

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A Appendix A - OHCM Model Development Report

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Appendix A

Okanagan Basin Water Board

Okanagan Hydrologic Connectivity Model: Model Development

Project: 2010-8005.000

May 2013

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1 INTRODUCTION

In an effort to understand and evaluate how water management actions are interconnected in the Okanagan Basin, the Okanagan Basin Water Board (OBWB) has taken a proactive step by developing a model to examine water allocation questions. At this phase of its development, the model considers surface water sources only; groundwater has not (yet) been included. The model, which is intended to assist provincial and local government agencies, local water suppliers, and others, is referred to as the Okanagan Hydrologic Connectivity Model (OHCM).

The OHCM is a computer-based model that was developed in the Water Evaluation and Planning (WEAP) platform developed by the Stockholm Environment Institute (SEI). It builds upon the information collected during Phase 2 of the Okanagan Water Supply and Demand Project (OWSDP) (Summit 2010a), and specifically utilizes hydrologic data produced by the Okanagan Water Accounting Model (OWAM). However, unlike the OWAM, the OHCM allows users to examine how water users are interconnected within the Okanagan's hydrologic context and through the "first-in-time, first-in-right" (FITFIR) principle within the B.C. *Water Act*.

The purpose of this report is to provide a technical summary of the development and verification of the OHCM. The report "*Okanagan Hydrologic Connectivity Model: Summary Report*" provides a discussion on the OHCM's application and results.

The development of the OHCM was a joint effort between Summit Environmental Consultants Inc., DHI Inc., Polar Geoscience Ltd., and Agua Consulting Inc.

2 MODEL DEVELOPMENT

During Phase 2 of the OWSDP, three (3) custom models for simulating water supply and demand in the Okanagan were developed. These models were the Okanagan Water Demand Model (OWDM), the Okanagan Basin Hydrology Model (OBHM), and the Okanagan Basin Water Accounting Model (OWAM). The OWDM was developed to compute irrigation and non-irrigation water use for discrete parcels of land (i.e. “water use areas”) and link the water use on each water use area to its water source (Summit 2010a). The OBHM is a hydrologic model that computes naturalized streamflow (i.e. streamflow in the absence of human effects), while the OWAM is a water accounting model that assessed the demand and supply information in an effort to represent the state of the Okanagan’s water resources under a number of land-use and climate scenarios. The OBHM and OWAM are based on DHI’s MIKE SHE and MIKE 11 modeling platforms. The three Phase 2 models are important elements of the OWSDP because they permit quantitative assessments of changes in water supply and demand due to climate and other drivers. However, they are complex models requiring specialized skills to operate, the simulation run times are quite long, and the output files require post-processing in order to distil information into something meaningful and understandable to most users and to the general public. Accordingly, the OBWB initiated the development of the OHCM in order to provide a model that makes use of the complex Phase 2 models, but which is simpler to operate, more nimble in its operation, and capable of producing simple summaries of results.

The OHCM was constructed using the Water Evaluation and Planning (WEAP) software tool developed by the Stockholm Environment Institute (SEI). The WEAP platform is a water management and allocation tool that has a graphical user interface to guide model input and output. WEAP uses an integrated approach to simulate both natural processes (e.g. evapotranspirative demands, runoff, baseflow) and human influences (e.g. water extraction and reservoir management). Since the user has the ability to adjust a broad range of factors that influence water supply and demand, the WEAP platform is useful for scenario analyses. Within the OHCM, separate datasets are used to impose different conditions within the Okanagan Basin using the WEAP platform’s flexibility.

In addition, the WEAP platform allows the user to set priority levels amongst water users (i.e. who gets water first in the case of limited supply) and a supply source preference. The allocation of water within WEAP uses a linear programming algorithm to maximize satisfaction of demand site and user-specified in-stream flow requirements (subject to demand priorities, supply preferences, mass balance, and other constraints). The application of the FITFIR water allocation policy can be modeled within the Okanagan Basin through this function.

The existing OWAM and data produced during Phase 2 of the OWSDP were heavily utilized for the OHCM development. The OWAM was developed using the Phase 2 data for the same eleven (11) year (i.e. 1996-2006) used for development of the OWAM. This 11-year period includes wet, normal, and dry hydrologic conditions within the Basin. Accordingly, the baseline period for the OWAM was adopted for the OHCM development and utilized the following inputs from the OWAM:

1. Naturalized and net (i.e. streamflows that account for human effects) streamflows for each sub-basin and residual area;
2. Water demand by all users and specifically by 21 major water utilities; and
3. In-stream flow requirements.

The following sections outline the general structure of the OHCM, the data requirements and processing, and the limitations.

2.1 RIVERS AND CREEKS

2.1.1 Model Representation

The OWSDP divided the Okanagan Basin into 32 watersheds (i.e. stream catchments), 40 residual areas (i.e. areas of interest, but not stream catchments), five mainstem lakes, and four points of interest on the Okanagan River (Summit 2009). These collectively represent 81 “nodes” of interest within the Okanagan Basin (Figure 2-1).

As the OHCM was only intended to investigate some key major water users in the Okanagan Basin, the model was developed to explicitly model only those surface water sources which are directly involved in the supply and delivery of water to the key water users selected for this study (see Section 2.3). The OHCM explicitly represents the mainstem lakes (Kalamalka, Okanagan, Skaha, Vaseux, and Osoyoos Lakes), the Okanagan River, and the major stream catchments where extractions and upland reservoirs are present. All other stream catchments and residual areas are accounted for, not individually, but rather as lumped values to a mainstem lake or river segment.

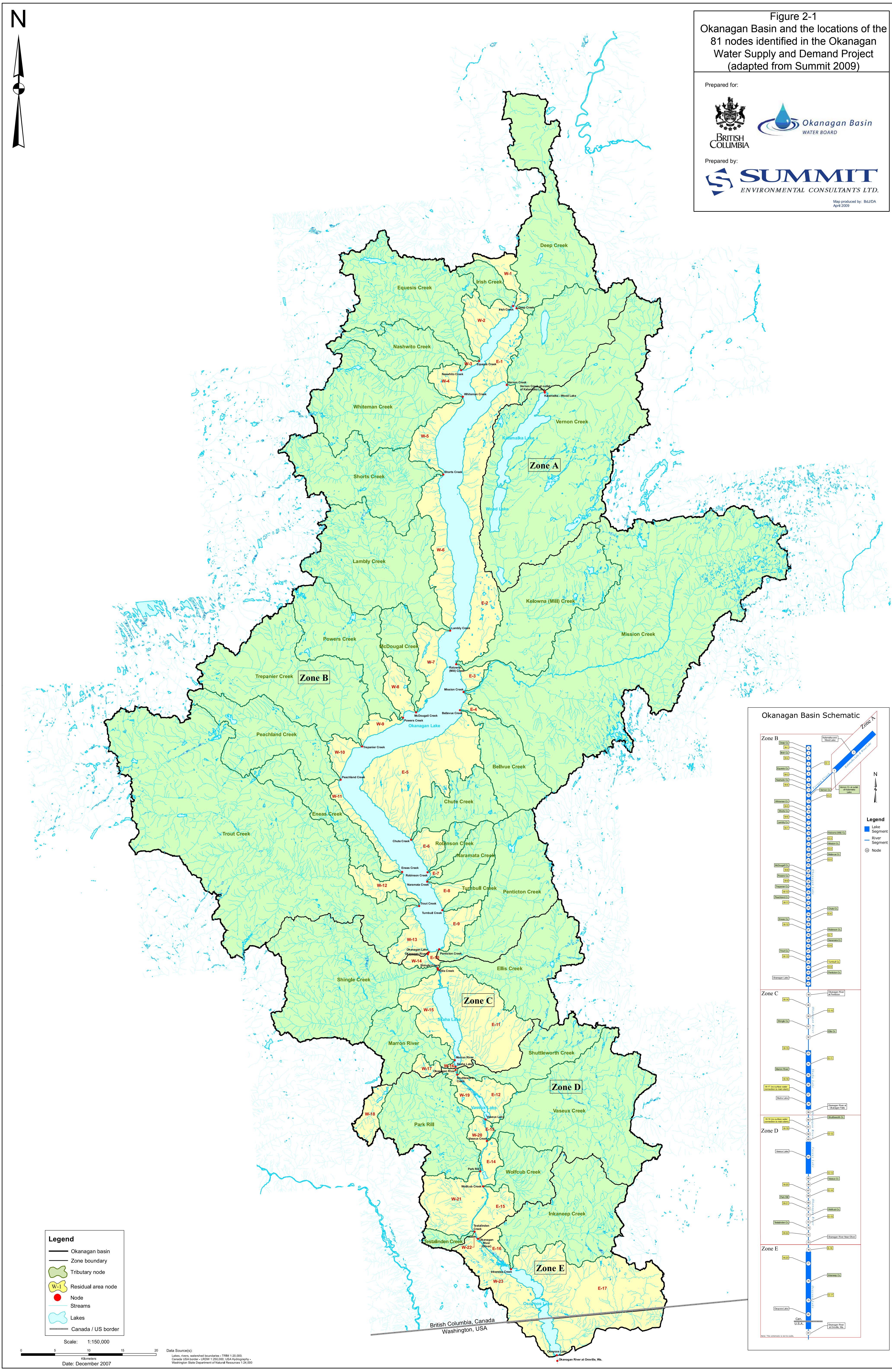

Figure 2-1
Okanagan Basin and the locations of the 81 nodes identified in the Okanagan Water Supply and Demand Project (adapted from Summit 2009)

In the OWAM, upland reservoirs were not modeled individually; all upland reservoirs within a specific stream catchment were lumped and represented using a single term (Q_R) and spreadsheet model to calculate reservoir release, filling, and storage. This term and spreadsheet model were developed during Phase 2 of the OWSDP to represent the upstream reservoir component of streamflow of a stream catchment; however, since the concept of the OHCM was to investigate individual water users and their supply and delivery of water to meet associated demands, all relevant upland reservoirs needed to be represented individually within the OHCM. Furthermore, all key areas contributing streamflow, either above or below the upland reservoirs were also accounted for. Within the OHCM there are a total of 60 "river branches" that reflect these contributing areas. A summary of the watercourses included within the OHCM is summarized in Table 2-1 and presented in Figure 2-2.

Table 2-1 Summary of watercourses within the Okanagan Hydrologic Connectivity Model.

Watercourse Feature in OHCM	Stream Catchment Modeled	
Okanagan River	n/a	
Main Tributaries (Individually modelled)	• Irish Creek • Vernon Creek • Lambly Creek • Kelowna (Mill) Creek • Mission Creek • Powers Creek • Robinson Creek	• Trepanier Creek • Peachland Creek • Eneas Creek • Trout Creek • Penticton Creek • Ellis Creek • Chute Creek
Okanagan Lake Tributaries (Lumped as "Okanagan Lake Headflows")	• Equesis Creek • Nashwito Creek • Whiteman Creek • Shorts Creek • McDougall Creek • Deep Creek	• Bellevue Creek • Turnbull Creek • Naramata Creek • Residual Areas W1-13 • Residual Areas E1-9
Skaha Lake Tributaries (All lumped under "Marron River")	• Shingle Creek • Marron River	• Residual Areas W14-16 • Residual Areas E10-11
Vaseux Lake Tributaries (All lumped under "E12 Reach")	• Shuttleworth Creek • Residual Area W-19	• Residual Area E12
Tributaries downstream of Vaseux Lake (All lumped under "Inkaneep Creek")	• Vaseux Creek • Park Rill • Wolfcub Creek • Testalinden Creek	• Inkaneep Creek • Residual Area W20-23 • Residual Area E13-17

Note:

1. Residual areas W-17 and W-18 were not included in the OHCM as they have no surface outlet and are considered sinks.

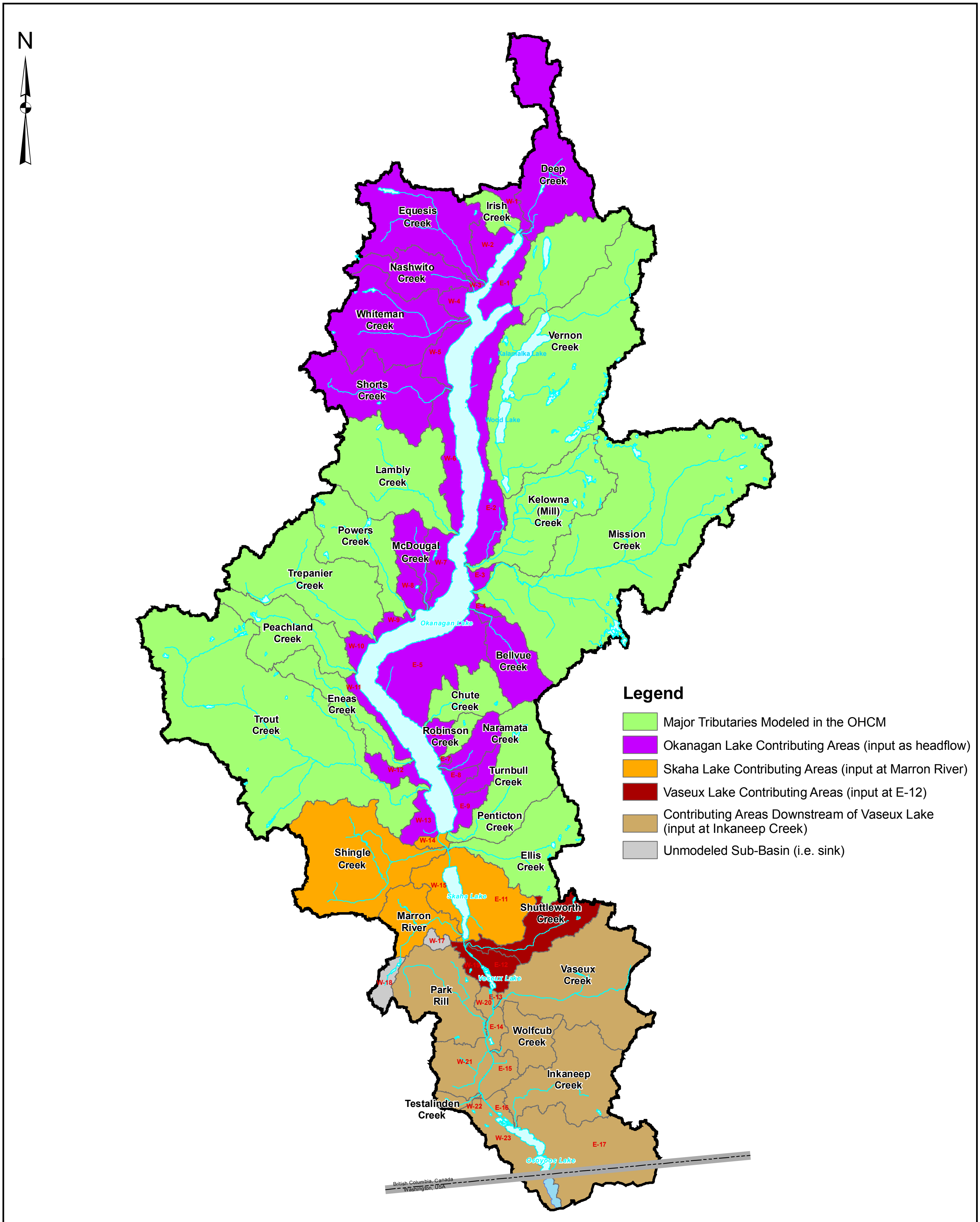

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Figure 2-2 Graphical Representation of Watercourse Groupings within the Okanagan Hydrologic Connectivity Model

2.1.2 Data Requirements and Processing

The WEAP platform facilitates the analysis of a number of supply and demand scenarios. Within the OHCM, the natural water supply (i.e. inflow) is specified at key locations throughout the Basin (e.g upland reservoirs, above water intakes, below water intakes). This data was available from the OWAM calibrated baseline time-series (1996-2006). Two different types of data from OWAM were used:

1. Natural or naturalized inflows to upland reservoirs or intakes, as well as natural inflows between points-of-interest (e.g. between a reservoir and an intake, or between an intake and the creek mouth); and
2. Net flows (i.e. that account for human effects) at the mouth of watersheds and residual areas not specifically modeled.

Natural streamflow data was extracted from internal OWAM files for major stream catchments where upland reservoirs are present and where water intakes are explicitly included in the OHCM. The details of the extraction process are technically complex and are provided in Appendix B. Data extraction from the OWAM was completed through the use of the AFETDataExtractor Tool developed by DHI Inc. and available from the OBWB.

Within the OWAM, calculations of streamflow and water level are made at Q-Point and H-Point computational points, respectively. The H-Points compare the level of the groundwater table and stream to determine the direction of flow of an aquifer (i.e. from or to), while the Q-Points represent the total streamflow at a designated point from a combination of overland, interflow, baseflow and (if applicable) reservoir releases. Accordingly, flows along streams can be extracted at their associated Q-Points and H-Points.

For the upland reservoirs, the natural flows into a reservoir were extracted from the Q-Point of the stream branch immediately upstream of the reservoir. Alternatively, for streams downstream of a reservoir and either upstream of an intake or mainstem lake, the natural flows included a component of overland, interflow, and baseflow contribution. These contributions were calculated by the OWAM at each Q-Point along the stream; therefore, natural flows for these sections of the stream branches were calculated by summing the overland, interflow, and baseflow contributions from each Q-Point on those sections. Due to slight differences in the points-of-interest between the OHCM and the OWAM (mainly related to the locations of upland reservoirs), some additional Q-Points and H-Points were added to the OWAM in order to extract the necessary information (see Appendix B).

All net flows were extracted at the outlets of watersheds not explicitly modeled in the OHCM. The net flows were extracted from OWAM at the Q-Point of the watershed immediately upstream of a mainstem lake or the Okanagan River. However, it was determined durng Phase 2 that residual area net flows calculated by the OWAM were overestimated. Accordingly, residual area net flows were corrected using natural flows, total water extractions, inter-basin transfers, and reservoir operations extracted individually from the OWAM.

Finally, all streamflow data (natural and net) was extracted from the OWAM result files containing data at 6 hour time-steps. This data was re-sampled to one-week time-step for application within the OHCM.

2.1.3 Data Limitations

All models are by definition simplified representations of reality, and therefore have limitations and inherent uncertainty. It is important to be aware of such limitations when evaluating the results of models such as the OHCM that are specifically related to representation of rivers and creeks. This section highlights some of the key limitations identified during development of the OHCM. It is important to recognize that several of these limitations are associated with the OWAM, which provided the principal input data for the OHCM.

Key limitations related to rivers and creeks are:

- The Phase 2 OWAM was not specifically designed nor calibrated to provide an optimized representation of the upland reservoirs or the hydrologic contributions to the reservoirs. The OWAM was built and calibrated as a basin-wide hydrologic model using 500 m x 500 m grid cells to delineate the Basin and it includes only the major rivers/creeks in each sub-basin. However, for the OHCM, the specific locations of each upland reservoir were identified and the closest Q-Point to the reservoir location was assumed representative of the reservoir. Because the assumed position is only approximated, there is some error in the estimated hydrology at the reservoir. However, since natural and net flows are also calculated below each reservoir in the OHCM, any over or underestimation of water into a reservoir is accounted for downstream, so this is not vey significant;
- The spatial extent of the OWAM includes the entire Okanagan Basin; however, water is imported into the Okanagan from stream catchments outside the Okanagan Basin, including: the West Kettle River (Kettle River watershed), Duteau Creek (Shuswap River watershed), Fortune Creek (Shuswap River watershed), and the Nicola River watershed. These areas were not within the spatial domain of the OBHM (the output of which feeds the OWAM) and therefore natural water supply estimates for these river systems were not available. Without the specific inclusion of the hydrology of these areas, the OHCM assumes an unlimited supply to feed demands within the Okanagan. This issue is significant as it substantially limits the ability to investigate water users (e.g. Greater Vernon Water, City of Armstrong) who rely heavily on water imports from outside the Okanagan Basin; and
- The Similkameen River watershed plays a significant role within the Okanagan Basin, as forecasting of flows in the Similkameen River, in conjunction with Okanagan Lake inflow forecasts, are used as drought triggers for reservoir operations of Osoyoos Lake. Since neither the OBHM nor the OWAM include the Similkameen River within the spatial extent of the model, future applications of the OHCM that include Osoyoos Lake will require support from other sources in order to estimate runoff forecasts for the Similkameen River. Environment Canada and Agriculture and Agri-Foods Canada (Cannon and Neilsen (unpublished)) have recently developed climate datasets for large portions of the southern interior of British Columbia, and this information could help generate flow forecasts for future years.

2.2 RESERVOIRS

2.2.1 Model Representation

Included in the OHCM are five (5) mainstem lakes (Kalamalka, Okanagan, Skaha, Vaseux, and Osoyoos Lakes) and 48 upland reservoirs (Table 2-2). As individual upland reservoirs were not included specifically within the OWAM, their geographic locations were identified and included in the OHCM using reservoir GIS coverage available from the Land Resources Data Warehouse (2011).

Table 2-2 Reservoirs included within the Okanagan Hydrologic Connectivity Model.

Waterbody	Reservoir/Lake	
Mainstem Lakes	• Kalamalka-Wood Lake • Skaha Lake • Osoyoos Lake	• Okanagan Lake • Vaseux Lake
Vernon Creek	• Swalwell Lake • Ellison Lake • Goose Lake • Swan Lake	• Crooked Creek • King Edward Lake • Oyama Lake
Kelowna Creek	• James Lake • Moore (Bulman) Lake	• Postill Lake • South Lake
Mission Creek	• Ideal Lake • Loch Long Lake • Browne Lake • Long Meadow Lake • Graystoke Lake	• Mission Lake • Fish Hawk Lake • McCulloch Reservoir • Fish Lake
Lambly Creek	• Big Horn Lake • Rose Valley Lake	• Tadpole Lake
Powers Creek	• Dobbin Lake • West Lake • Jackpine Lake	• Islaht Lake • Paynter Lake • Lambly Lake
Peachland Creek	• Peachland Lake	
Eneas Creek	• Eneas Lake	• Garnet Lake
Trout Creek	• Munro Lake • Tsuh Lake • Isintok Lake • Crescent Lake • Headwaters Lake #2 • Headwaters Lake #4	• Darke Lake • Thirsk Lake • Whitehead Lake • Headwaters Lake #1 • Headwaters Lake #3
Penticton Creek	• Greyback Lake	
Ellis Creek	• Ellis Lake #4	
Chute Creek	• Chute Lake	
Robinson Creek	• Naramata Lake	• Big Meadow Lake

2.2.2 Data Requirements and Processing

For each reservoir in the OHCM, both physical properties and operational rules were included. The physical properties were:

- Storage – elevation curves;

- Maximum storage capacity;
- Initial storage level (i.e. at a specified time);
- Maximum hydraulic outflow; and
- Net evaporation.

The operational rules were:

- Elevation of the top of Conservation Zone;
- Elevation of the top of Inactive Zone; and
- Basin-wide priority level.

A description of these physical properties and operational rules is provided below.

Storage – Elevation Curves

Storage – elevation curves for the mainstem lakes were developed using bathymetric data from the OWAM, while those for the upland reservoirs were obtained from bathymetric mapping completed by the B.C. Ministry of Environment and the Ministry of Lands, Forests, and Water Resources in the 1970s and 1980s (the 48 mapping documents are listed in the reference list to this Appendix). For the upland reservoirs, each curve identified the level of dead, live, and "potential" storage. In the OHCM, it was assumed that the live storage elevation was the upper limit of current reservoir operations, while the "potential" storage elevation represented the maximum storage capacity for the reservoir assuming that additional infrastructure was built to support the increase in storage. Accordingly, in the OHCM, total storage capacities can be set to either the live storage or potential storage elevations depending upon the scenario.

In addition, initial storage levels in the model (i.e. Week 1 of 1996) for each mainstem lake were set equal to the mean weekly water level for Week 1 of 1996 as identified in the OWAM. For upland reservoirs, due to the lack of hydrometric records for each reservoir, it was assumed that initial storage was at 50% of their total storage.

Reservoir Operations

Figure 2-3 presents the reservoir storage levels and zones identified within the WEAP modeling platform. For the OHCM, separate Buffer and Flood Control zones were not specified within the model; therefore, the Conservation Zone can range from the top of the Inactive Zone to the Total Storage elevation. By not including a buffer zone in the OHCM, releases from the mainstem lakes or upland reservoirs are not restricted (i.e. not reduced by a certain fraction) in order to meet downstream demands, unless the reservoir is empty and is no longer able to release water.

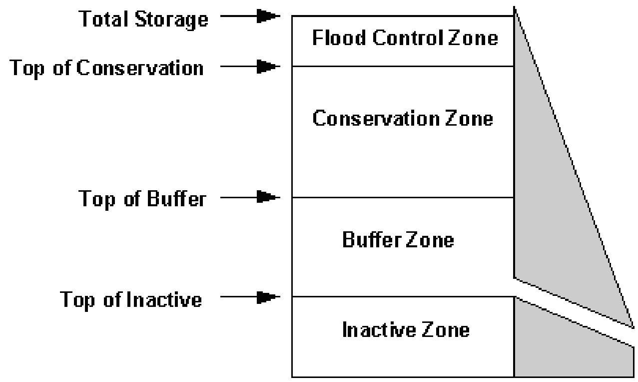

Figure 2-3 Definition of reservoir storage levels and zones in WEAP (adapted from Stockholm Environment Institute (2005)).

Reservoir operations followed the rules documented within the Okanagan Lake Regulation System Operating Plan (Okanagan Basin Implementation Board 1982) for Kalamalka, Okanagan, Skaha, and Vaseux Lakes. For these lakes, the top of the Conservation Zone was set based on the monthly lake level target for the lake, while the top of the Inactive Zone was set to the minimum allowable lake level (e.g. 341.5 m for Okanagan Lake and 391.0 m for Kalamalka Lake). Initially, the lake level month-end targets were entered for each week of the month; however, this led to an excessive amount of water being released or stored within the first few weeks after month-end. This was solved using linear interpolation and a 5-week moving average to smooth the weekly transitions between month-end targets. Figure 2-4 presents the top of conservation zones (i.e. lake level targets) for Okanagan Lake included within the OHCM.

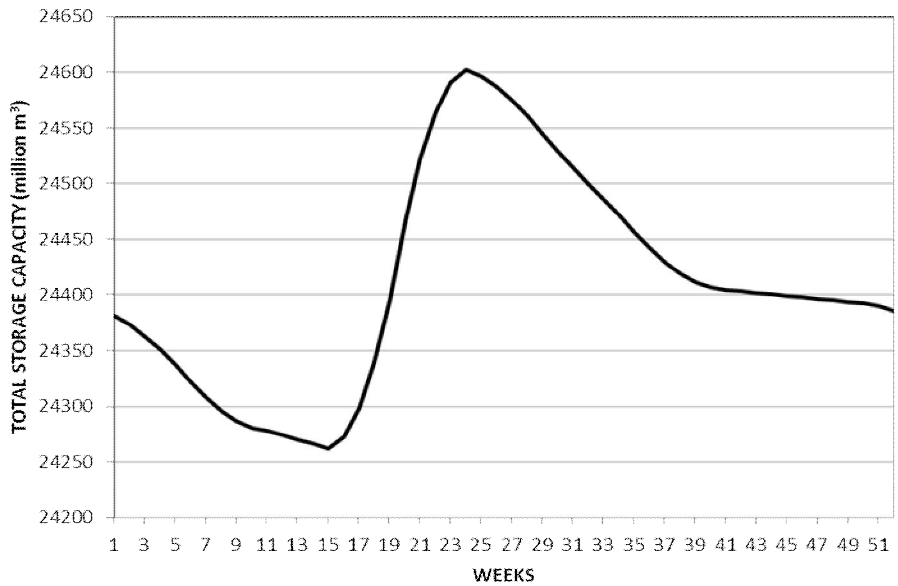

Figure 2-4 Representation of Okanagan Lake's operational rules within the Okanagan Hydrologic Connectivity Model.

For Osoyoos Lake, reservoir operations followed the rules outlined by the International Joint Commission's (IJC) Orders of Approval (IJC 1982; 1985). The Orders of Approval identify separate summer and winter operating ranges and timing, as well as summer normal and drought operating ranges based on inflow forecasts for Okanagan Lake and the Similkameen River. However, since flow forecasting is not an available function within the WEAP modeling platform, a synthesized time series of the normal upper and lower operating limits of Osoyoos Lake was developed following the actual 1996-2006 management operations and drought declarations. Figure 2-5 presents the "top of conservation" zone elevation for Osoyoos Lake for the 1996-2006 period of investigation.

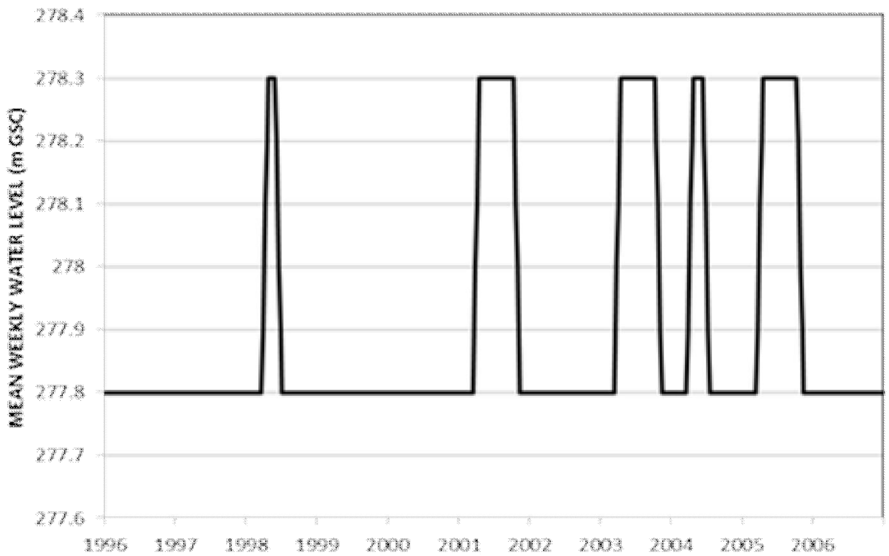

Figure 2-5 Time series for the top of conservation zone for Osoyoos Lake, 1996-2006.

For the upland reservoirs, the “top of conservation” zone elevation was set equal to the reservoir’s maximum live storage elevation (or potential storage elevation), while the “top of inactive” zone elevation was assumed equal to the “top of dead storage” elevation.

Maximum Hydraulic Outflows

The maximum hydraulic outflow from a lake or reservoir is defined as the maximum possible rate of outflow that hydraulic constraints will allow. For the mainstem lakes, maximum hydraulic outflows were included for Kalamalka, Okanagan, Skaha, and Vaseux Lakes, but not Osoyoos Lake[1]. Initially, maximum hydraulic outflows identified by the Okanagan Lake Regulation System Operating Plan (Okanagan Basin Implementation Board 1982) for Kalamalka (10 m^3/s), Okanagan (78 m^3/s), and Skaha Lakes (78 m^3/s) were included for each weekly time-step; however, this caused the model to release an unrealistically large amount of water being released during some weeks as the model attempted to meet monthly elevation targets (e.g. 78 m^3/s released during certain time-steps in the winter months in Okanagan Lake). Accordingly, using available hydrometric records for Kalamalka and Okanagan Lakes, the observed maximum outflows directly downstream of each lake (for each weekly timestep) for the 1996-2006 period were used to constrain outflows. In addition, a 5-week moving average was used to further smooth each time-step transition. Figure 2-6 presents the maximum hydraulic outflows for Okanagan Lake included within the OHCM.

[1] Maximum hydraulic outflows were not included for Osoyoos Lake due to the instability of the lake levels and lake outflows that were caused by including the hydraulic constraints. In addition, backwater conditions caused by high Similkameen River flows at the outlet of Osoyoos Lake naturally restrict the maximum hydraulic outflows from the lake, which could not be included under this phase of the OHCM.

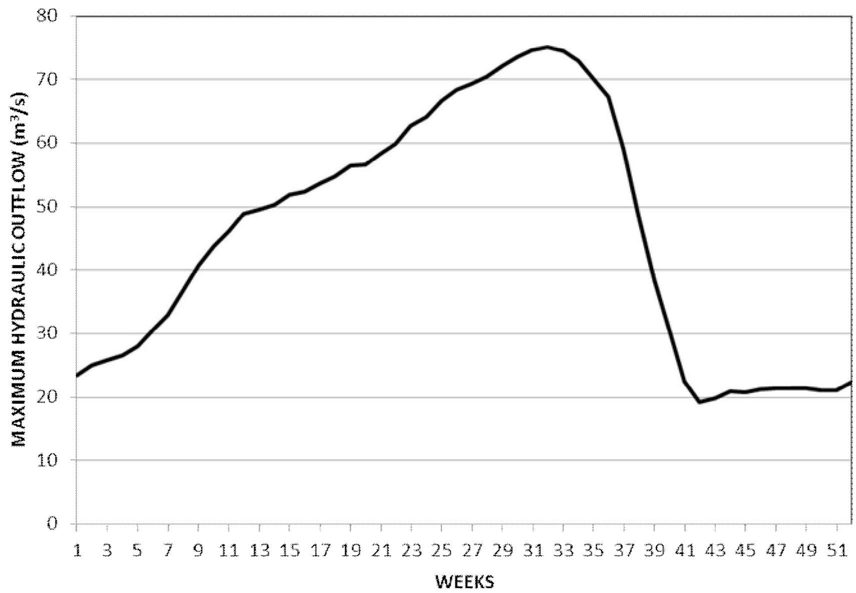

Figure 2-6 Maximum hydraulic outflow time-series adopted for Okanagan Lake, 1996-2006.

Due to the lack of information on channel capacities downstream of individual upland reservoirs, limitations on the maximum hydraulic outflows were not implemented for upland reservoirs.

Net Evaporation

The net evaporation (i.e. Net Evaporation = Evaporation – Precipitation) from each mainstem lake and upland reservoir was estimated by extracting the daily potential evapotranspiration and precipitation data available from the gridded climate datasets developed by Environment Canada for Phase 2 of the OWSDP (Summit 2010b). All extracted daily evaporation and precipitation data was converted to weekly values for the 1996-2006 period.

2.2.3 Data Limitations

With respect to reservoirs, the OHCM is limited by the WEAP modeling platform and limitations of the OWAM. These limitations include:

- DHI Inc. (2010) identified that the representation of reservoir management of Okanagan Lake was the single biggest challenge during the development of the OWAM. This was in large part due to the large dependence on “human decisions” for reservoir management; and inflow forecasting for the lake. Accordingly, DHI Inc. (2010) recommended that for future applications of the OWAM, basin snow coverage and inflow volume forecasts were necessary in order to improve Okanagan Lake management and ultimately lake level and outflow representation. Okanagan Lake management within the OHCM follows the rules outlined by the Operating Plan, but the representation of the rules is limited at times due to the lack of available forecast information from the OWAM (e.g. basin snow coverage) and the WEAP modeling platform's inability to include flow forecasting as a management parameter to support identification of lake elevation targets for future years;

- The absence of lake inflow forecasting within the WEAP modeling platform also limits its ability to accurately reflect the operating ranges of Osoyoos Lake, which are predicated on the assignment of "normal" and "dry" years. Similar to Okanagan Lake, this limitation presents a concern for future applications of the OHCM, as correct Osoyoos Lake operations would require the pre-processing of weekly inflow estimates for Okanagan Lake and the Similkameen River;
- Within the current OHCM framework, the upland reservoirs are strictly driven by downstream demands (i.e. water is released from the reservoir to meet specific water demand downstream). However, within the OWAM upland reservoirs were lumped together and reservoir filling, releases, and storage were modeled separately; therefore, upland reservoir releases within the OWAM were not directly tied to water demands downstream. Actual reservoir operations likely fall somewhere between those represented by the OHCM and the OWAM. Fortunately, the results from the two models only indicate slight differences in net flows at the mouths of major stream catchments, since total natural runoff and water demands are the same in both models; and
- Lastly, there is limited information of channel capacities downstream of each upland reservoir; therefore, the maximum hydraulic outflow was not defined for any upland reservoir within the OHCM. If any such outflow restrictions exist, the upland reservoir level and outflow may not accurately reflect true reservoir operations.

2.3 WATER DEMAND

2.3.1 Model Representation

The OHCM is intended to be a tool the major water users in the Okanagan Basin. Accordingly, a total of 21 of the largest water users were represented individually (Table 2-3) while the remainder of the water users and licence holders in each sub-basin were lumped together according to their water source (Table 2-4). In the context of the OHCM, a water user is an organization or utility that is extracting water from a surface waterbody. Only surface water sources are considered, as groundwater use is not being considered in this phase of the project. During Phase 2 of the OWSDP, water use areas were aggregated for each major water user and estimates of off-stream water demands by the OWDM provide a means to estimate water withdrawals from a specific water source for a specific water use area. Figure 2-7 provides a summary of the water use areas identified within the Okanagan Basin.

Table 2-3 Water users included within the Okanagan Hydrologic Connectivity Model.

No.	Water User	Water Use Area[1]	1996-2006 Mean Annual Water Use (ML)[2]
1	Greater Vernon Water Utility (GVW)	466, 467	26,009
2	City of Kelowna (COK)	433	14,255
3	South East Kelowna Irrigation District (SEKID)	559	11,614
4	District of Lake Country (DLC)	490, 491, 492, 494	10,326
5	District of Summerland (DOS)	442, 443	10,301
6	City of Penticton (COP)	436, 437, 439	9,764
7	Black Mountain Irrigation District (BMID)	410	9,306
8	Town of Oliver (OLIV)	568, 569, 570, 571, 572, 573	8,093
9	Glenmore Ellison Improvement District (GEID)	457, 458, 459	6,341
10	Town of Osoyoos (OSO)	576, 577	4,215
11	Westbank Irrigation District (WID)	586	4,098
12	Lakeview Irrigation District (LID)	483	2,966
13	District of Peachland (DOS)	495, 497	2,402
14	Regional District of Okanagan-Similkameen (former Naramata Irrigation District) (RDOS)	453, 454, 455	2,327
15	Bylaw 1083 – Sunnyside (SUL)	418	1,499
16	Kaleden Irrigation District (KID)	477	985
17	Meadow Valley Irrigation District (MVID)	488	643
18	Bylaw 597 – West Kelowna Estates (WKEWU)	422	487
19	Grandview Irrigation District (GID)	463	482
20	City of Armstrong (COA)	432	420
21	Bylaw 793 – Pritchard/Shanboolard (SWUL)	424	243

Note:

1. Water use areas as defined by Phase 2 of the OWSDP; and
2. Mean annual water use does not include groundwater use (data source OWDM (Summit 2010c)).

Table 2-4 Other water user groupings included within the Okanagan Hydrologic Connectivity Model.

Watershed	Water User	Water Use Area[1]	1996-2006 Mean Annual Water Use (ML)[2]
Ellis Creek	Ellis Creek – Other Users	642	15
Eneas Creek	Eneas Creek – Other Users	628	864
Irish Creek	Irish Creek – Other Users	513, 597	1.2
Kelowna Creek	Kelowna Creek – Other Users	612	160
Lambly Creek	Lambly Creek – Other Users	610	57
Mission Creek	Mission Creek – Other Users	614	1,631
Peachland Creek	Peachland Creek – Other Users	624	101
Penticton Creek	Penticton Creek – Other Users	638	29
Powers Creek	Powers Creek – Other Users	620	98
Trepanier Creek	Trepanier Creek – Other Users	421, 622	197
Trout Creek	Trout Creek – Other Users	634	381
Vernon Creek	Lower Vernon Creek – Other Users	604	2,085
Okanagan River	Okanagan River – Other Users	417, 444, 487, 518, 520	4,237
Okanagan Lake	Okanagan Lake – Other Users	420, 427, 429, 430, 448, 451, 465, 470, 479, 511, 554, 584, 585, 590, 598, 599, 603, 605, 607, 609, 611, 613, 615, 617, 619, 621, 623, 625, 627, 629, 631, 633, 635, 637, 640	8,832
Osoyoos Lake	Osoyoos Lake – Other Users	415, 522, 545, 662, 663, 665	8,257
Kalamalka Lake	Kalamalka Lake – Other Users	481, 593, 594	5,691
Skaha Lake	Skaha Lake – Other Users	482, 558, 643, 644, 646	995
Vaseux Lake	Vaseux Lake – Other Users	651, 652	1,420

Note:
1. Water use areas as defined by Phase 2 of the OWSDP; and
2. Mean annual water use does not include groundwater use (data source OWDM (Summit 2010c)).

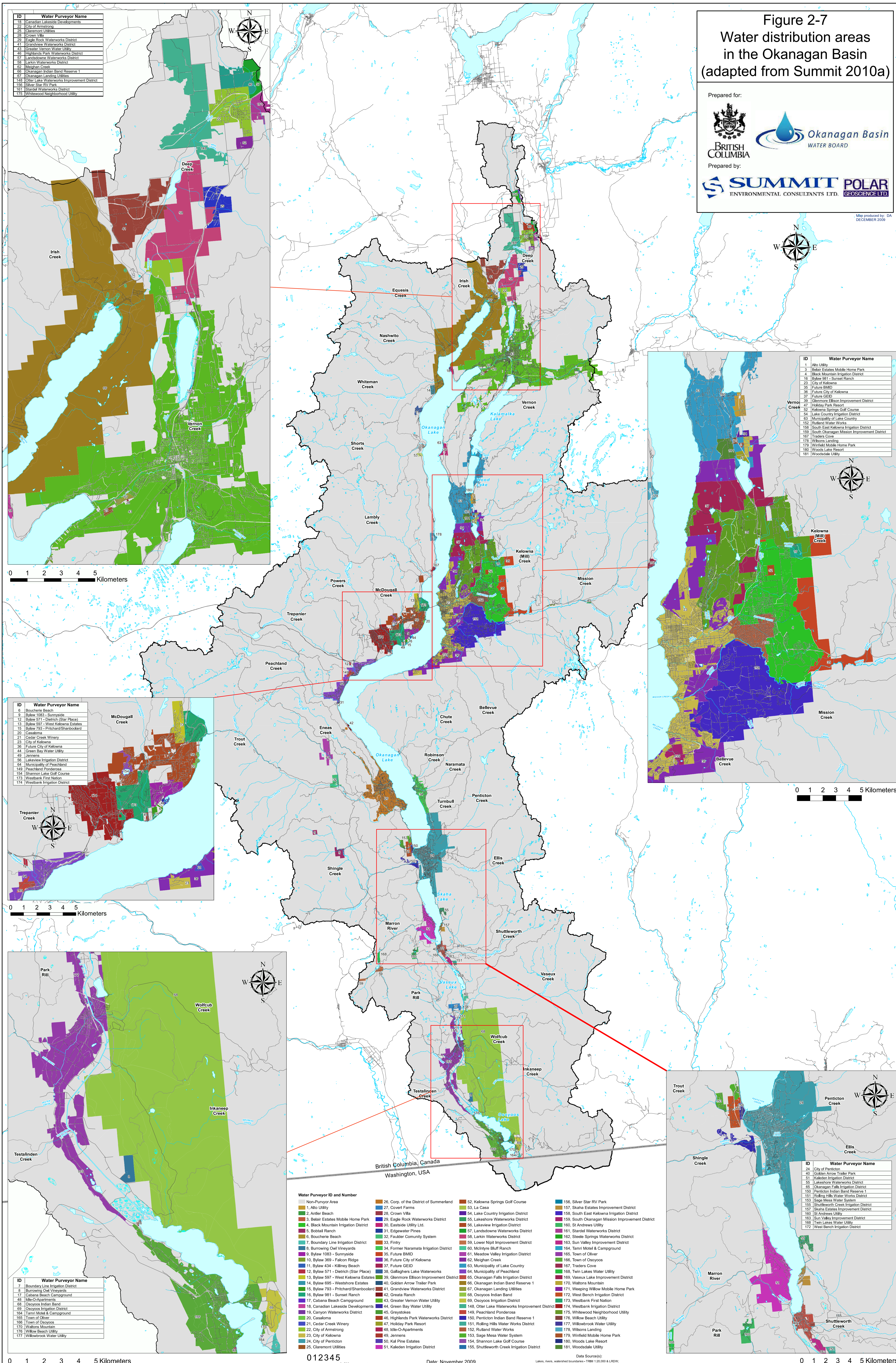
Figure 2-7
Water distribution areas
in the Okanagan Basin
(adapted from Summit 2010a)
Prepared for:
British Columbia
Okanagan Basin
WATER BOARD
Prepared by:
SUMMIT
ENVIRONMENTAL CONSULTANTS LTD.
POLAR
GEOSCIENCE LTD.
Map produced by: DA
DECEMBER 2009
British Columbia, Canada
Washington, USA
Okanagan Lake
Kalamalka Lake
Wood Lake
Skaha Lake
Vaseux Lake
Osoyoos Lake
Water Purveyor ID and Number
Non-Purvyor Area
1, Alto Utility
2, Antler Beach
3, Belair Estates Mobile Home Park
4, Black Mountain Irrigation District
5, Bobtail Ranch
6, Boucherie Beach
7, Boundary Line Irrigation District
8, Burrowing Owl Vineyards
9, Bylaw 1083 - Sunnyside
10, Bylaw 369 - Falcon Ridge
11, Bylaw 434 - Killiney Beach
12, Bylaw 571 - Dietrich (Star Place)
13, Bylaw 597 - West Kelowna Estates
14, Bylaw 695 - Westshore Estates
15, Bylaw 793 - Pritchard/Shanboolard
16, Bylaw 981 - Sunset Ranch
17, Cabana Beach Campground
18, Canadian Lakeside Developments
19, Canyon Waterworks District
20, Casaloma
21, Cedar Creek Winery
22, City of Armstrong
23, City of Kelowna
24, City of Penticton
25, Claremont Utilities
26, Corp. of the District of Summerland
27, Covert Farms
28, Crown Villa
29, Eagle Rock Waterworks District
30, Eastside Utility Ltd.
31, Edgewater Pines
32, Faulder Comunity System
33, Fintry
34, Former Naramata Irrigation District
35, Future BMID
36, Future City of Kelowna
37, Future GEID
38, Gallaghers Lake Waterworks
39, Glenmore Ellison Improvement District
40, Golden Arrow Trailer Park
41, Grandview Waterworks District
42, Greata Ranch
43, Greater Vernon Water Utility
44, Green Bay Water Utility
45, Greystokes
46, Highlands Park Waterworks District
47, Holiday Park Resort
48, Idle-O-Apartments
49, Jennens
50, Kal Pine Estates
51, Kaleden Irrigation District
52, Kelowna Springs Golf Course
53, La Casa
54, Lake Country Irrigation District
55, Lakeshore Waterworks District
56, Lakeview Irrigation District
57, Landsdowne Waterworks District
58, Larkin Waterworks District
59, Lower Nipit Improvement District
60, McIntyre Bluff Ranch
61, Meadow Valley Irrigation District
62, Meighan Creek
63, Municipality of Lake Country
64, Municipality of Peachland
65, Okanagan Falls Irrigation District
66, Okanagan Indian Band Reserve 1
67, Okanagan Landing Utilities
68, Osoyoos Indian Band
69, Osoyoos Irrigation District
148, Otter Lake Waterworks Improvement District
149, Peachland Ponderosa
150, Penticton Indian Band Reserve 1
151, Rolling Hills Water Works District
152, Rutland Water Works
153, Sage Mesa Water System
154, Shannon Lake Golf Course
155, Shuttleworth Creek Irrigation District
156, Silver Star RV Park
157, Skaha Estates Improvement District
158, South East Kelowna Irrigation District
159, South Okanagan Mission Improvement District
160, St Andrews Utility
161, Stardel Waterworks District
162, Steele Springs Waterworks District
163, Sun Valley Improvement District
164, Tamri Motel & Campground
165, Town of Oliver
166, Town of Osoyoos
167, Traders Cove
168, Twin Lakes Water Utility
169, Vaseux Lake Improvement District
170, Waltons Mountain
171, Weeping Willow Mobile Home Park
172, West Bench Irrigation District
173, Westbank First Nation
174, Westbank Irrigation District
175, Whitewood Neighborhood Utility
176, Willow Beach Utility
177, Willowbrook Water Utility
178, Wilsons Landing
179, Winfield Mobile Home Park
180, Woods Lake Resort
181, Woodsdale Utility
0 1 2 3 4 5
Kilometers
Date: November 2009
Data Source(s):
Lakes, rivers, watershed boundaries - TRIM 1:20,000 & LRDW;
Canada USA border, Hydrometric stations - LRDW 1:250,000;
USA Hydrography - Washington State Department of Natural Resources 1:24,000

Each water user generally has one or more water intakes from which they extract water from a surface waterbody. The volume of extraction is legally limited by the water licences held by the water user. In the OHCM, water licences are organized based on the intake that is associated with each water user, and each licence associated with that intake is represented as a specific node called a “demand site”. Due to the number of water licences and the complexity of managing the annual demands from each water user throughout the year, some simplification of the data was required in order to accommodate the requirements and limitations of the WEAP modeling platform.

2.3.2 Data Requirements and Processing

The methodology used to include water users and their associated water licences and demands within the OHCM is described in this section.

Aggregation of Water Licences

Within the Okanagan Basin there are more than 4,000 individual water licences, with each licence having an annual volume and a priority based on the date when the licence was issued. Since the WEAP modeling platform is restricted to only 99 individual demand priority rankings, the total number of licences for each of the included water users (177) needed to be reduced in order to be able to account for water licence priorities within in the OHCM. Therefore, a ranking scheme was developed whereby the period during which licences have been issued (1871-2002) was subdivided into 2-year increments (Table 2-5). In addition, in order to reduce the number of demand sites in the OHCM, all water licences for offstream purposes were classified either as “irrigation” or “waterworks”. Those licences classified as waterworks includes all non-irrigation related offstream purposes. To simplify the model, licences with the same purpose and ranking at a given intake were combined. For the OHCM, the ranking of water licences ranges from 11-76. This provides the user some flexibility in adjusting the rankings, if scenarios involving different priority rankings are desired. In addition, all other water users not specifically modeled within a major stream catchment or lake in the OHCM (e.g. all water licences within Mission Creek watershed not held by BMID or SEKID) were assigned a priority ranking of 77. All water licences located on waterbodies not modeled by the OHCM (e.g. Shorts Creek, Inkaneep Creek) were accounted for indirectly by the net flow data and were therefore not assigned a priority ranking.

A summary of the water licences and associated volumes, intakes, supply source, purposes, and priority rankings for each of the individual water users and other water users included in the OHCM is provided in Table A1-1 of Appendix A1. In addition, a schematic of the OHCM that summarizes the water sources, the water users, the water user’s intakes and locations, and licences and priorities associated with each intake, is also provided in Figure A1-1 of Appendix A1.

Table 2-5 Water licence priority ranking scheme utilized within the Okanagan Hydrologic Connectivity Model.

Rank	Priority Date
1-10	Available for other uses
11	1871-1872
12	1873-1874
13	1875-1876
14	1877-1878
15	1879-1880
16	1881-1882
17	1883-1884
18	1885-1886
19	1887-1888
20	1889-1890
21	1891-1892
22	1893-1894
23	1895-1896
24	1897-1898
25	1899-1900

Rank	Priority Date
26	1901-1902
27	1903-1904
28	1905-1906
29	1907-1908
30	1909-1910
31	1911-1912
32	1913-1914
33	1915-1916
34	1917-1918
35	1919-1920
36	1921-1922
37	1923-1924
38	1925-1926
39	1927-1928
40	1929-1930
41	1931-1932

Rank	Priority Date
42	1933-1934
43	1935-1936
44	1937-1938
45	1939-1940
46	1941-1942
47	1943-1944
48	1945-1946
49	1947-1948
50	1949-1950
51	1951-1952
52	1953-1954
53	1955-1956
54	1957-1958
55	1959-1960
56	1961-1962
57	1963-1964

Rank	Priority Date
58	1965-1966
59	1967-1968
60	1969-1970
61	1971-1972
62	1973-1974
63	1975-1976
64	1977-1978
65	1979-1980
66	1981-1982
67	1983-1984
68	1985-1986
69	1987-1988
70	1989-1990
71	1991-1992
72	1993-1994
73	1995-1996

Rank	Priority Date
74	1997-1998
75	1999-2000
76	2001-2002
77	Other water users
78-99	Available for other uses

Water Demand Separation

A key step in developing the OHCM was to identify and link the intake(s), water licence(s), and water use (i.e. distribution) areas for each of the 21 water utilities examined in this study. Each utility's water intake is associated with one or more water licences. Within the context of the OHCM, each water licence is identified as a "demand site", although this should not be confused with the utility's water use (i.e. distribution) area(s). In many cases, several water licences (or "demand sites" in OHCM) support a utility's water use area (Figure 2-8). The identification of individual "demand sites" reflecting each of a utility's water licences was required in order to incorporate and evaluate water licence priorities (e.g. FITFIR) when running demand-supply scenarios.

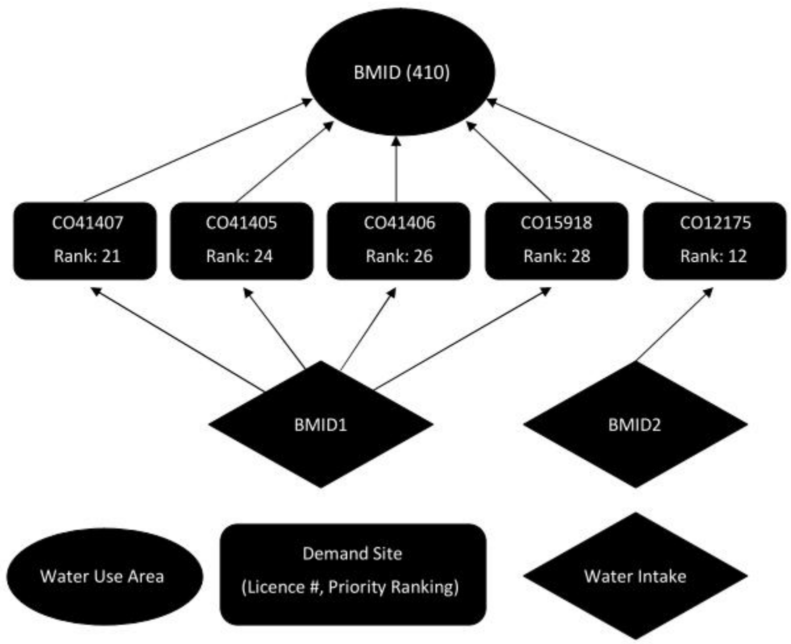

Figure 2-8 Example schematic of a water user, intakes, and demand sites within the Okanagan Hydrologic Connectivity Model.

The total water use from surface sources within each utility's water use area was obtained from the OWDM Phase 2 results (Table 2-3 and Figure 2-7)[2]. These volumes were partitioned (where necessary) between the utility's various intakes (using information developed during Phase 2) and thence amongst its water licences (as discussed below).

Since water utilities don't necessarily monitor and reconcile extractions with <u>individual</u> licences at an intake, one of the biggest challenges during development of the OHCM was to partition total surface water demand

[2] Water demands provided by the OWDM include both surface water and groundwater supplied demands. For the purpose of this investigation, the groundwater component of the demand was first removed using estimates of supply usage identified during Phase 2 of the OWSDP.

amongst each water licence (i.e. each "demand site"). In order to accomplish this, the Demand Calculator Tool was developed using a Microsoft Excel macro. To determine the weekly demand distribution associated with water licences, the "Demand Calculator Tool" accounts for the total volume of water allocated to each licence, the priority of each licence held, and the weekly variation of water use during the year (both for irrigation and for waterworks uses). This last item is based on the demand patterns for each year in the 1996 to 2006 periods as estimated by the OWDM.

For the OHCM, it was assumed that waterworks demand occurs throughout the year (i.e. January (Week 1) to December (Week 52)), while irrigation demand is seasonal (i.e. April (Week 10) to October (Week 40)). Therefore, in order to reflect the seasonal variation of water usage, the weekly fraction of waterworks[3] and irrigation demands (from the OWDM) were calculated using the following formula:

Weekly fraction (k) = Weekly Demand (i,j,k) / Annual Total Demand (j,k)
Where: i = 1….52 (week)
j = 1….11 (year)
k = waterworks, irrigation (licence type)

Therefore, when calculating the weekly fraction for waterworks demands, the annual total demand in the formula is the annual total waterworks demand, and similarly for irrigation demands, such that the sum of the weekly fraction within a year is equal to 1.

Once the weekly fractions are calculated, the separation of the total demand into individual licences for a water use area can be performed using the Demand Calculator Tool. The separation routine in the tool first distributes total demand to the licence with the highest priority ranking by multiplying annual licence quantity with the weekly fraction (depending on the licensed purpose (i.e. waterworks or irrigation)) for each time-step. Once the weekly licensed fraction is met for the first licence (for an individual time-step), the tool then moves to the next licence with the second highest priority ranking and same purpose (and so forth) until the total weekly demand is met or all available licence quantities at a given intake are utilized for each time-step. Finally, in order to simplify further, once the demand is separated into individual licences, the licences with the same priority, but different purposes, are combined. The association of the water demand with individual demand sites is then considered ready for input into the OHCM.

For scenarios involving water users using their maximum licensed volume, the same data processing steps were completed as noted above; however, the total demand volume is assumed equal to the total licensed volume, but with the same weekly distribution pattern as the actual demand values.

[3] Water demand output by the OWDM includes water demand estimates for each water use area for agricultural use, golf course use, residential indoor and outdoor use, parks and open spaces, industrial, commercial, and institutional uses, and losses. Total waterworks use was considered to include all purposes except agricultural, golf courses, and parks and open space uses.

2.3.3 Data Limitations

With respect to water users, water supply intakes and associated water licences, and water demands, the OHCM has the following limitations:

- It is common for many water utilities to have multiple licences for multiple purposes. Usually these licences are associated with one or two principal intakes. Although distinction amongst licences is not normally made at an operational level, for the OHCM it was necessary to clearly distinguish each water licence and treat each independently despite each being associated with the same intake and water use area. This is not a limitation of the OHCM, but it does represent an operational level distinction not necessarily considered in previous models;
- The partitioning of total demand amongst individual licences can be approached in different ways. For example, one method (a volumetric approach) involves assigning volumes to junior licences and as they become filled, then move to progressively more senior licences. However, this method requires considerable accounting both within and between utilities. Under the current OHCM framework, a rate-based approach is utilized whereby all licences are considered simultaneously and their associated volumes are consumed according to their weekly use fraction and priority. Under current conditions in the Okanagan Basin, this method is satisfactory; however, under future scenarios of increased demands and potentially drier climate, water users could take a different approach to water management and licensed use (e.g. going to a volumetric approach). This could impact the way FITFIR is modelled within the OHCM. Therefore, an evaluation of the way demand is associated with licences is recommended for future applications of the model;
- Upon review of some of the water demands in the OWDM, the following situations were discovered:
    - Some water use areas had a waterworks or irrigation demand, but no associated water licence for that use and water user.
        - In these situations, a "dummy licence" was created and assigned the lowest priority ranking within the available licences of the water user; and
        - Dummy licences were also used when the total weekly demand could not be met through the partitioning process (e.g. the fraction of waterworks use for a respective week restricted the distribution of demand to the associated licensed volumes). In this case, the priority ranking of the dummy licence was determined by investigating if the annual licenced quantities were fully utilized. If the annual quantity of a licence was not fully used, then that ranking of the licence was used, otherwise the lowest ranking licence within the available licences was selected;
    - Annual water demands from the OWDM were higher than the total licensed volume for that water user (e.g. Greater Vernon Water using their Kalmalka Lake source). This may be related in part to the import of water from outside the Okanagan Basin.
        - In these situations, a dummy licence was also used to account for the total annual demand, but with the lowest ranking priority of the respective water user;

    - Some water use areas had an irrigation demand outside the specified period of licensed use (e.g. irrigation demands were present during Weeks 6-7, when the period of licensed use is Weeks 10-40).
        - In these situations, the irrigation period of licensed use was changed to include any irrigation demand outside of the designated period.
- Under the current OHCM framework, shallow irrigation return flows are not included. The OHCM assumes that all water supplied for irrigation purposes meets irrigation demands and that no irrigation water returns to a waterbody as baseflow. Within the OWAM, it was assumed that 5% of irrigation water goes to deep percolation, which is not considered in the OHCM. This results in a conservative estimate of water supply within some watersheds. However, by not including irrigation returns flows within the OHCM, the results likely reflect actual baseflow conditions, as return flow volumes are not consistent throughout the Okanagan Basin, or from individual parcels of land.

2.4 INTER-BASIN DIVERSIONS

2.4.1 Model Representation

Two types of inter-basin diversions are included: transfers of water between watersheds within the Okanagan Basin and imports of water from outside the Okanagan Basin. Both of these transfers represent additions or removal of water between identified watersheds.

Inter-Basin Transfers

- Lambly Creek – Lambly Creek diversion into Rose Valley Lake; and
- Peachland Creek – Macdonald Creek (Trepanier Creek watershed) into Peachland Creek.

Water Imports

- Alocin Diversion – Nicola River watershed into Powers Creek watershed;
- Stirling Creek Diversion – West Kettle River watershed into Mission Creek watershed;
- Duteau Creek Diversion – Duteau Creek watershed into Vernon Creek watershed; and
- Fortune Creek Diversion – Fortune Creek watershed into Deep Creek watershed.

2.4.2 Data Requirements and Processing

During Phase 2 of the OWSDP, the volume of water transferred between watersheds was calculated for the OWAM's 1996-2006 calibration period (represented by the Q_T term in the OK Water Database). Accordingly, for the Alocin and Stirling diversions and the Peachland Creek transfer, a diversion function was implemented in the OHCM to represent water being added to a watershed, which was assumed equal to the Q_T values for each respective transfer. However, for the Duteau and Fortune Creek diversions, as these diversions were directly into the water user's distribution system (Greater Vernon Water and City of Armstrong, respectively), the diversion volume was assumed equal to the demand of the water use area (from OWDM). Within the OHCM framework, this was represented by a supply function which receives the same amount of water as the demand associated with it. Lastly, for the Lambly Creek transfer, a diversion function was utilized that assumed that the transfer volume into Rose Valley Lake was equal to the demand out of the lake by the Lakeview Irrigation District's water use area.

2.4.3 Data Limitations

Limitations related to the representation of inter-basin transfers and water imports include:

- As noted in Section 2.1.3, the spatial extent of the Phase 2 OWAM only included the Okanagan Basin; however, water is imported into the Okanagan from watersheds outside the Okanagan Basin, including: the West Kettle River (Kettle River watershed), Duteau Creek (Shuswap River watershed), Fortune Creek (Shuswap River watershed), and the Nicola River watershed. Without including the watershed areas contributing to the water imports in the model from outside the Okanagan Basin, natural runoff estimates are not available for these areas. This limits both the OHCM's representation of water users that rely on these imports, as well as supply predictions under different climatic conditions. This limitation by the OWAM currently limits further investigations into some water users (e.g. Greater Vernon Water, City of Armstrong) who rely heavily on water imports from outside the Okanagan Basin.

2.5 IN-STREAM FLOWS

2.5.1 Model Representation

Water licences within the Okanagan Basin have been issued for "conservation purposes" on only a few streams: Mission Creek, Powers Creek, Kelowna Creek, Eneas Creek, Peachland Creek, and the Okanagan River. In addition, minimum flow release requirements at the outlets of each mainstem lake are documented by the Okanagan Fish Water Management Tool and the Lake Operating Plan.

To investigate the effects of in-stream flow needs (IFN's) on the main water users, an IFN was included at the mouth of all the major streams and outlets of the mainstem lakes regardless of whether conservation licences were present.

2.5.2 Data Requirements and Processing

In Phase 2 of the OWSDP, considerable effort was made to identify IFN's for maintenance of aquatic ecosystem function throughout the Okanagan Basin. These flows included those associated with specific water licences for "conservation purposes", as well as those flows which are not legally required, but nevertheless required to maintain aquatic ecosystem function. This information was compiled within the Phase 2 In-stream Flow Needs Study (ESSA & Solander) (2009). That study produced IFN's based on the BC IFN method (a conservative "minimum" level). As a reference, flows corresponding to the 25th flow percentile of the natural streamflows were also presented. In addition, for Mission and Trout Creeks, site-specific IFN relationships were developed by ESSA & Solander (2009), which are currently included within their respective watershed water use plans.

The 25th flow percentile of naturalized flow was selected as a surrogate for IFN's within the major tributaries (excluding Mission and Trout Creeks that follow the specific IFN relationships within their respective watershed water use plans), while minimum flow releases from the mainstem lakes followed the Lake Operating Plans and the Okanagan Fish Water Management Tool. The 25th flow percentiles were calculated from the natural flow estimates included within the OWAM.

For Osoyoos Lake, a constant outflow of 2.83 m^3/s (or 100 ft^3/s) was adopted; this is consistent with recent modeling work for Osoyoos Lake completed by Urban Systems Ltd. (2011). In addition, the IFN adopted at the mouth of Vernon Creek was assumed the same as the minimum flow release requirement at the outlet of Kalamalka Lake (0.085 m^3/s)

2.5.3 Data Limitations

The OHCM was limited to the IFN information developed during Phase 2. Accordingly, limitations associated with IFN's within the context of the OHCM include:

- Previous studies (e.g. ESSA & Solander 2009) within the Okanagan Basin have investigated IFN's using a meta-analysis approach and the BC IFN method; however, further review and refinement was recommended due to the naturally dry climate of the Okanagan Basin resulting in sub-optimal natural flows for fish. Accordingly, a better representation of basin-wide IFN's is still needed for the Okanagan Basin. In the absence of additional IFN investigations, the 25th percentile of natural flows is a reasonable surrogate for instream flows for the current version of the OHCM. It is recommended that if future applications of the OHCM are focused on impacts associated to IFN's, further IFN investigations or sensitivity analyses are completed for each watershed under investigation; and
- As only twelve (12) major stream catchments were specifically included within the OHCM, only those 12 have assigned IFN's. IFN's are not specified in the non-modeled stream catchments (e.g. Shorts Creek, Inkaneep Creek). As such, the results reflect the influence of these 12 IFN's only. In the future, if a more comprehensive basin-wide investigation is completed, the current IFN input information will need to be expanded.

2.6 RETURN FLOWS

2.6.1 Model Representation

Two types of return flows are included: wastewater treatment plant (WWTP) discharges and reclaimed water use. WWTP discharge represents a return of water directly back into a waterbody, while reclaimed water is recycled for use as irrigation in certain areas. Within the Okanagan Basin, water users that contribute return flows and the receiving waterbody include:

Wastewater Treatment Plants

- City of Kelowna – Okanagan Lake;
- District of West Kelowna – Okanagan Lake;

- District of Summerland – Okanagan Lake; and
- City of Penticton – Okanagan River.

Reclaimed Water
- City of Armstrong;
- City of Penticton;
- Greater Vernon Water; and
- Town of Osoyoos.

2.6.2 Data Requirements and Processing

During Phase 2 of the OWSDP, WWTP releases were calculated for each associated water user for the OWAM's 1996-2006 calibration period (represented by the R_{fs} term in the OK Water Database). Accordingly, two separate WWTP return flow supply locations were included in the OHCM: one discharging into Okanagan Lake (the Kelowna, West Kelowna, and Summerland WWTP discharges) and one discharging into the Okanagan River at Penticton (the Penticton WWTP discharges) (Table 2-6).

The water use areas supplied by reclaimed water were defined in Phase 2 and the irrigation demands for each reclaimed water use area were included within the OWDM (Table 2-6). Within the OHCM, reclaimed areas are represented by a supply function in which the amount of water delivered is made equal to the demand.

Table 2-6 Summary of return flows within the Okanagan Hydrologic Connectivity Model.

Watershed	Water User	Water Use Area[1]	1996-2006 Mean Annual Return Flow (ML)[2]
Deep Creek	City of Armstrong	432	0.4
Penticton Creek	City of Penticton	440	0.3
Vernon Creek	Greater Vernon Water	469	6
Residual Area W-23	Town of Osoyoos	578	0.8
Okanagan River	City of Penticton (WWTP)	n/a	3,590
Okanagan Lake	City of Kelowna (WWTP), District of West Kelowna (WWTP), and District of Summerland (WWTP)	n/a	13,034

Note:
1. Water use areas as defined by Phase 2 of the OWSDP; and
2. Mean annual water use does not include groundwater use (data source OWDM (Summit 2010c)).

2.6.3 Data Limitations

The OHCM was limited to the return flow information developed during Phase 2. The key OHCM limitation associated with return flows is:

- A water user that contributes to return flows (e.g. City of Kelowna) is not directly connected to a WWTP's return flow location or a reclaimed water use area. The supply of water is represented by an addition of water to the system at the location of the WWTP. This lack of connectivity is insignificant however, as return flow volumes are still represented individually within the OHCM and irrigation return flows from reclaimed areas are not considered in the OHCM (see Section 2.3.3). However, future applications of the OHCM could benefit by the connection of a water user's demand site to its associated return flow location. This connection would complete the connectivity between water users and returns flows and not limit return flows to strictly an independent addition of water.

2.7 WATER USE PRIORITIES

2.7.1 Model Representation

The WEAP modeling platform uses a linear programming (LP) algorithm to attempt to satisfy the requirements for all the demand sites, IFN's, reservoir operations, and other uses, subject to demand priorities, supply preferences, mass balance and other constraints. As discussed in Section 2.3.2, a priority ranking scheme was developed in order to apply the FITFIR concept to water licences within the Okanagan Basin (Table 2-5). Following that ranking scheme, IFN's were given a rank of either 1 or 80 based on the scenario under evaluation (i.e. either higher or lower priority than extractive demands). In addition, minimum outflows from each mainstem lake were given a priority ranking of 1 to ensure minimum flow releases were always met within the Okanagan River.

Significant effort was made to optimize reservoir operations as it was observed during the model development phase that the assigned priority significantly impacts the results. The optimized priority scheme for reservoir operations in the OHCM was found to be as follows:

- Upland Reservoirs – Priority 94;
- Kalamalka Lake – Priority 95;
- Okanagan Lake – Priority 96;
- Skaha – Priority 97;
- Vaseux Lake – Priority 98; and
- Osoyoos Lake – Priority 99.

2.7.2 Data Limitations

Under the priority ranking adopted for the OHCM, water users are not influenced by reservoir operations, since water demands have a higher priority. However, each reservoir (upland or mainstem) is restricted in a "top-down manner" (i.e. upstream-to-downstream). This means that the further upstream in the

Okanagan system the reservoir is located, the higher the priority its reservoir operation is. For example, reservoir operations within Kalamalka Lake have a higher priority than those on Okanagan Lake, which means that the OHCM will try to meet the operational targets for Kalamalka Lake first before releasing any water downstream into Okanagan Lake. This priority ranking is considered to be generally representative of reservoir management strategies within the Okanagan Basin. However, this approach ensures that all water demands are met first (if water is available) at the possible cost of the upland reservoirs and mainstem lakes moving out of their preferred operating ranges. This approach represents a worst case scenario for the Basin, as water utilities and water managers would likely impose water restrictions to limit water demands prior to reservoirs being drained. If a different Okanagan Basin management approach is considered (e.g. Okanagan Lake operational targets have a higher priority than downstream water demands); the OHCM's priority ranking scheme will require adjustment.

Also, as only 21 major water users were specifically included within the OHCM, only those 21 have assigned licence priorities that actually reflect the true application of FITFIR. The rest of the licences were grouped into "other users", or not specified in the non-modeled stream catchments (e.g. Shorts Creek, Inkaneep Creek). As such, the results are specific to the influence of these 21 major water users. However, since the 21 major water users in the OHCM represent the largest users of water within the Basin, the inclusion of other licensed users would likely not change the results significantly.

3 MODEL SCENARIOS

3.1 SELECTED SCENARIOS

In an effort to understand and evaluate hydrologic connectivity within the Okanagan Basin, eight (8) separate modeling scenarios were identified. Each scenario encompasses the same 1996-2006 period and fundamentally contains the same building blocks of the OHCM. A summary of each of the scenarios is provided in Table 3-1.

Table 3-1 Okanagan Hydrologic Connectivity Model Scenarios.

Scenario	Period of Investigation	Demand	Upland Storage	In-stream Flow Needs
1	1996-2006	1996-2006 Water Demands	Existing Storage	Highest Priority
2	1996-2006	1996-2006 Water Demands	Existing Storage	Lowest Priority
3	1996-2006	1996-2006 Water Demands	Potential Storage	Highest Priority
4	1996-2006	1996-2006 Water Demands	Potential Storage	Lowest Priority
5	1996-2006	Maximum Licensed Volume	Existing Storage	Highest Priority
6	1996-2006	Maximum Licensed Volume	Existing Storage	Lowest Priority
7	1996-2006	Maximum Licensed Volume	Potential Storage	Highest Priority
8	1996-2006	Maximum Licensed Volume	Potential Storage	Lowest Priority

The 8 scenarios include variations in water demands, upland reservoir storage capacities, and the priority of IFN. The water demand scenarios range between estimated "actual" water demands as identified in the OWDM (for 1996-2006) versus a situation where utilities extract their maximum licensed volume. With respect to upland reservoirs, storage capacities for the scenarios ranged between current values and potential values (i.e. if dams were raised to a reasonable physical limit), while the IFN scenarios ranged between scenarios where the IFN in a watershed has a higher or lower priority than water demands within that watershed.

A further discussion of the OHCM scenarios and the results of the scenario comparisons for individual water users are provided within the "*Okanagan Hydrologic Connectivity Model: Summary Report*".

3.2 SCENARIO OPTIMIZATION

Due to the large variation in magnitude of input parameter values (i.e. quantities ranging from 0.001 m^3/s to >10,000 ML) within the OHCM, numerous modeling errors were encountered while running the selected scenarios. Therefore, a test scaling script (*TestScaling.vbs*) was developed by SEI to specify the correct combination of largest and smallest value ranges that result in a scenario run with no unsolved time-steps. With an incorrect combination of maximum and minimum ranges, the OHCM results can range from a single unsolved time-step to multiple unsolved time-steps. Therefore, the identification of the appropriate maximum and minimum range for the WEAP modeling platform is critical to having error free results for all time-steps in an OHCM scenario run.

The test scaling script simply runs the WEAP modeling platform (i.e. the OHCM) and iterates through combinations of maximum and minimum orders of magnitude ranging from 0.0001 – 0.0000001 for minimum and from 1,000 – 1,000,000 for maximum. The script logs the optimization results in a file (*Failures.csv*), which notes the combination results and how many unsolved time-steps were encountered for the scenario run. The run that has a result of ‘0’ indicates the combination of maximum and minimum values that optimizes the WEAP modeling platform for that respective OHCM scenario.

Once the optimum minimum and maximum values are identified, the values are required within two files: maximum values (*LargestLPSolver.txt*) and minimum values (*SmallestLPSolver.txt*). These files update the OHCM, thus allowing a scenario to run with no errors. Without correcting unsolved time-steps within the OHCM, changes in storage (e.g. reservoirs) and hydrological inputs that would happen during the unsolved time-step are not considered. For example, if there was an unsolved time-step in week 10, then week 11 would start with the storage and hydrological inputs from the end of week 9. Therefore, the OHCM output for any scenario after an unsolved time-step is not reliable.

Upon first application of the test scaling script for the OHCM scenarios, unsolved time-steps were still encountered. As a result, all storage related volumes (e.g. top of conservation zone, top of inactive zone, storage capacity) within Okanagan Lake were reduced (by 23,690 million m^3), since it represents the largest unit parameter within the OHCM. This reduction results in the OHCM only considering the useable volume of Okanagan Lake (e.g. the difference between the top of conservation zone and top of inactive zone) within operational guidelines and provided the best optimization of the OHCM scenarios. Note that all Okanagan Lake volumetric results require the removed volume to be added back to the scenario results.

4 MODEL VERIFICATION

Since the naturalized streamflows used in the OHCM were based on the hydrologic modeling results from the Phase 2 OWAM, the verification of the OHCM was more an exercise in quality assurance and quality control (QA/QC) to ensure the various components of the OHCM were properly assembled and produce reasonable results. The QA/QC procedure compared the net flows of the selected major watersheds and the Okanagan River calculated by the OHCM with the net flows calculated by the OWAM at the outlets of the selected stream catchments and at strategic locations along the Okanagan River. In addition, the QA/QC procedure also compared actual mainstem lake levels with the lake levels calculated by the OHCM and OWAM. It is important to note that the OWAM is subject to its own limitations and this QA/QC was completed to identify significant variations between the two models only.

OHCM results for Scenario 2 (Table 3.1) were selected as the closest representation of the OWAM results for the baseline period (Phase 2 results). Scenario 2 incorporates the assignment of priorities amongst water users/licences (i.e. FITFIR) unlike the OWAM. However, with a low IFN priority and actual water demands, Scenario 2 was considered sufficiently comparable to the OWAM.

The statistics used as measures of goodness-of-fit between the OHCM and the OWAM include:

1. Mean Error (ME) – the average error between the OHCM and OWAM results;
2. Root Mean Square Error (RMSE) – a measure of difference between values predicted by a model (i.e. OHCM) and the actual values observed (i.e. OWAM);
3. Correlation (R) – a measure of how strongly the results of the OHCM and OWAM are related; and
4. Nash-Sutcliffe Model Efficiency Coefficient (R^2) – a measure to quantitatively describe the accuracy of the OHCM outputs (the closer the OHCM efficiency is to 1 (range of 1 to negative infinity), the more closely the OHCM results are to the OWAM).

A summary of OHCM verification is provided in the following sections.

4.1 MAJOR STREAM CATCHMENTS

The stream catchments included in the QA/QC procedure were Mission Creek, Kelowna Creek, Trout Creek, Powers Creek, Trepanier Creek, Lambly Creek, Ellis Creek, Penticton Creek, Peachland Creek, Eneas Creek, Irish Creek, and Vernon Creek. Table 4-1 summarizes the goodness-of-fit statistics from the comparison of calculated weekly net flows from the OHCM and OWAM. The results suggest that the correlation and Nash-Sutcliffe coefficients for most streams are generally close to 1, indicating that the OHCM is comparable to the OWAM. However, for Kelowna, Vernon, and Eneas Creeks, the goodness-of-fit coefficients suggest poor agreement between the OHCM and the OWAM. On average, the OHCM underestimates the annual net flows in most streams, with Eneas, Kelowna, Peachland, Penticton, and Vernon Creeks indicating the largest annual variability between the two models. Appendix A2 provides comparison plots of weekly and annual calculated net flows by the OHCM and OWAM for the selected watersheds (Figures A2-1 to A2-6).

In the OHCM, the 48 upland reservoirs are explicitly represented with storage – elevation curves and releases from the reservoir are driven by downstream demands. However, in the OWAM, the upland reservoirs were not explicitly included in the model, but rather the influence of a reservoir was pre-calculated to track storage based on available live storage, downstream extractions, and some assumptions on reservoir releases. In addition, many of the reservoirs within an OWAM watershed were lumped together. Differences in upland reservoir releases (e.g. timing and magnitude of releases) between the two models can likely be attributed to the differences in how the upland reservoirs are represented in the two models: the OHCM reservoir releases are strictly demand driven and the OWAM's are based on an assumed release pattern.

Table 4-1 Statistical comparison of weekly net flows between OWAM and OHCM.

Tributary	Mean Error (m^3/s)	Root Mean Square Error (m^3/s)	Correlation	Nash-Sutcliffe Efficiency
Mission Creek	0.0002	0.003	0.97	0.95
Kelowna Creek	0.092	0.696	0.77	-0.006
Trout Creek	-0.057	1.07	0.98	0.96
Powers Creek	0.010	0.398	0.94	0.75
Trepanier Creek	0.00002	0.0002	1.00	1.00
Lambly Creek	-0.022	0.571	0.98	0.95
Ellis Creek	-0.034	0.219	0.99	0.99
Penticton Creek	-0.215	0.740	0.94	0.87
Peachland Creek	-0.060	0.271	0.95	0.91
Eneas Creek	-0.116	0.237	0.85	0.61
Irish Creek	-0.016	0.043	0.99	0.98
Vernon Creek	-0.508	1.95	0.80	0.09

Additionally, in the OHCM, water extractions occur at actual intake locations and the extraction rates are managed by demands, priorities, and licences, while in the OWAM, bulk extractions are applied at the outlet of a watershed and there are no priorities associated with the extractions. The OWAM was not specifically designed nor calibrated to provide an optimized representation of upland reservoirs or other points-of-interest at a finer resolution than the catchment scale. As such, the inflow hydrology (into reservoirs and between points-of-interest) from the OWAM may or may not provide a sufficiently detailed representation and could also contribute to the observed variation in net flows between the OHCM and OWAM in some watersheds.

The net flow verification for the major catchments suggests that for the majority of catchments within the OHCM, the natural hydrology and timing of flows, as well as demand volumes and extraction period, are consistent with the OWAM. However, for Eneas, Kelowna, Peachland, Penticton, and Vernon Creeks, the variability in the net flows between the two models indicated that the agreement of the models is relatively weak and any results calculated from these watersheds should be reviewed with caution.

4.2 MAINSTEM LAKES

All five mainstem lakes were included in the QA/QC procedure. Table 4-2 summarizes the goodness-of-fit statistics from the comparison of lake level elevations and outflows from the OHCM and OWAM. The results suggest that the correlation and Nash-Sutcliffe coefficients for Okanagan Lake levels are close to 1 indicating good agreement in lake levels between the OHCM and OWAM. However, for Kalamalka Lake levels and outflows as well as Okanagan lake outflows, the goodness-of-fit statistics are low, suggesting the OWAM and OHCM are quite dissimilar at a weekly time-step. Additionally, for Skaha, Vaseux, and Osoyoos Lakes, the goodness-of-fit statistics also suggest a poor match between the models. Finally, the OHCM lake level and Okanagan River results were also compared to actual values; the results indicated that the goodness-of-fit statistics were similar to those presented in Table 4-2, with the lake levels statistics slightly better. Appendix A2 provides comparison plots of weekly calculated lake levels and lake outflows by the OHCM, the OWAM, and actual values in some plots for the selected lakes (Figures A2-7 to A2-13).

As noted in Section 2.2.3, DHI Inc. (2010) identified that the representation of reservoir management of Okanagan Lake as the single biggest challenge within the development of the OWAM due to the large dependence on “human decisions” on reservoir management and inflow forecasting for the lake. Similar challenges in reservoir management were also encountered within the OHCM for all of the mainstem lakes. Understanding that Okanagan Lake outflows in the OWAM require additional investigation (and possible updating), cumulative outflows from Okanagan Lake were reviewed in order to verify Okanagan Lake volume releases (Figure A2-9). This comparison indicates that the Okanagan Lake cumulative outflows between the OHCM and OWAM are almost identical to each other, but both are smaller than the actual recorded releases. Similarity in cumulative releases does not necessarily equate to similarity in weekly lake outflows, which can be different based on differences in reservoir management representation between the two models (Figure A2-7).

Even with differences in weekly outflows, weekly Okanagan Lake water levels are still comparable between both models (Figure A2-7). In addition, the modeled lake levels also compare well to actual lake levels.

Table 4-2 Statistical comparison of weekly lake elevation and outflow between OWAM and OHCM.

Waterbody	Parameter	Mean Error	Root Mean Square Error	Correlation	Nash-Sutcliffe Efficiency
Okanagan Lake	Lake Elevation (m GSC)	-0.10	0.15	0.91	0.67
	Lake Outflow (m^3/s)	-0.267	15.8	0.50	0.09
Kalamalka Lake	Lake Elevation (m GSC)	0.43	0.55	0.60	-4.54
	Lake Outflow (m^3/s)	-0.973	1.58	0.58	-0.18
Skaha Lake	Lake Elevation (m GSC)	-0.12	0.37	0.55	-45.2
	Lake Outflow (m^3/s)	0.034	14.9	0.60	0.22
Vaseux Lake	Lake Elevation (m GSC)	-0.04	0.21	0.32	-2.92
Osoyoos Lake	Lake Elevation (m GSC)	-0.30	0.38	0.45	-1.43
	Lake Outflow (m^3/s)	-0.547	17.2	0.69	0.39

Cumulative outflows from Kalamalka Lake indicate significantly less water being released in the OHCM than in the OWAM (Figure A2-9). The difference in the Kalamalka Lake results between the OHCM and the OWAM is likely related to the inflow hydrology from the OWAM and the water demands from the OWDM resulting in an under-prediction of inflows into the lake and/or excessive demands from the lake. This can be observed in the Kalamalka Lake level comparison in which OHCM lake levels fall below actual and OWAM lake levels in 1998 and a portion of the 2001-2004 period (Figure A2-8). This suggests that the natural hydrology of Vernon Creek watershed that is contributing to Kalamalka Lake is likely underestimated and that it might not be accurately represented within the OHCM. This result is also likely contributing to the poor goodness-of-fit for Vernon Creek reported earlier as well. However, even though Kalamalka Lake and Vernon Creek are not represented particularly well within the OHCM, the net flow differences from Vernon Creek does not seem to significantly impact Okanagan Lake, as the Okanagan Lake levels are modeled reasonably well. This suggests that results from the Vernon Creek watershed should be reviewed with caution at this time, and the inflow hydrology in the OWAM should be re-examined.

With Okanagan Lake represented adequately within the OHCM, the poor goodness-of-fit for Skaha, Vaseux, and Osoyoos Lakes are likely related to reservoir operation limitations within the WEAP modeling platform, as well as a function of the outflow releases from Okanagan Lake. For Skaha Lake (Figure A2-10), the large fluctuations in lake levels are directly tied to the Okanagan Lake outflows. Since the Okanagan Lake outflows can oscillate significantly with each time-step (Figure A2-7), the reservoir operations struggle to release enough water to meet target levels due to the small storage capacity available within the normal operating ranges (i.e. approximately 0.10 m difference in monthly lake level targets) of the lake and the maximum hydraulic constraint downstream. As a result, for approximately four years, lake levels within Skaha Lake are significantly outside the operating range; with lake levels tuned to outflows from Okanagan Lake. Even though Skaha Lake levels are generally poorly represented, the outflows from Skaha Lake indicate a stronger goodness-of-fit. Similar to Okanagan Lake, the cumulative outflows from Skaha Lake almost match the OWAM, but are slightly lower than actual records (Figures A2-10 and A2-11).

For Vaseux Lake (Figure A2-11), the poor goodness-of-fit is related to large lake level fluctuations above the operating ranges that are similar in timing to the large fluctuations observed in Skaha Lake. These fluctuations are related to the large outflows from Skaha Lake and the small storage capacity available within the operating range (i.e. approximately 0.20 m) and the maximum hydraulic constraint downstream. In summary, outflows from Okanagan Lake directly impact both Skaha and Vaseux Lakes in the OHCM due to the significant volumes of water released during some time-steps.

Finally, for Osoyoos Lake (Figure A2-12), the poor goodness-of-fit is related to the lake levels matching the top of conservation levels identified within the OHCM. This result suggests that the volume of water entering Osoyoos Lake is significant enough during each time-step for the top of conservation target to be met. This is likely related to the representation of the operating rules, as the Orders of Approval specify what range lake levels are to be operated within, but “human decisions” determine how the rules are implemented (i.e. increasing or decreasing the lake levels). In addition, with a minimum flow release of 2.83 m^3/s assumed for Osoyoos Lake, once the minimum flow release is met, the OHCM will store the remaining water within the lake within the allowance of the operating rules. As such, the lake levels remain close to the top of conservation targets, which result in Osoyoos Lake not being able to store much of the volume of water released down the Okanagan River from Okanagan Lake. This suggests that the minimum flow release from Osoyoos Lake might be underestimated for certain time-steps and therefore it might not be accurately represented within the OHCM. However, the outflows from Osoyoos Lake indicate a stronger goodness-of-fit relationship than lake levels, and the cumulative outflows out of the lake almost match OWAM, but have a slightly different pattern than actual records (Figure A2-13).

The results of the QA/QC procedure for the mainstem lakes indicate that the representation of Okanagan Lake within the OHCM is similar to OWAM both on a lake level and outflow standpoint. However, the mainstem lakes downstream of Okanagan Lake are not represented particularly well in terms of lake levels, but flows down the Okanagan River are similar. As a result, the OHCM does reproduce the results of the OWAM; however, due to the poor representation of lake levels downstream of Okanagan Lake and the significant oscillations in weekly Okanagan River flows, water users downstream of Okanagan Lake (e.g. Town of Oliver, Town of Osoyoos) might not be modelled accurately at a weekly time-step. This is due to the excessive lake levels or Okanagan River flow suggesting larger volume of water available to water users then there actually is.

5 MODEL LIMITATIONS AND IMPROVEMENTS

5.1 LIMITATIONS

Individual limitations of available datasets have been described within Section 2.0. Based on the model verification results, the OHCM does produce reasonable results for Okanagan Lake and its major stream catchments and generally reflects the results produced by the OWAM. However, the results underscore the challenges in modelling a complex hydrologic system such as Okanagan Basin, particularly one where human influences, such as lake regulation, are difficult to quantify and reliably predict.

Some variation in results between the OHCM and the OWAM likely stems from the fact that inflows for the OHCM were extracted from the OWAM at different locations than the model was originally designed to provide. Accordingly, the spatial resolution of the OWAM may not be fine enough to accurately capture the detailed hydrologic responses at sub-catchment scales (i.e. above upland reservoirs). Consequently, the inflows to some of the upland reservoirs (especially in the upper reaches of a watershed where the drainage areas are small) could be underestimated (or overestimated). In addition, with upland reservoir operations represented differently between the OHCM and OWAM, some of the assumptions on the timing of reservoir releases and filling could also be causing variations between the models.

In addition, for the mainstem lakes and lake outflows, the unique set of rules and parameters required to appropriately represent the mainstem lakes make their operation difficult to replicate. Lake operations were identified in Phase 2 of the OWSDP as one of the most difficult components to replicate in the OWAM due to human decisions and operational choices based on forecasts. Consequently, without forecasting abilities embedded within the OHCM and an improved understanding or description of actual lake management operations, mainstem lake levels and outflows will continue to deviate from OWAM and actual observations. However, mainstem lake operations in the OHCM are currently represented as closely as possible to the lake operating plans, and even though lake levels in the mainstem lakes downstream of Okanagan Lake deviate from the OWAM and actual records, the total volume of water being released down the Okanagan River is consistent with the OWAM. This suggests that all of the water within the Basin is accounted for within the OHCM, but some of the timing and volume of flows within the Okanagan River and stream catchments might not match the OWAM or actual records. This means that downstream of Okanagan Lake, results for water users might not necessarily reflect reality properly.

Finally, it must be reiterated again that the results from the OHCM are only specific to this phase of model development and the representation and assumptions of the selected 21 water users, the partitioning of water demand to water licences, the application of FITFIR and the adopted priority ranking scheme for water licences, IFN’s, and reservoir operations. However insightful the results might be for the Basin or a stream catchment scale, the user must understand the limitations of the OHCM before using it to make management or planning decisions.

5.2 IMPROVEMENTS

At this time, the OHCM is limited to datasets available from the OWAM and assumptions developed during Phase 2 of the OWSDP; therefore, the OHCM results are largely impacted by the accuracy of this information and these assumptions. Improvements that could improve the OHCM include:

1. A better representation of smaller upland stream catchments delivering flow to the upland reservoirs within the OWAM could improve inflow estimates utilized within the OHCM. By including these smaller upland stream catchments, the topography could be examined more closely to ensure that topographic smoothing that is necessary for the 500 m grid cell resolution does not adversely impact the drainage area for the upland reservoirs and the natural inflow hydrology.
2. The OHCM currently operates on a weekly time-step; however, some of the assumptions and intricacies of reservoir operations could be eliminated by moving to a monthly time-step. As noted earlier, outflows from Okanagan Lake largely dictate the resultant flows down the mainstem system to Osoyoos Lake. As such, during some weekly time-steps, large volumes are released from Okanagan Lake in an attempt to meet lake levels targets of the lake. These large volumes do not necessarily agree with OWAM or actual records and as a result cause large fluctuations in mainstem lake levels and outflows downstream, as the OHCM tries to manage the volumes within reservoir operating rules. However, by moving to a monthly time-step, some of the large fluctuations in outflows would be eliminated, which could improve mainstem lake representation.
3. A large number of assumptions have been made in regards to upland reservoir operations in both the OWAM and OHCM. Reservoir release and fill patterns have been assumed (or set equal to demands downstream) and minimum flow releases from the reservoirs (if applicable) have not been included. To better reflect management operations within a stream catchment, all reservoir operations should be updated to match actual water utility management operations and strategies. This would provide a better reflection of reality, which would be carried into future applications.
4. The absence of inflow forecasting within the WEAP platform limits the OHCM's ability to accurately reflect mainstem lake operations for future scenarios. Okanagan and Osoyoos Lake management within the OHCM follows the rules outlined by the Operating Plan and Orders of Approval, respectively, but the representation of the rules is limited at this time due to the lack of available forecast information from the OWAM (e.g. basin snow coverage) and the WEAP modeling platform's inability to include flow forecasting as a management parameter to support identification of lake elevation targets. However, DHI Inc. (2010) identified that the representation of reservoir management of the mainstem lakes was the single biggest challenge during the development of the OWAM due to the large dependence on "human decisions" for reservoir management. Therefore, a better understanding of the "human decisions" behind the mainstem lake operations is necessary in order to improve results for both the OWAM and OHCM to better reflect actual operations.
5. The spatial extent of the OWAM includes the entire Okanagan Basin. However, water is imported into the Okanagan from stream catchments outside the Okanagan Basin (e.g. Duteau Creek watershed). Without including these stream catchments within the OWAM's spatial extent, the OHCM's representation of water users that rely on these imports to supply water use areas under future climatic conditions is limited. However, by updating the spatial extent of the OWAM to

include the necessary stream catchments outside of the Okanagan Basin, specific water user investigations could be improved.

6. The Similkameen River watershed plays a significant role within the Okanagan Basin, as forecasting of flows in the Similkameen River, in conjunction with Okanagan Lake inflow forecasts, are used as drought triggers for reservoir operations of Osoyoos Lake. Since neither the OBHM nor the OWAM include the Similkameen River within the spatial extent of the model, future applications of the OHCM that include Osoyoos Lake would require support from other sources in order to estimate runoff forecasts for the Similkameen River. However, by updating the spatial extent of the Phase 2 models to include the Similkameen River watershed, Osoyoos Lake reservoir operations could be improved.
7. The absence of a maximum hydraulic outflow from Osoyoos Lake within the OHCM limits the ability to accurately reflect Osoyoos Lake operations for future scenarios. In addition, a review of the minimum flow release from Osoyoos Lake is also required to improve Osoyoos Lake operations in order to reduce the storage of water within the lake unnecessarily. Therefore, a better representation of Osoyoos Lake operations is necessary in order to improve results for the OHCM to better reflect actual operations.
8. The partitioning of total demand amongst individual licences can be approached in different ways. Under the current OHCM framework, a rate-based approach is utilized whereby all licences are considered simultaneously and their associated volumes are consumed according to their weekly use fraction and priority. Under current conditions in the Okanagan Basin, this method is satisfactory; however, under future scenarios of increased demands and potentially drier climate, water users could take a different approach to water management and licensed use. This could impact the way FITFIR is applied within the OHCM. Therefore, a re-evaluation of the way demand is associated with licences could potentially improve the model.

6 SUMMARY

The WEAP modeling platform was selected as the tool to investigate hydrologic and legal connectivity in the Okanagan Basin. The advantage of the WEAP modeling platform is that it offers a Basin-wide priority function to assign different levels of allocation priority for each water licence (i.e. demand site), which is in line with the provincial licensing system (that embodies FITFIR). The OHCM is well suited to demonstrate hydrologic and regulatory connectivity, and inter-dependence among major water users in the Okanagan Basin.

The OHCM was successfully developed and verified using the WEAP modeling platform to represent both the natural processes and human influences on the Okanagan Basin's water resources including rivers and creeks, reservoirs, inter-basin transfers, water users, return flows, and IFN's.

Inflows for the OHCM were extracted from the OWAM using natural flows to creeks and reservoirs where water extractions were being accounted for in the OHCM, and using net flows to account for contributions from those areas of the watershed not being explicitly accounted for in the OHCM.

The development of the OHCM required considerable data processing and simplification in order to accommodate the limitations of the WEAP modeling platform and to facilitate the practical use of the OHCM in a decision-making process. These simplifications included:

- Reducing the number of water licences from more than 4000 individual licences throughout the Basin to 177 water user defined licences in the OHCM; and
- Partitioning the total weekly water demand for each water user into waterworks and irrigation demands for each respective water licence, based on the annual licensed quantity, the licence priority ranking, and the weekly fractions of waterworks and irrigation demands.

The OHCM was verified using a QA/QC process to establish whether the model results reflected the OWAM outputs. The primary measure of model performance was a comparison of net flows calculated by the OHCM against net flows calculated by the OWAM at the outlets of the major stream catchments; as well as comparing the lake levels and outflows calculated by the OHCM against the actual observations and OWAM estimates of the mainstem lakes. The comparisons of net flows indicated that the OHCM generally performed well for the major stream catchments and Okanagan Lake levels; however, net outflows from Okanagan and Kalamalka Lakes and water levels in Skaha, Vaseux, and Osoyoos Lake levels were not replicated well on a weekly basis. As a result, water users downstream of Okanagan Lake might not be represented accurately at this short time scale. These results underscore the challenges in modelling a complex hydrologic system such as Okanagan Basin, particularly one where human influences, such as lake regulation, are difficult to quantify and reliably predict.

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A Appendix A1 - OHCM Water Users

Table A1-1 Summary of Water Users included within the Okanagan Hydrologic Connectivity Model.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
BLACK MOUNTAIN IRRIGATION DISTRICT	BMID1	Mission Creek	21	C041407	WATERWORKS LOCAL AUTH	200.5
		Mission Creek	24	C041405	WATERWORKS LOCAL AUTH	137.3
		Mission Creek	26	C041406	WATERWORKS LOCAL AUTH	235.7
		Mission Creek	28	C015918	IRRIGATION LOCAL AUTH	17867.2
		Daves Creek	35	C062851	IRRIGATION LOCAL AUTH	90.7
		Mission Creek	50	C041410	WATERWORKS LOCAL AUTH	246.8
		Mission Creek	53	C023069	WATERWORKS LOCAL AUTH	663.7
		Mission Creek	59	C038013	IRRIGATION LOCAL AUTH	123.4
		Mission Creek	59	C036375	WATERWORKS LOCAL AUTH	1659.3
		Mission Creek	60	C036576	WATERWORKS LOCAL AUTH	1244.5
		Mission Creek	60	C038183	WATERWORKS LOCAL AUTH	622.2
		Mission Creek	60	C038503	IRRIGATION LOCAL AUTH	709.3
		Mission Creek	60	C038505	IRRIGATION LOCAL AUTH	1233.5
	BMID2	Scotty Creek	12	F012175	IRRIGATION LOCAL AUTH	2744.5
GLENMORE-ELLISON IMPROVEMENT DISTRICT	GEID1	Kelowna Creek	18	C015908	IRRIGATION LOCAL AUTH	7401.0
		Kelowna Creek	18	C017088	IRRIGATION LOCAL AUTH	2467.0
		Kelowna Creek	58	C032395	WATERWORKS LOCAL AUTH	24.9
		Kelowna Creek	58	C032433	IRRIGATION LOCAL AUTH	111.0
		Kelowna Creek	58	C034698	IRRIGATION LOCAL AUTH	246.7
		Kelowna Creek	58	C034698	WATERWORKS LOCAL AUTH	62.2
		Kelowna Creek	58	C124883	IRRIGATION LOCAL AUTH	493.4
		Kelowna Creek	58	C124883	WATERWORKS LOCAL AUTH	429.8
		Kelowna Creek	66	C061860	IRRIGATION LOCAL AUTH	224.5
	GEID2	Okanagan Lake	41	C015910	IRRIGATION LOCAL AUTH	2220.3
		Okanagan Lake	57	C120427	WATERWORKS LOCAL AUTH	39.0
		Okanagan Lake	64	C120428	WATERWORKS LOCAL AUTH	58.9
		Okanagan Lake	64	C120429	WATERWORKS LOCAL AUTH	28.2
		Okanagan Lake	68	C120430	WATERWORKS LOCAL AUTH	14.9
		Okanagan Lake	75	C120431	WATERWORKS LOCAL AUTH	58.1

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
GRANDVIEW WATERWORKS DISTRICT	GID1	Irish Creek	22	C011737	WATERWORKS LOCAL AUTH	83.0
		Irish Creek	30	C005820	WATERWORKS LOCAL AUTH	49.8
		Irish Creek	42	C011738	WATERWORKS LOCAL AUTH	83.0
KALEDEN IRRIGATION DISTRICT	KID1	Skaha Lake	61	C122208	IRRIGATION LOCAL AUTH	2467.0
		Skaha Lake	61	C122208	WATERWORKS LOCAL AUTH	995.6
KELOWNA CITY OF	COK1	Okanagan Lake	32	C000945	WATERWORKS LOCAL AUTH	829.6
		Okanagan Lake	44	C014633	WATERWORKS LOCAL AUTH	2488.9
		Okanagan Lake	45	F018907	DOMESTIC	4.1
		Okanagan Lake	45	F018907	IRRIGATION	32.1
		Okanagan Lake	50	C019098	WATERWORKS LOCAL AUTH	1659.3
		Okanagan Lake	52	C022362	WATERWORKS LOCAL AUTH	9955.7
		Okanagan Lake	56	C027158	WATERWORKS LOCAL AUTH	4977.9
		Okanagan Lake	59	C032829	WATERWORKS LOCAL AUTH	14933.6
		Okanagan Lake	59	C032828	WATERWORKS LOCAL AUTH	8296.5
		Okanagan Lake	59	C036578	WATERWORKS LOCAL AUTH	207.4
		Okanagan Lake	61	C040839	WATERWORKS LOCAL AUTH	3318.6
		Okanagan Lake	63	C113326	WATERWORKS LOCAL AUTH	340.2
		Okanagan Lake	65	C058871	WATERWORKS LOCAL AUTH	74.7

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
LAKE COUNTRY DISTRICT OF	DLC1	Vernon Creek	21	F070848	INCIDENTAL - DOMESTIC	0.4
		Vernon Creek	21	F070848	IRRIGATION LOCAL AUTH	61.7
		Vernon Creek	21	F070849	INCIDENTAL - DOMESTIC	0.4
		Vernon Creek	21	F070849	IRRIGATION LOCAL AUTH	17.3
		Vernon Creek	21	F070850	DOMESTIC	0.4
		Vernon Creek	21	F070850	IRRIGATION	32.1
		Vernon Creek	21	F070851	INCIDENTAL - DOMESTIC	0.4
		Vernon Creek	21	F070851	IRRIGATION LOCAL AUTH	16.0
		Vernon Creek	21	F070852	DOMESTIC	0.4
		Vernon Creek	21	F070852	IRRIGATION	29.6
		Vernon Creek	21	F070853	DOMESTIC	0.4
		Vernon Creek	21	F070853	IRRIGATION	15.4
		Vernon Creek	21	F070854	DOMESTIC	0.4
		Vernon Creek	21	F070854	IRRIGATION	30.8
		Vernon Creek	21	F070855	DOMESTIC	0.4
		Vernon Creek	21	F070855	IRRIGATION	29.9
		Vernon Creek	21	F070856	DOMESTIC	0.4
		Vernon Creek	21	F070856	IRRIGATION	24.1
		Vernon Creek	21	F070857	INCIDENTAL - DOMESTIC	0.4
		Vernon Creek	21	F070857	IRRIGATION LOCAL AUTH	13.3
		Vernon Creek	21	F070858	DOMESTIC	0.4
		Vernon Creek	21	F070858	IRRIGATION	72.2
		Vernon Creek	21	F018936	IRRIGATION LOCAL AUTH	0.6
		Vernon Creek	24	C056171	DOMESTIC	0.3

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
LAKE COUNTRY DISTRICT OF	DLC1	Vernon Creek	24	C056171	IRRIGATION LOCAL AUTH	15.7
		Vernon Creek	29	C122462	IRRIGATION LOCAL AUTH	5184.7
		Vernon Creek	29	C122462	WATERWORKS LOCAL AUTH	82.7
		Vernon Creek	29	C122463	WATERWORKS LOCAL AUTH	83.0
		Swalwell Lake	29	F006991	INCIDENTAL - DOMESTIC	3.3
		Swalwell Lake	29	F006991	IRRIGATION LOCAL AUTH	678.4
		Vernon Creek	59	C034636	IRRIGATION LOCAL AUTH	1299.2
		Vernon Creek	59	C034636	WATERWORKS LOCAL AUTH	414.8
		Vernon Creek	64	C059645	WATERWORKS LOCAL AUTH	618.3
		Vernon Creek	65	C059644	IRRIGATION LOCAL AUTH	616.8
	DLC2	Oyama Creek	21	F008819	DOMESTIC	8.3
		Oyama Creek	21	F008819	IRRIGATION LOCAL AUTH	2450.7
		Oyama Creek	21	F012148	IRRIGATION LOCAL AUTH	11.7
		Oyama Creek	21	F014777	IRRIGATION LOCAL AUTH	37.0
		Oyama Creek	25	F003659	DOMESTIC	1.7
		Oyama Creek	25	F003659	IRRIGATION LOCAL AUTH	139.4
		Oyama Creek	61	C037445	WATERWORKS LOCAL AUTH	83.0
		Oyama Creek	73	C109328	WATERWORKS LOCAL AUTH	1159.5
	DLC3	Kalamalka Lake	30	C109389	IRRIGATION LOCAL AUTH	48.7
		Kalamalka Lake	38	C109390	IRRIGATION LOCAL AUTH	342.6
		Kalamalka Lake	40	C109392	IRRIGATION LOCAL AUTH	1202.4
		Kalamalka Lake	40	C109392	WATERWORKS LOCAL AUTH	62.2
		Kalamalka Lake	57	C109391	WATERWORKS LOCAL AUTH	62.2
	DLC4	Okanagan Lake	60	C108281	WATERWORKS LOCAL AUTH	8794.2
		Okanagan Lake	72	C108271	WATERWORKS LOCAL AUTH	2198.6
	DLC5	Okanagan Lake	58	C033959	WATERWORKS LOCAL AUTH	48.9
		Okanagan Lake	73	C110266	WATERING	1.9
		Okanagan Lake	73	C110266	WATERWORKS LOCAL AUTH	2.5

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
LAKEVIEW IRRIGATION DISTRICT	LID1	Rose Valley Lake	48	C034762	WATERWORKS/IRRIGATION	116.2
		Rose Valley Lake	48	C034762	IRRIGATION LOCAL AUTH	4440.6
		Rose Valley Lake	60	C119359	WATERWORKS LOCAL AUTH	1493.4
		Rose Valley Lake	64	C050778	WATERWORKS LOCAL AUTH	1659.3
		Rose Valley Lake	71	C105255	WATERWORKS LOCAL AUTH	1973.5
MEADOW VALLEY IRRIGATION DISTRICT	MVID1	Darke Creek	21	F064259	IRRIGATION LOCAL AUTH	778.6
		Darke Creek	51	C064260	IRRIGATION LOCAL AUTH	267.7
		Lapsley Creek	57	C029859	IRRIGATION LOCAL AUTH	614.9
GREATER VERNON WATER	GVW1	Kalamalka Lake	11	C062306	WATERWORKS LOCAL AUTH	1862.6
		Kalamalka Lake	22	C062307	WATERWORKS LOCAL AUTH	974.8
		Kalamalka Lake	40	F009242	WATERWORKS LOCAL AUTH	2389.4
		Kalamalka Lake	46	C036203	WATERWORKS LOCAL AUTH	73.8
		Kalamalka Lake	48	C025731	WATERWORKS LOCAL AUTH	211.1
		Kalamalka Lake	52	C022235	WATERWORKS LOCAL AUTH	165.9
		Kalamalka Lake	54	C024587	WATERWORKS LOCAL AUTH	11.6
		Kalamalka Lake	55	C025732	WATERWORKS LOCAL AUTH	165.9
		Kalamalka Lake	55	C025666	WATERWORKS LOCAL AUTH	493.6
		Kalamalka Lake	57	C036202	DOMESTIC	0.8
		Kalamalka Lake	57	C032474	WATERWORKS LOCAL AUTH	995.6
		Kalamalka Lake	59	F072833	WATERWORKS LOCAL AUTH	879.8
		Kalamalka Lake	59	C059154	WATERWORKS LOCAL AUTH	617.3
	GVW2	Duteau Creek	54	C025665	WATERWORKS LOCAL AUTH	1862.6
		Duteau Creek	55	C025909	WATERWORKS LOCAL AUTH	1862.6
		Duteau Creek	59	C124618	WATERWORKS LOCAL AUTH	1862.6

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
GREATER VERNON WATER	GVW2	Duteau Creek	28	C032119	IRRIGATION LOCAL AUTH	18294.7
		Duteau Creek	28	C032119	WATERWORKS LOCAL AUTH	1862.6
		Duteau Creek	58	C032123	WATERWORKS LOCAL AUTH	1862.6
		Duteau Creek	59	C034700	IRRIGATION LOCAL AUTH	3700.5
OKANAGAN-SIMILKAMEEN REGIONAL DIST OF	RDOS1	Okanagan Lake	56	C113317	WATERWORKS LOCAL AUTH	829.6
		Okanagan Lake	59	C034312	IRRIGATION LOCAL AUTH	1233.5
		Okanagan Lake	70	C113324	IRRIGATION LOCAL AUTH	246.7
PEACHLAND DISTRICT OF	DOP1	Peachland Creek	24	C106289	IRRIGATION LOCAL AUTH	1497.5
		Peachland Creek	26	C106290	IRRIGATION LOCAL AUTH	986.8
		Mile Creek	40	C057847	IRRIGATION LOCAL AUTH	98.7
		Peachland Creek	58	C112139	WATERWORKS LOCAL AUTH	4070.4
		Peachland Creek	59	C106291	WATERWORKS LOCAL AUTH	663.7
		Mile Creek	62	C062129	IRRIGATION LOCAL AUTH	123.4
	DOP2	Trepanier Creek	24	C057861	IRRIGATION LOCAL AUTH	10.5
		Trepanier Creek	24	C065176	IRRIGATION LOCAL AUTH	296.4
		Trepanier Creek	24	C065176	WATERWORKS LOCAL AUTH	8.3
		Trepanier Creek	25	C057862	IRRIGATION LOCAL AUTH	17.4
		Trepanier Creek	25	C057863	IRRIGATION LOCAL AUTH	3.4
		Trepanier Creek	25	C057864	IRRIGATION LOCAL AUTH	15.2
		Trepanier Creek	25	C057865	IRRIGATION LOCAL AUTH	5.2
		Trepanier Creek	25	C057866	IRRIGATION LOCAL AUTH	4.1
		Trepanier Creek	25	C057871	IRRIGATION LOCAL AUTH	8.7
		Trepanier Creek	29	C057858	DOMESTIC	0.8
		Trepanier Creek	29	C057858	IRRIGATION LOCAL AUTH	150.0
		Trepanier Creek	30	C020626	WATERWORKS LOCAL AUTH	1725.2
		Trepanier Creek	30	C065175	IRRIGATION LOCAL AUTH	61.7
		Trepanier Creek	36	C057854	IRRIGATION LOCAL AUTH	16.7
		Trepanier Creek	36	C062126	IRRIGATION LOCAL AUTH	16.7
		Trepanier Creek	39	C057856	IRRIGATION LOCAL AUTH	8.4

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
PEACHLAND DISTRICT OF	DOP2	Trepanier Creek	43	C068220	DOMESTIC	0.8
		Trepanier Creek	44	C068221	DOMESTIC	0.8
		Trepanier Creek	44	C068221	IRRIGATION LOCAL AUTH	6.6
		Trepanier Creek	44	C068222	DOMESTIC	0.8
		Trepanier Creek	44	C068222	IRRIGATION LOCAL AUTH	6.6
		Trepanier Creek	45	C068223	DOMESTIC	0.8
		Trepanier Creek	45	C068223	IRRIGATION LOCAL AUTH	6.6
		Trepanier Creek	48	C068224	IRRIGATION LOCAL AUTH	5.9
		Trepanier Creek	48	C057859	IRRIGATION LOCAL AUTH	9.3
		Trepanier Creek	49	C063738	IRRIGATION LOCAL AUTH	4.0
		Trepanier Creek	49	C062128	IRRIGATION LOCAL AUTH	48.1
		Trepanier Creek	49	C062891	IRRIGATION LOCAL AUTH	45.9
		Trepanier Creek	56	C057860	IRRIGATION LOCAL AUTH	7.1
		Trepanier Creek	60	C057867	IRRIGATION LOCAL AUTH	18.5
		Trepanier Creek	60	C057869	IRRIGATION LOCAL AUTH	38.9
		Trepanier Creek	60	C068225	IRRIGATION LOCAL AUTH	9.3
		Trepanier Creek	64	C059246	DOMESTIC	0.8
		Trepanier Creek	65	C062124	IRRIGATION LOCAL AUTH	255.3

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
PENTICTON CITY OF	COP1	Penticton Creek	21	C005729	IRRIGATION LOCAL AUTH	5396.6
		Penticton Creek	21	C005729	WATERWORKS LOCAL AUTH	33.2
		Penticton Creek	21	C014229	WATERWORKS LOCAL AUTH	6637.2
	COP2	Okanagan Lake	50	C116810	WATERWORKS LOCAL AUTH	11.4
		Okanagan Lake	55	C116811	WATERWORKS LOCAL AUTH	9.1
		Okanagan Lake	66	C116809	WATERWORKS LOCAL AUTH	4977.9
	COP3	Ellis Creek	21	C005731	IRRIGATION LOCAL AUTH	1733.1
		Ellis Creek	21	C005731	WATERWORKS LOCAL AUTH	33.2
		Ellis Creek	28	C005732	IRRIGATION LOCAL AUTH	826.4
		Ellis Creek	28	C005732	WATERWORKS LOCAL AUTH	2846.9
		Ellis Creek	55	C025234	WATERWORKS LOCAL AUTH	2846.9
SHANBOOLARD WATER UTILITY LTD	SWUL1	Okanagan Lake	61	C045631	WATERWORKS LOCAL AUTH	103.7
		Okanagan Lake	66	C067500	WATERWORKS LOCAL AUTH	11.6
		Okanagan Lake	69	C066306	WATERWORKS LOCAL AUTH	10.8
		Okanagan Lake	72	C108214	WATERING	0.9
		Okanagan Lake	73	C109695	PUBLIC FACILITIES	0.8

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
SOUTH EAST KELOWNA IRRIGATION DISTRICT	SEKID1	Hydraulic Creek	29	C109618	IRRIGATION LOCAL AUTH	10484.8
		Stirling Creek	29	C015969	IRRIGATION LOCAL AUTH	3083.8
		Turtle Lake	29	C109619	IRRIGATION LOCAL AUTH	1850.3
		Hydraulic Creek	38	C107924	IRRIGATION LOCAL AUTH	1196.5
		Browne Lake	46	C015962	IRRIGATION LOCAL AUTH	616.8
		Hydraulic Creek	51	C020470	WATERWORKS LOCAL AUTH	165.9
		Pooley Creek	60	C047975	WATERWORKS LOCAL AUTH	1244.5
		Pooley Creek	60	C047976	IRRIGATION LOCAL AUTH	6784.3
		Affleck Creek	60	C037575	IRRIGATION LOCAL AUTH	493.4
		Affleck Creek	60	C037575	WATERWORKS LOCAL AUTH	414.8
SUMMERLAND CORP OF THE DISTRICT OF	DOS1	Trout Creek	19	C016412	IRRIGATION LOCAL AUTH	3910.2
		Trout Creek	19	F066492	IRRIGATION LOCAL AUTH	859.7
		Trout Creek	19	F066492	WATERWORKS LOCAL AUTH	8.3
		Trout Creek	20	F066493	IRRIGATION LOCAL AUTH	6.2
		Trout Creek	27	C016413	IRRIGATION LOCAL AUTH	7401.0
		Trout Creek	45	C014569	WATERWORKS LOCAL AUTH	414.8
		Trout Creek	46	C066491	IRRIGATION LOCAL AUTH	92.5
		Trout Creek	62	C060898	IRRIGATION LOCAL AUTH	1850.3

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
SUMMERLAND CORP OF THE DISTRICT OF	DOS1	Trout Creek	62	C060898	WATERWORKS LOCAL AUTH	968.3
		Trout Creek	69	C066455	IRRIGATION LOCAL AUTH	3083.8
	DOS2	Eneas Creek	20	C016415	IRRIGATION LOCAL AUTH	3700.5
		Eneas Creek	49	C056161	IRRIGATION LOCAL AUTH	30.8
SUNNYSIDE UTILITIES LTD	SUL1	Okanagan Lake	48	C033620	IRRIGATION LOCAL AUTH	123.4
		Okanagan Lake	56	C116481	IRRIGATION LOCAL AUTH	148.0
		Okanagan Lake	59	C035174	WATERWORKS LOCAL AUTH	41.5
		Okanagan Lake	61	C040051	WATERWORKS LOCAL AUTH	50.6
		Okanagan Lake	62	C043224	WATERWORKS LOCAL AUTH	69.7
		Okanagan Lake	62	C045175	WATERWORKS LOCAL AUTH	26.5
		Okanagan Lake	66	C062216	WATERWORKS LOCAL AUTH	4.1
		Okanagan Lake	68	C066241	WATERWORKS LOCAL AUTH	21.6
		Okanagan Lake	71	C103964	WATERWORKS LOCAL AUTH	97.1
		Okanagan Lake	75	C115585	IRRIGATION LOCAL AUTH	8.6
		Okanagan Lake	75	C115585	WATERWORKS LOCAL AUTH	951.3
OLIVER TOWN OF	OLIV1	Okanagan River	29	C043221	IRRIGATION LOCAL AUTH	48259.6
		Okanagan River	29	C043221	WATERWORKS LOCAL AUTH	553.4
		Okanagan River	45	F066166	IRRIGATION LOCAL AUTH	616.8
		Okanagan River	75	C114907	IRRIGATION LOCAL AUTH	1973.6
OSOYOOS TOWN OF	OSO1	Osoyoos Lake	29	C043221	IRRIGATION LOCAL AUTH	12046.8
		Osoyoos Lake	29	C043221	WATERWORKS LOCAL AUTH	138.1
		Osoyoos Lake	75	C114653	AMUSEMENT PARK	28.2
	OSO2	Osoyoos Lake	29	C043221	IRRIGATION LOCAL AUTH	12046.8
		Osoyoos Lake	29	C043221	WATERWORKS LOCAL AUTH	138.1

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
WEST KELOWNA ESTATES WATER UTILITY	WKEWU1	Okanagan Lake	60	C038192	WATERWORKS LOCAL AUTH	63.9
		Okanagan Lake	61	C039156	WATERWORKS LOCAL AUTH	22.4
		Okanagan Lake	61	C040050	WATERWORKS LOCAL AUTH	16.6
		Okanagan Lake	61	C042042	WATERWORKS LOCAL AUTH	35.7
		Okanagan Lake	62	C112170	DOMESTIC	0.8
		Okanagan Lake	62	C112170	IRRIGATION	2.8
		Okanagan Lake	62	C045174	WATERWORKS LOCAL AUTH	37.3
		Okanagan Lake	63	C046845	WATERWORKS LOCAL AUTH	45.6
		Okanagan Lake	63	C048444	WATERWORKS LOCAL AUTH	52.3
		Okanagan Lake	64	C053284	WATERING	6.2
		Okanagan Lake	64	C053284	WATERWORKS LOCAL AUTH	23.2
		Okanagan Lake	65	C057515	WATERWORKS LOCAL AUTH	22.4
		Okanagan Lake	65	C058070	WATERWORKS LOCAL AUTH	48.9
		Okanagan Lake	66	C060458	WATERWORKS LOCAL AUTH	28.2
		Okanagan Lake	66	C062390	WATERWORKS LOCAL AUTH	1.7
		Okanagan Lake	68	C066199	WATERWORKS LOCAL AUTH	8.3
		Okanagan Lake	69	C066335	WATERWORKS LOCAL AUTH	30.7
		Okanagan Lake	69	C066336	WATERWORKS LOCAL AUTH	1.7
		Okanagan Lake	69	C066393	WATERWORKS LOCAL AUTH	20.7
		Okanagan Lake	70	C070477	WATERWORKS LOCAL AUTH	11.6
		Okanagan Lake	70	C070478	WATERWORKS LOCAL AUTH	13.3
		Okanagan Lake	70	C103305	WATERWORKS LOCAL AUTH	14.9
		Okanagan Lake	71	C103896	WATERWORKS LOCAL AUTH	15.8

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
WEST KELOWNA ESTATES WATER UTILITY	WKEWU1	Okanagan Lake	71	C103904	WATERWORKS LOCAL AUTH	13.3
		Okanagan Lake	71	C104942	WATERWORKS LOCAL AUTH	1.7
		Okanagan Lake	73	C109938	WATERWORKS LOCAL AUTH	0.8
		Okanagan Lake	73	C111293	WATERWORKS LOCAL AUTH	149.3
		Okanagan Lake	76	C117252	WATERWORKS LOCAL AUTH	857.0
WESTBANK IRRIGATION DISTRICT	WID1	Powers Creek	25	C015444	IRRIGATION LOCAL AUTH	478.0
		Powers Creek	25	C015442	IRRIGATION LOCAL AUTH	470.3
		Powers Creek	25	F011741	IRRIGATION LOCAL AUTH	33.9
		Powers Creek	25	F011739	IRRIGATION LOCAL AUTH	59.5
		Powers Creek	25	F011740	IRRIGATION LOCAL AUTH	70.0
		Powers Creek	27	C003778	IRRIGATION LOCAL AUTH	616.8
		Powers Creek	27	C003778	WATERWORKS LOCAL AUTH	1.7
		Powers Creek	27	C015443	IRRIGATION LOCAL AUTH	898.9
		Powers Creek	28	F015806	IRRIGATION LOCAL AUTH	40.4
		Powers Creek	28	F015807	IRRIGATION LOCAL AUTH	36.1
		Powers Creek	28	F015808	IRRIGATION LOCAL AUTH	33.0
		Powers Creek	34	F011742	IRRIGATION LOCAL AUTH	18.2
		Powers Creek	34	F011743	IRRIGATION LOCAL AUTH	51.8
		Powers Creek	34	F011744	IRRIGATION LOCAL AUTH	11.7
		Powers Creek	37	F011748	IRRIGATION LOCAL AUTH	15.4
		Powers Creek	45	C014418	IRRIGATION LOCAL AUTH	107.9
		Lambly Lake	48	C017582	IRRIGATION LOCAL AUTH	1609.7

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
WESTBANK IRRIGATION DISTRICT	WID1	Powers Creek	59	C033404	IRRIGATION LOCAL AUTH	1757.7
		Powers Creek	59	C033404	WATERWORKS LOCAL AUTH	829.6
		Whiterocks Creek	69	C067990	WATERWORKS LOCAL AUTH	2468.2
		Lambly Lake	69	C067991	WATERWORKS LOCAL AUTH	333.2
ELLIS CREEK OTHER USERS	ELLIS CREEK OTHER	Ellis Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	18.3
ENEAS CREEK OTHER USERS	ELLIS CREEK OTHER	Eneas Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	72.6
IRISH CREEK OTHER USERS	IRISH CREEK OTHER	Irish Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	347.3
KELOWNA CREEK OTHER USERS	KELOWNA CREEK OTHER	Kelowna Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	2660.1
LAMBLY CREEK OTHER USERS	LAMBLY CREEK OTHER	Lambly Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	270.0
MISSION CREEK OTHER USERS	MISSION CREEK OTHER	Mission Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	5099.2
PEACHLAND CREEK OTHER USERS	PEACHLAND CREEK OTHER	Peachland Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	332.6
PENTICTON CREEK OTHER USERS	PENTICTON CREEK OTHER	Penticton Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	213.2
POWERS CREEK OTHER USERS	POWERS CREEK OTHER	Powers Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	331.6

Table A1-1 Cont'd.

Water Supplier	Intake ID	Water Source	Priority Rank	Licence Number	Purpose	Licensed Volume (ML)
TREPANIER CREEK OTHER USERS	TREPANIER CREEK OTHER	Trepanier Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	794.2
TROUT CREEK OTHER USERS	TROUT CREEK OTHER	Trout Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	717.9
VERNON CREEK OTHER USERS	VERNON CREEK OTHER	Vernon Creek Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	1551.9
OKANAGAN RIVER OTHER USERS	OKANAGAN RIVER OTHER	Okanagan River Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	9430.9
OKANAGAN LAKE OTHER USERS	OKANAGAN LAKE OTHER	Okanagan Lake Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	37262.6
OSOYOOS LAKE OTHER USERS	OSOYOOS LAKE OTHER	Osoyoos Lake Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	16835.0
KALAMALKA LAKE OTHER USERS	KALAMALKA LAKE OTHER	Kalamalka Lake Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	7448.1
SKAHA LAKE OTHER USERS	SKAHA LAKE OTHER	Skaha Lake Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	1089.8
VASEUX LAKE OTHER USERS	VASEUX LAKE OTHER	Vaseux Lake Watershed	77	LUMPED LICENCES	WATERWORKS & IRRIGATION	397.4


Deep Creek
Irish Creek
Equesis Creek
Nashwito Creek
Vernon Creek
Whiteman Creek
Shorts Creek
Lambly Creek
Mill Creek
Scotty Creek
Mission Creek
Hydraulic Creek
Bellevue Creek
McDougall Creek
Powers Creek
Trepanier Creek
Peachland Creek
Chute Creek
Eneas Creek
Robinson Creek
Naramata Creek
Trout Creek
Darke Cr.
Turnbull Creek
Penticton Creek
All residual area net inflow to the mouth of Okanagan Lake
DLC (1) Lic. Vol Priority A 347 21 B 16 24 C 6032 29 E 1713 59 F 618 64 H 614 65 Total: 9340
DLC (2) Lic. Vol Priority A 2507 21 B 141 25 C 83 61 D 1159 73 Total: 3890
Crooked Lk. Oyama Lk. Swallwell Lk.
DLC (3) Lic. Vol Priority A 49 30 B 342 38 C 1264 40 D 62 57 Total: 1717
GVW Lic. Vol Priority A 1862 11 B 974 22 C 2389 40 D 73 46 E 211 48 F 166 52 G 12 54 H 660 55 I 996 57 J 1497 59 Total: 8840
GID Lic. Vol Priority A 83 22 B 50 30 C 83 42 Total: 216
Other Lic. Vol Priority A 7448 77
Kalamalka / Wood Lake
LID Big Horn Res.
Rose Valley Lake
LID Lic. Vol Priority A 4557 48 B 1493 60 C 1659 64 D 1973 71 Total: 9682
GEID Moore Lk. South Lk. Postill Lk.
GEID (1) Lic. Vol Priority A 9868 18 B 1367 58 C 224 66 Total: 11459
BMID James Lk.
BMID (1) Lic. Vol Priority A 201 21 B 137 24 C 236 26 D 17867 28 E 91 35 F 247 50 G 664 53 H 1782 59 I 3810 60 Total: 25035
BMID (2) Lic. Vol Priority A 2745 12
BMID Fish Hawk Lk. Graystoke Lk. Mission Lk. Loch Long Ideal Lk.
SEKID McCulloch Lk. Long Meadow Lk. Browne Lk. Fish Lk.
SEKID Lic. Vol Priority A 15419 29 B 1196 38 C 617 46 D 166 51 E 8937 60 Total: 26335
WID 6 Reservoirs
DOP (2) Lic. Vol Priority A 315 24 B 54 25 C 151 29 D 1787 30 E 33 36 F 8 39 G 7 43 H 15 44 I 7 45 J 15 48 K 98 49 L 7 56 M 67 60 N 1 64 O 255 65 Total: 2820
WID Lic. Vol Priority A 1042 25 B 1517 27 C 109 28 D 82 34 E 15 37 F 108 45 G 1610 48 H 2587 59 I 2801 69 Total: 9871
Dist. of Peachland Peachland Lk.
DOP (1) Lic. Vol Priority A 1497 24 B 987 26 C 99 40 D 4070 58 E 664 59 F 123 62 Total: 7440
DOS Big Eneas Lk. Garnet Lk.
DOS (2) Lic. Vol Priority A 3700 20 B 30 49 Total: 3730
DOS 9 Reservoirs
DOS Munro Lk.
MVID Darke Lk.
MVID Lic. Vol Priority A 779 21 B 263 51 C 615 57 Total: 1657
DOS (1) Lic. Vol Priority A 4778 19 B 6 20 C 7401 27 D 415 45 E 93 46 F 2819 62 G 3084 69 Total: 18596
COP Greyback Lk.
COP (1) Lic. Vol Priority A 12085 21
Other Lic. Vol Priority A 347 77
Other Lic. Vol Priority A 1552 77
Other Lic. Vol Priority A 270 77
Other Lic. Vol Priority A 2660 77
Other Lic. Vol Priority A 5099 77
Other Lic. Vol Priority A 332 77
Other Lic. Vol Priority A 794 77
Other Lic. Vol Priority A 332 77
Other Lic. Vol Priority A 72 77
Other Lic. Vol Priority A 717 77
Other Lic. Vol Priority A 213 77
Okanagan Lake
SUL Lic. Vol Priority A 123 48 B 148 56 C 41 59 D 51 61 E 26 62 F 4 66 G 22 68 H 97 71 J 960 75 Total: 1472
DLC (4) Lic. Vol Priority A 8794 60 B 2199 72 Total: 10993
DLC (5) Lic. Vol Priority A 49 58 B 4 73 Total: 53
COP (2) Lic. Vol Priority A 11 50 B 9 55 C 4978 66 Total: 4998
COK Lic. Vol Priority A 830 32 B 2489 44 C 36 45 D 1659 50 E 9955 52 F 4978 56 G 23437 59 H 3318 61 I 340 63 J 75 65 Total: 47117
WKEWU Lic. Vol Priority A 64 60 B 75 61 C 87 62 D 98 63 E 29 64 F 71 65 G 30 66 H 8 68 I 53 69 J 40 70 K 31 71 L 150 73 M 857 76 Total: 1593
GEID (2) Lic. Vol Priority A 337 21 B 16 24 C 6032 29 D 1713 59 E 8794 60 F 618 64 G 614 65 H 2199 72 Total: 20323
RDOS Lic. Vol Priority A 830 56 B 1234 59 C 247 70 Total: 2311
SWUL Lic. Vol Priority A 104 61 B 12 66 C 11 69 D 1 72 E 1 73 Total: 129
Other Lic. Vol Priority A 37262 77
Shingle Creek
Ellis Creek
COP Ellis Creek Reservoir
Marron River
KID Lic. Vol Priority A 3463 61
Skaha Lake
Other Lic. Vol Priority A 18 77
COP (3) Lic. Vol Priority A 1766 21 B 3673 28 C 2847 55 Total: 8286
Other Lic. Vol Priority A 1090 77
Shuttleworth Creek
All residual area net inflow below Okanagan Lake to the outlet of Skaha Lake
Other Lic. Vol Priority A 397 77
Vaseux Lake
All residual area net inflow below Skaha Lake to the outlet of Vaseux Lake
Vaseux Creek
Park Rill
Wolfcub Creek
Testalinden Creek
OLIV Lic. Vol Priority A 48813 29 B 617 45 C 1973 75 Total: 51403
Other Lic. Vol Priority A 9431 77
OSO (1) Lic. Vol Priority A 12185 29 B 28 75 Total: 12213
OSO (2) Lic. Vol Priority A 12185 29 Total: 12185
Other Lic. Vol Priority A 1635 77
Osoyoos Lake
Inkaneep Creek
Ok. River
All residual area net inflow below Vaseux Lake
Purveyor ID Legend
BMID - Black Mountain Irrigation District
COK - City of Kelowna
COP - City of Penticton
DLC - District of Lake Country
DOP - District of Peachland
DOS - District of Summerland
GEID - Glenmore Ellison Improvement District
GID - Grandview Irrigation District
GVW - Greater Vernon Water
KID - Kaleden Irrigation District
LID - Lakeview Irrigation District
MVID - Meadow Valley Irrigation District
OLIV - Town of Oliver
OSO - Town of Osoyoos
RDOS - Regional District of Okanagan Similkameen (Naramata)
SEKID - South East Kelowna Irrigation District
SUL - Sunnyside Utilities Limited
SWUL - Shanboolard Water Utility Limited
WKEWU - West Kelowna Estates Water Utility
WID - Westbank Irrigation District.
Conservation (fish) Flow
Streams where flows and withdrawals are explicitly modelled in this study
streams where flows were obtained from Okanagan Water Accounting Model data (Phase 2).
Withdrawal Point
Upland Reservoir
Mainstem Lake
Purveyor Extraction Point Information
Purveyor ID
Licence Group Reference
Total Annual Licence Volume (dam³)
Licence Priority Ranking
DOS (2) Lic. Vol Priority A 337 21 B 16 24 C 6032 29 D 1713 59 E 8794 60 F 618 64 G 614 65 H 2199 72
CONCEPTUAL SCHEMATIC ONLY - NOT ALL CONNECTIONS ARE SHOWN
Okanagan Hydrologic Connectivity Model - Schematic of the W.E.A.P. Model
PREPARED FOR:
Okanagan Basin WATER BOARD
PROJECT NO.: 2008-8540.020
DATE: October 2011
DRAWN BY: DA
SUMMIT Environmental Consultants Inc.
A Member of the Associated Engineering Group of Companies

A

Appendix A2 - Model Verification Results

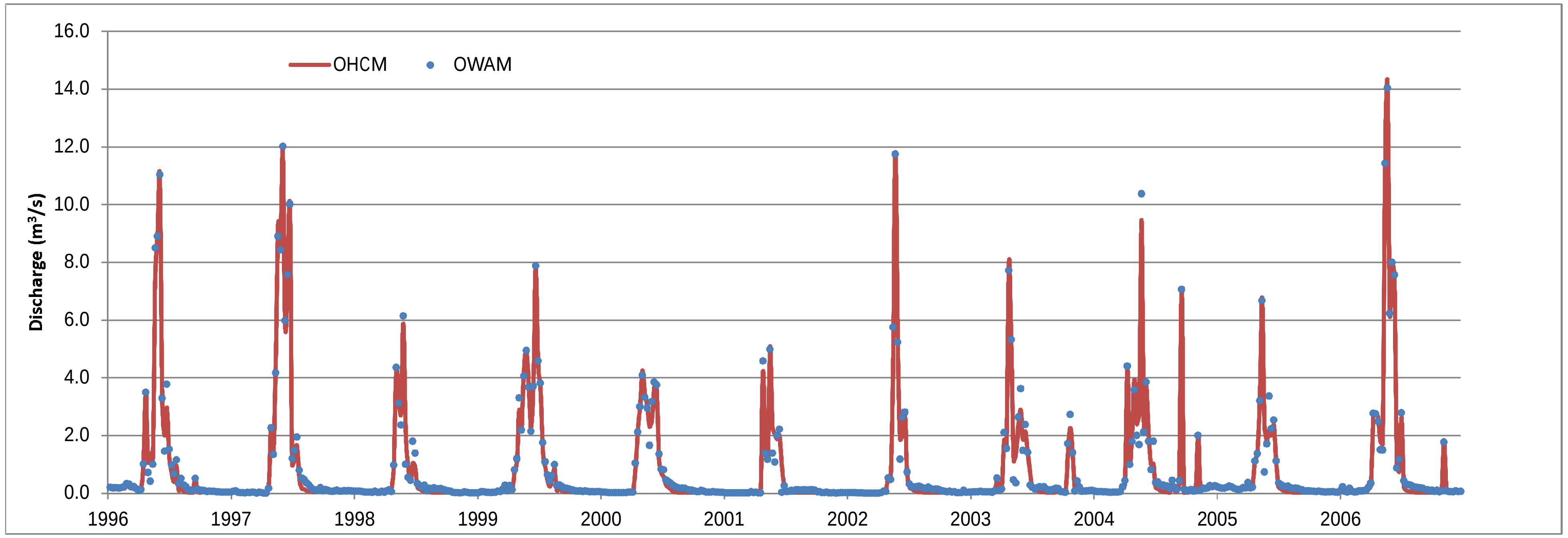


Figure A: Comparison of net weekly streamflow at Ellis Creek at the Mouth by OHCM and OWAM.

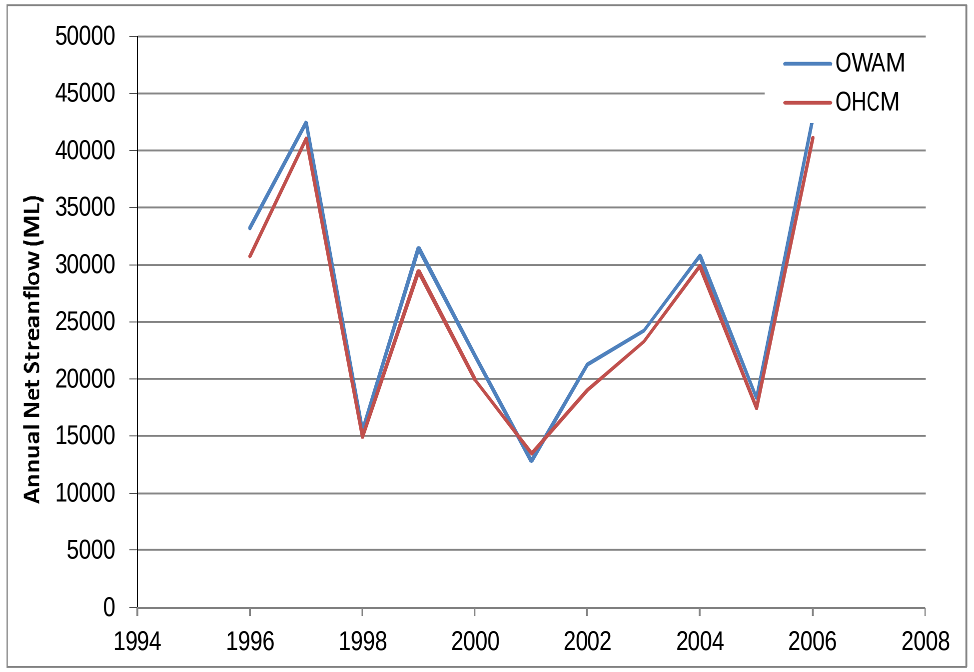


Figure B: Comparison of net annual streamflow at Ellis Creek at the Mouth by OHCM and OWAM.

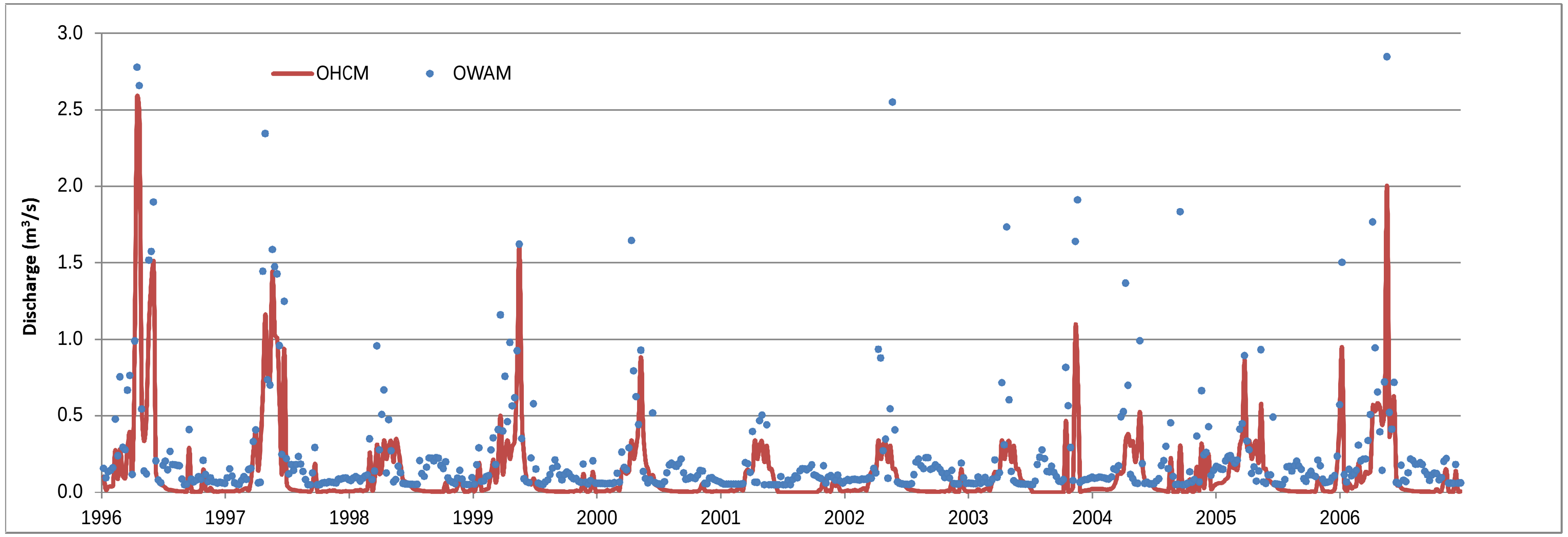


Figure C: Comparison of net weekly streamflow at Eneas Creek at the Mouth by OHCM and OWAM.

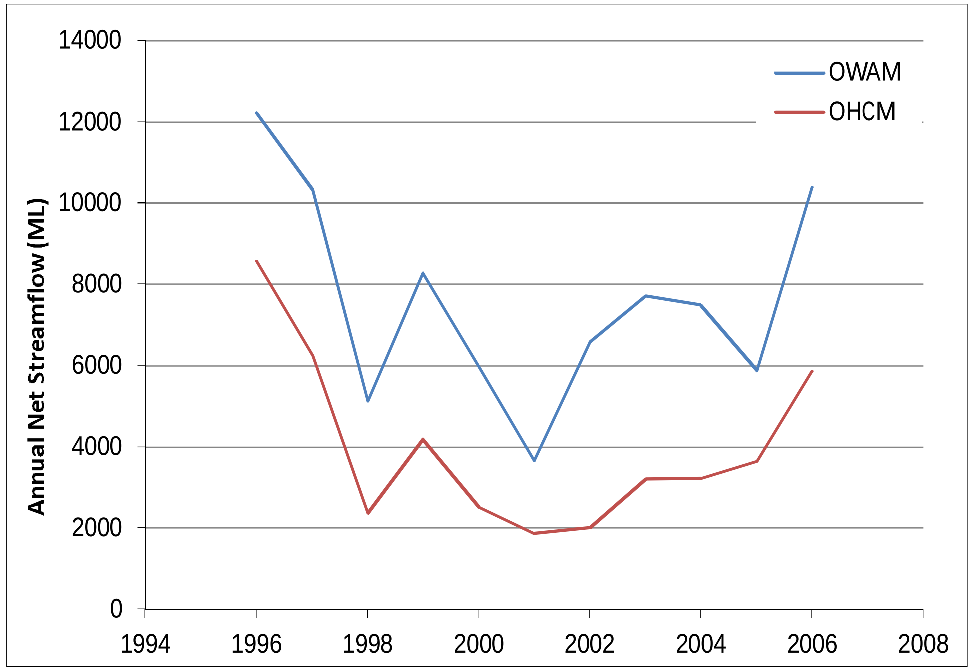


Figure D: Comparison of net annual streamflow at Eneas Creek at the Mouth by OHCM and OWAM.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**	
DRAWN BY: TN			
DATA SOURCE(S): OWAM and OHCM	PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000	FIGURE A2-1: Annual and Weekly Net Streamflow Comparison
		DRAWNING NO. 1 of 6	
		FILE: Appendix A.cdr	

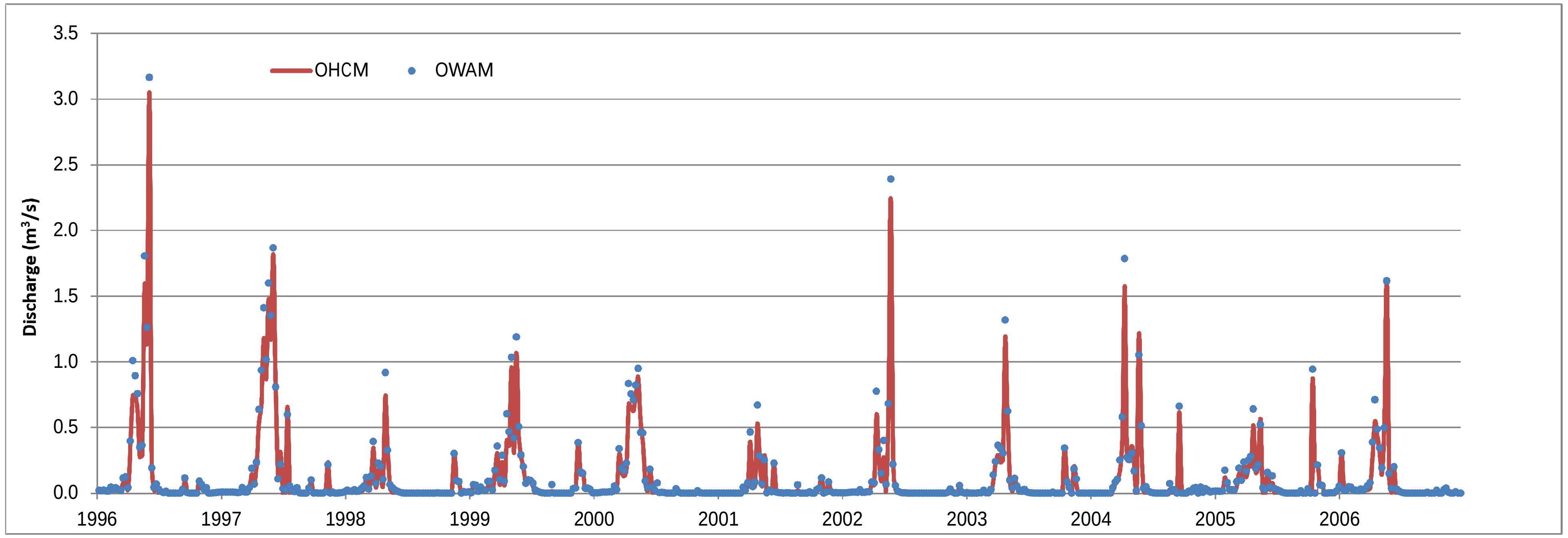


Figure A: Comparison of net weekly streamflow at Irish Creek at the Mouth by OHCM and OWAM.

Figure B: Comparison of net annual streamflow at Irish Creek at the Mouth by OHCM and OWAM.

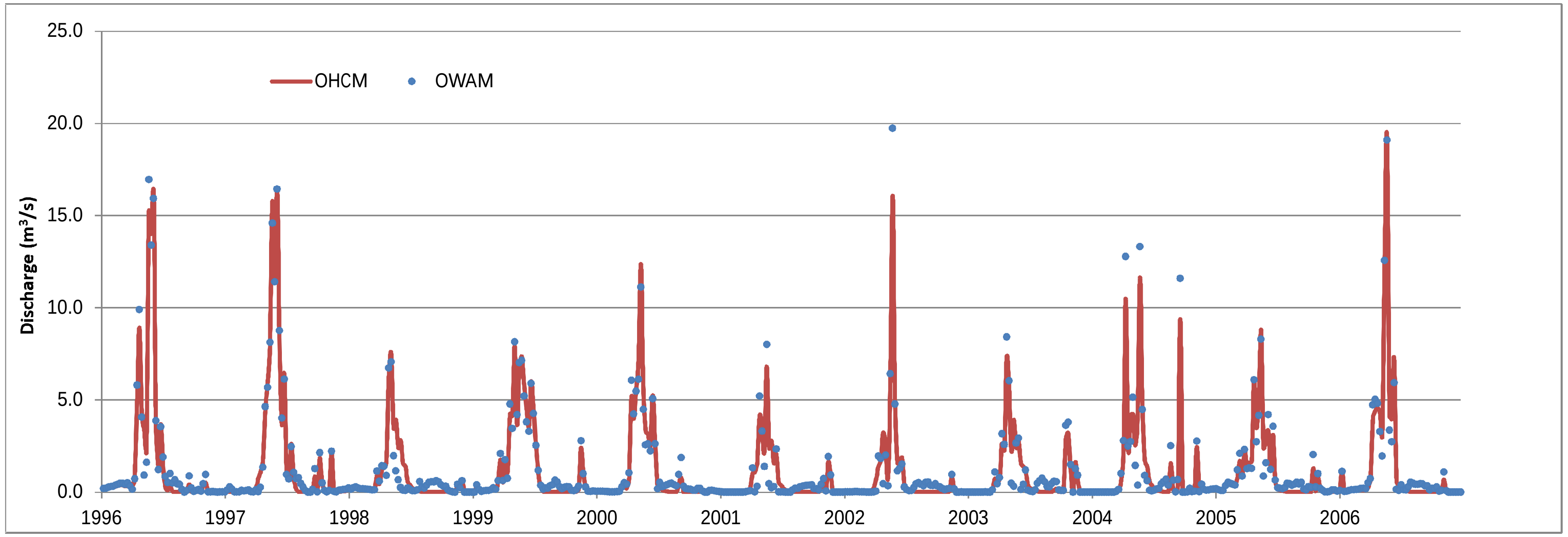


Figure C: Comparison of net weekly streamflow at Lambly Creek at the Mouth by OHCM and OWAM.

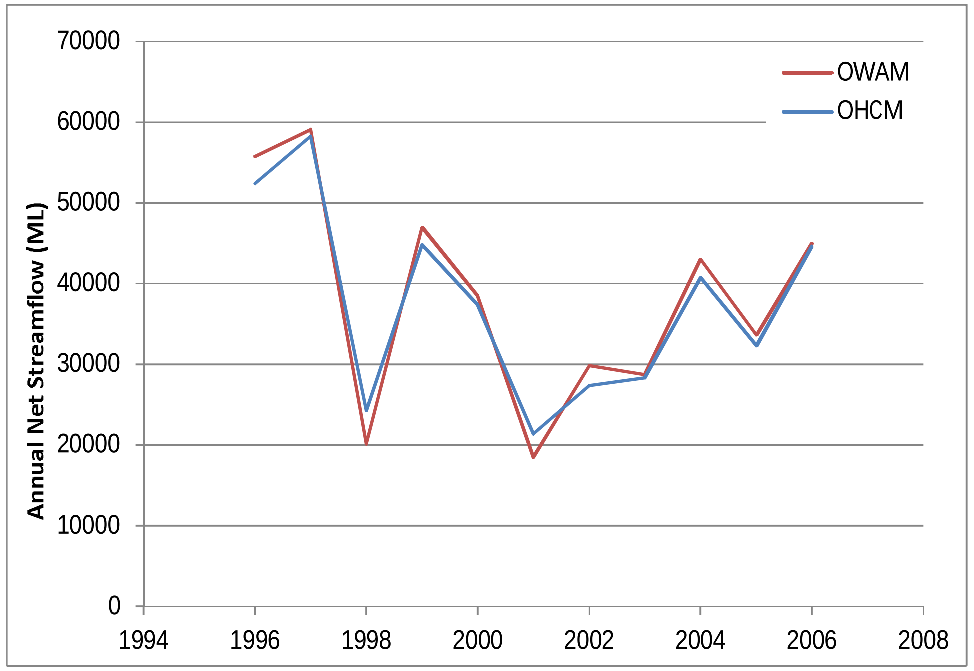


Figure D: Comparison of net annual streamflow at Lambly Creek at the Mouth by OHCM and OWAM.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**	
DRAWN BY: TN			
DATA SOURCE(S): OWAM and OHCM	PREPARED BY: SUMMIT Environmental Consultants Inc. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000	FIGURE A2-2: Annual and Weekly Net Streamflow Comparison
		DRAWNING NO. 2 of 6	
		FILE: Appendix A.cdr	

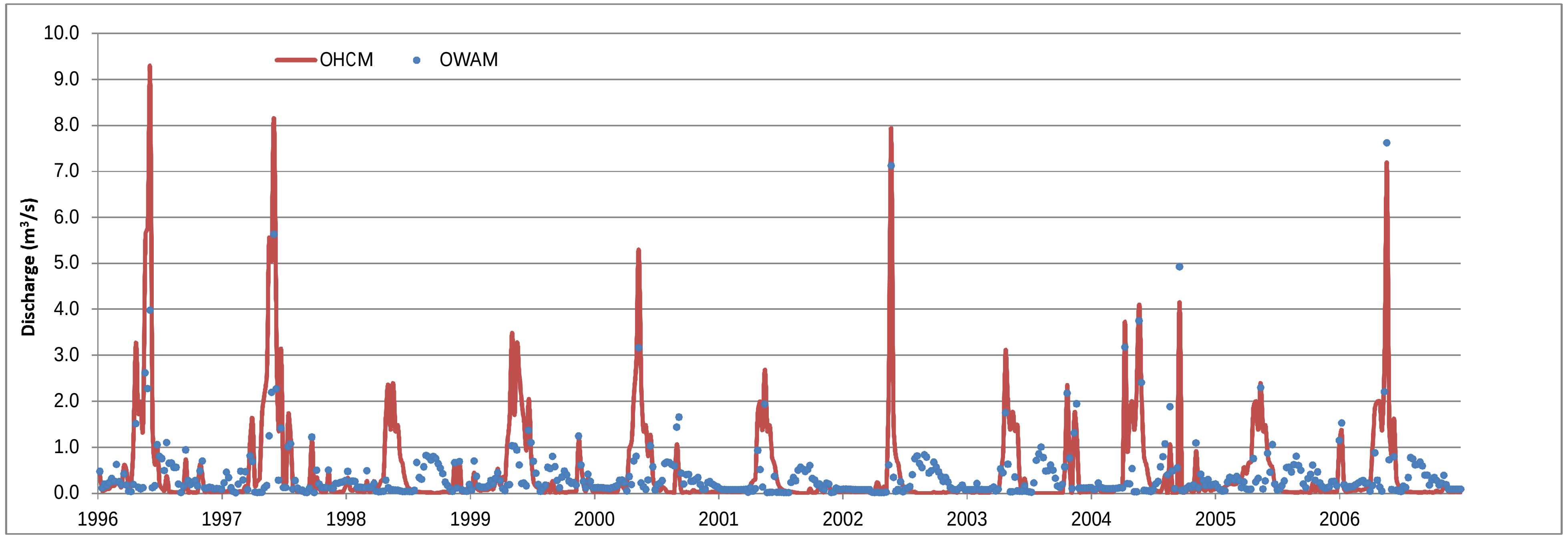


Figure A: Comparison of net weekly streamflow at Kelowna Creek at the Mouth by OHCM and OWAM.

Figure B: Comparison of net annual streamflow at Kelowna Creek at the Mouth by OHCM and OWAM.

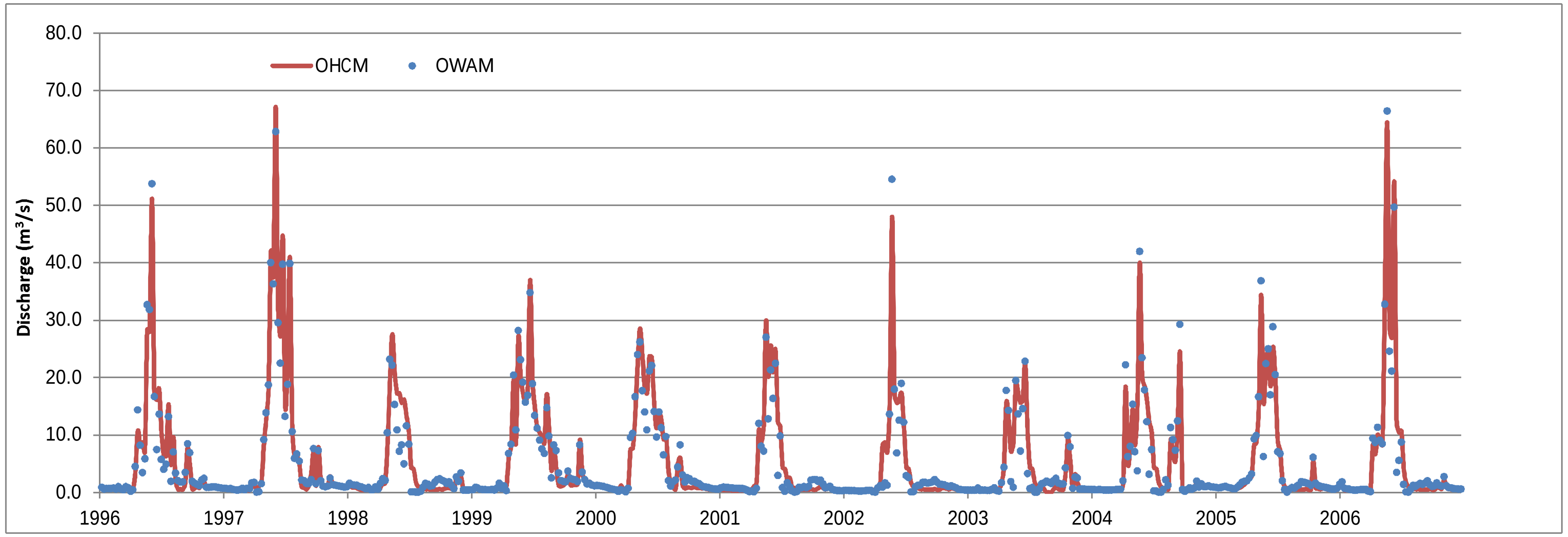


Figure C: Comparison of net weekly streamflow at Mission Creek at the Mouth by OHCM and OWAM.

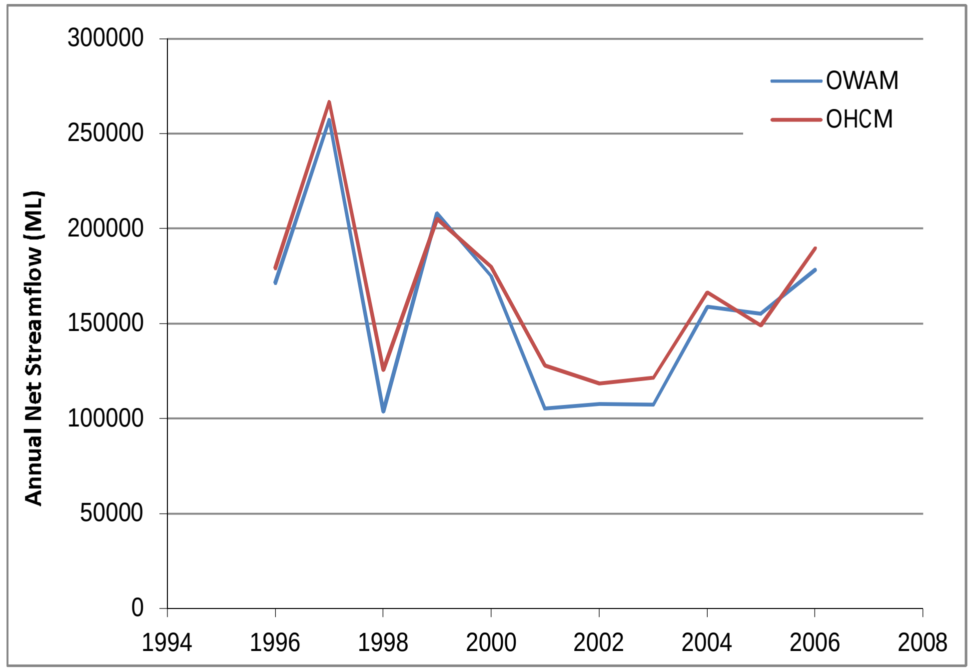


Figure D: Comparison of net annual streamflow at Mission Creek at the Mouth by OHCM and OWAM.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**	
DRAWN BY: TN			
DATA SOURCE(S): OWAM and OHCM	PREPARED BY: SUMMIT Environmental Consultants Inc. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000	FIGURE A2-3: Annual and Weekly Net Streamflow Comparison
		DRAWNING NO. 3 of 6	
		FILE: Appendix A.cdr	

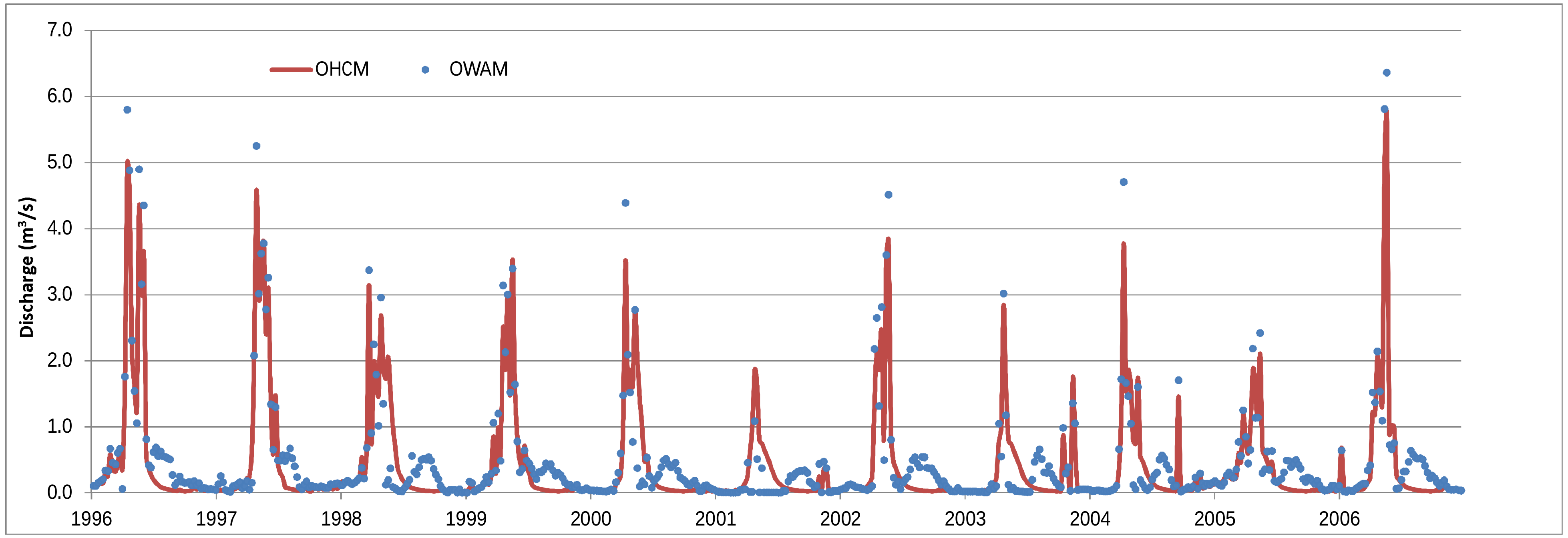


Figure A: Comparison of net weekly streamflow at Peachland Creek at the Mouth by OHCM and OWAM.

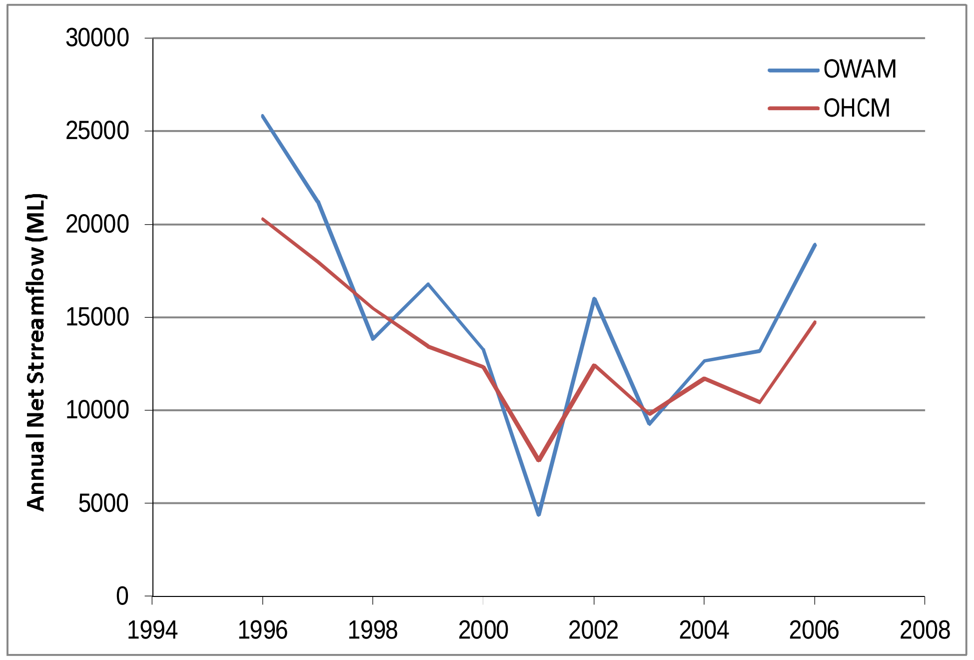


Figure B: Comparison of net annual streamflow at Peachland Creek at the Mouth by OHCM and OWAM.

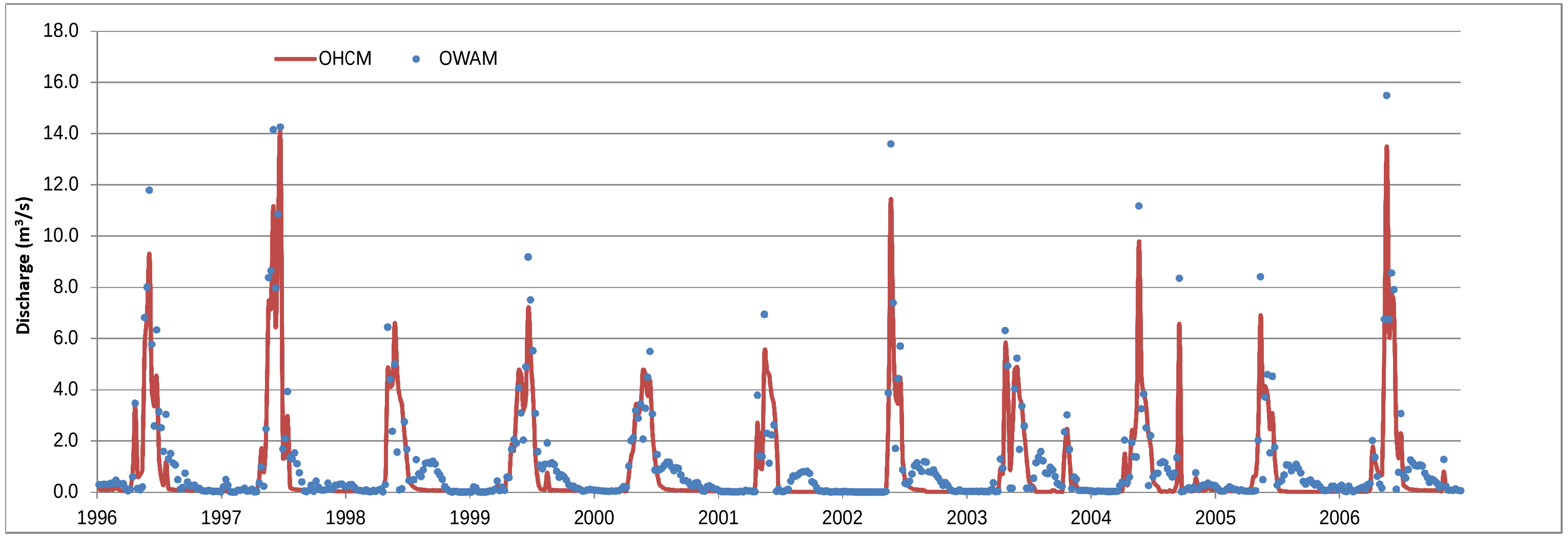


Figure C: Comparison of net weekly streamflow at Penticton Creek at the Mouth by OHCM and OWAM.

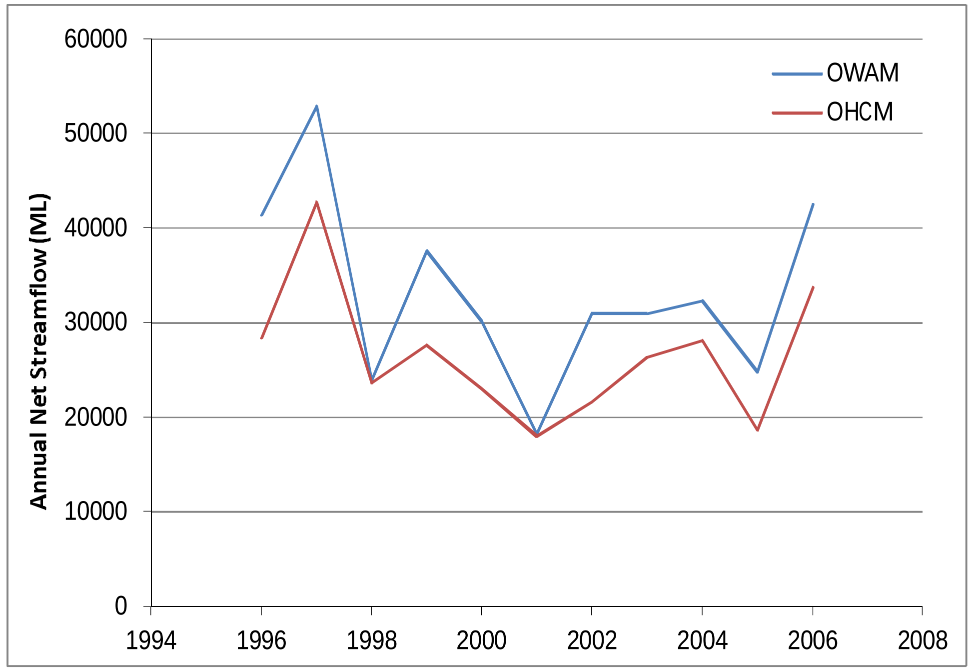


Figure D: Comparison of net annual streamflow at Penticton Creek at the Mouth by OHCM and OWAM.

DATE: May 2013

DRAWN BY: TN

DATA SOURCE(S): OWAM and OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO.: 2010-8005.000

DRAWNING NO. 4 of 6

FILE: Appendix A.cdr

FIGURE A2-4: Annual and Weekly Net Streamflow Comparison

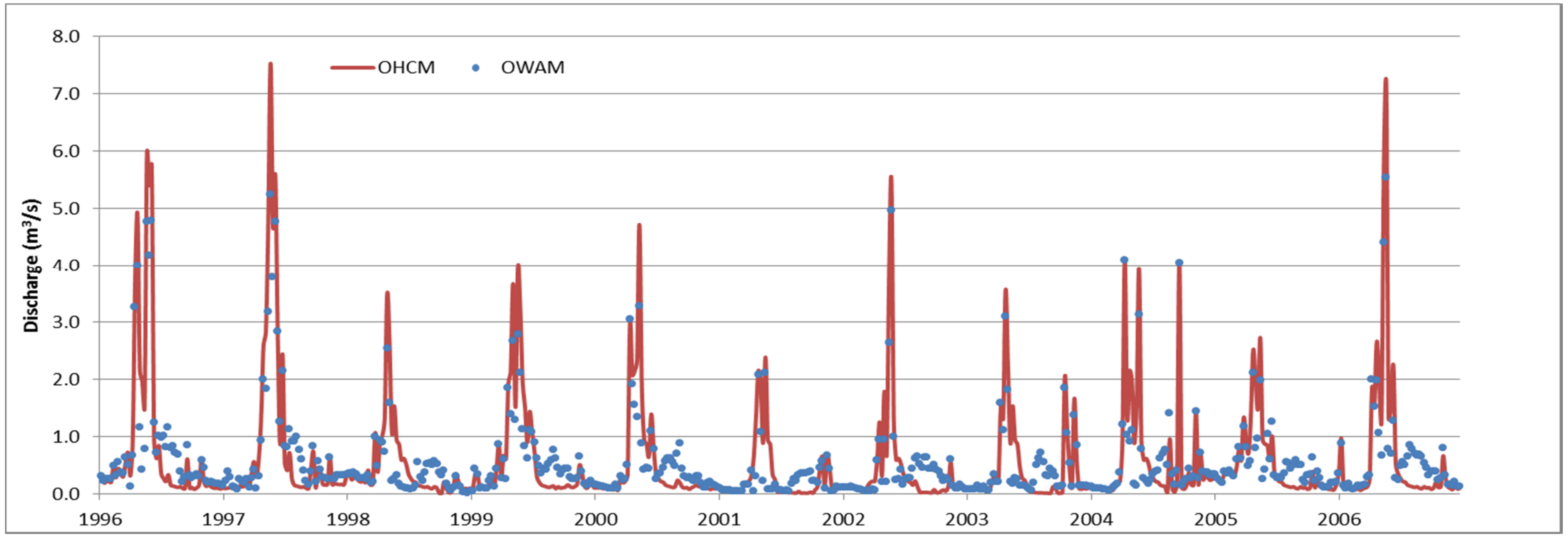


Figure A: Comparison of net weekly streamflow at Powers Creek at the Mouth by OHCM and OWAM.

Figure B: Comparison of net annual streamflow at Powers Creek at the Mouth by OHCM and OWAM.

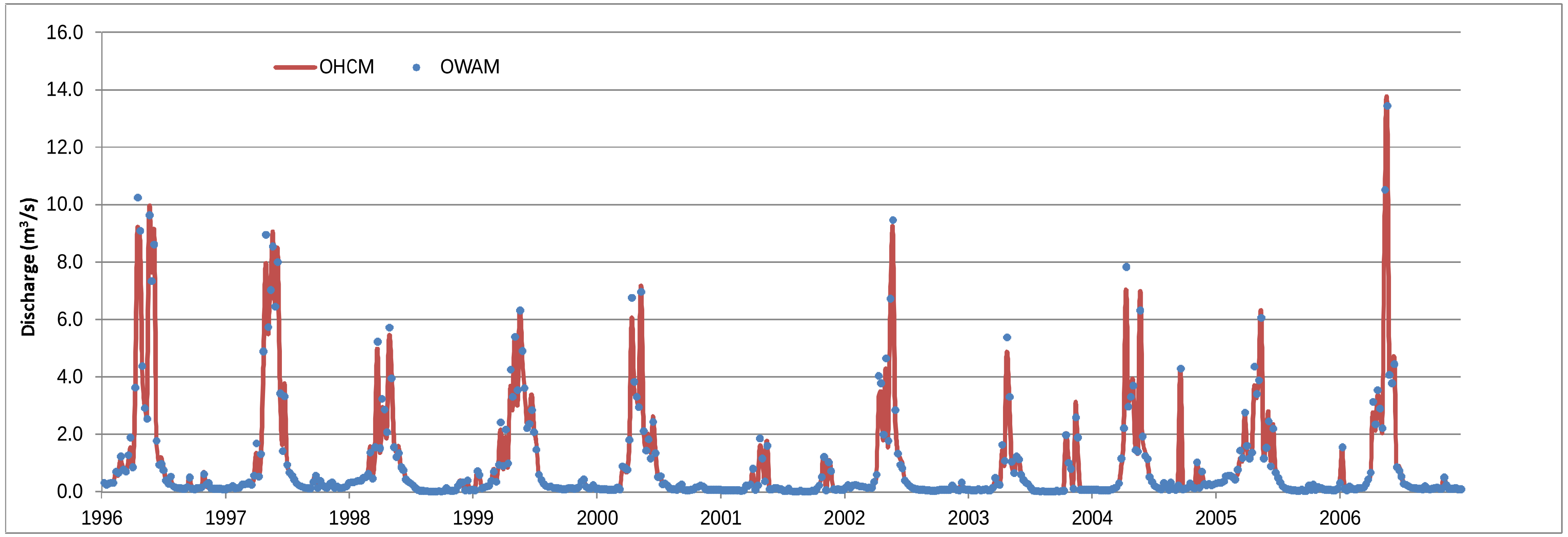


Figure C: Comparison of net weekly streamflow at Trepanier Creek at the Mouth by OHCM and OWAM.

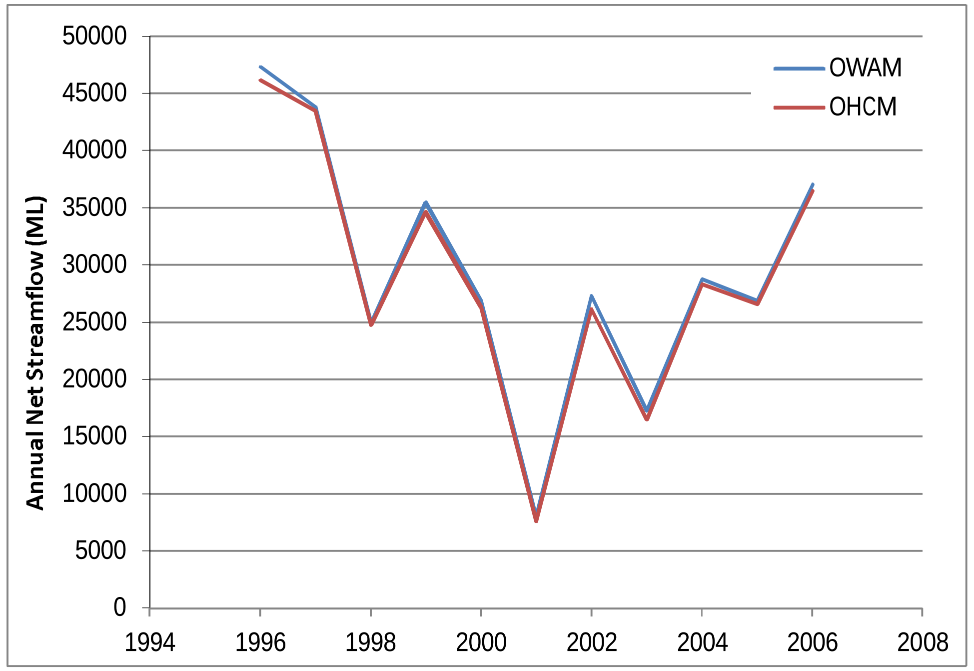


Figure D: Comparison of net annual streamflow at Trepanier Creek at the Mouth by OHCM and OWAM.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**	
DRAWN BY: TN			
DATA SOURCE(S): OWAM and OHCM	PREPARED BY: SUMMIT Environmental Consultants Inc. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000	FIGURE A2-5: Annual and Weekly Net Streamflow Comparison
		DRAWNING NO. 5 of 6	
		FILE: Appendix A.cdr	

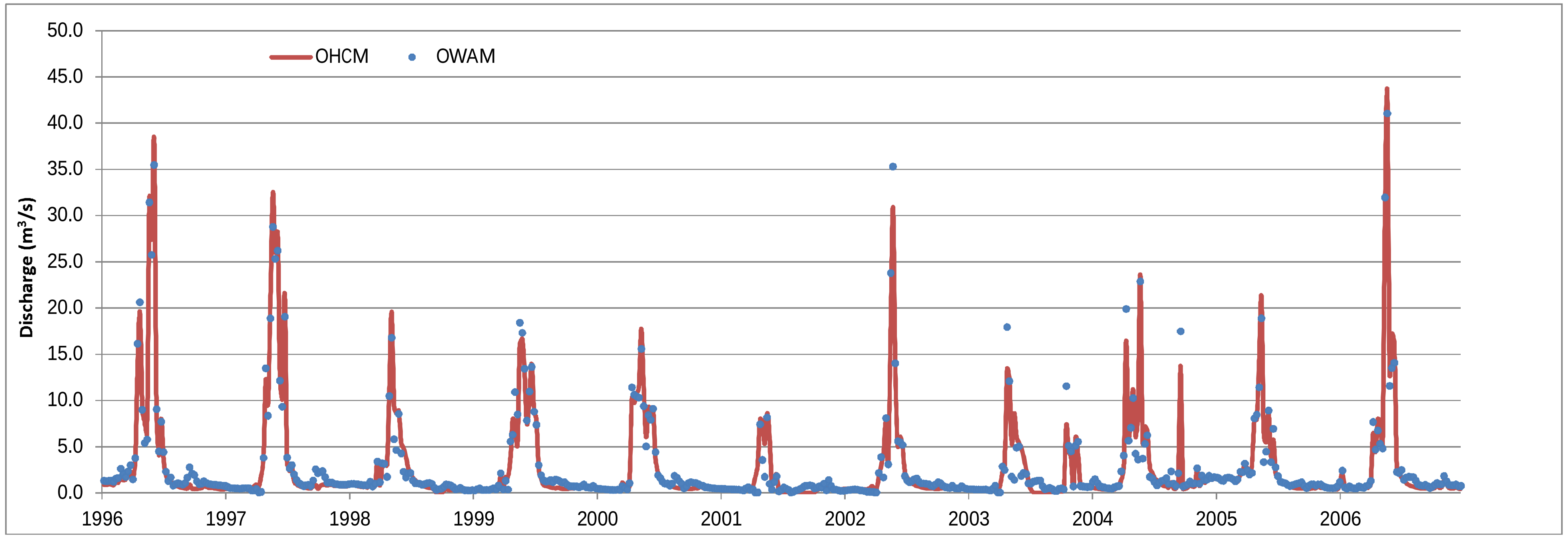


Figure A: Comparison of net weekly streamflow at Trout Creek at the Mouth by OHCM and OWAM.

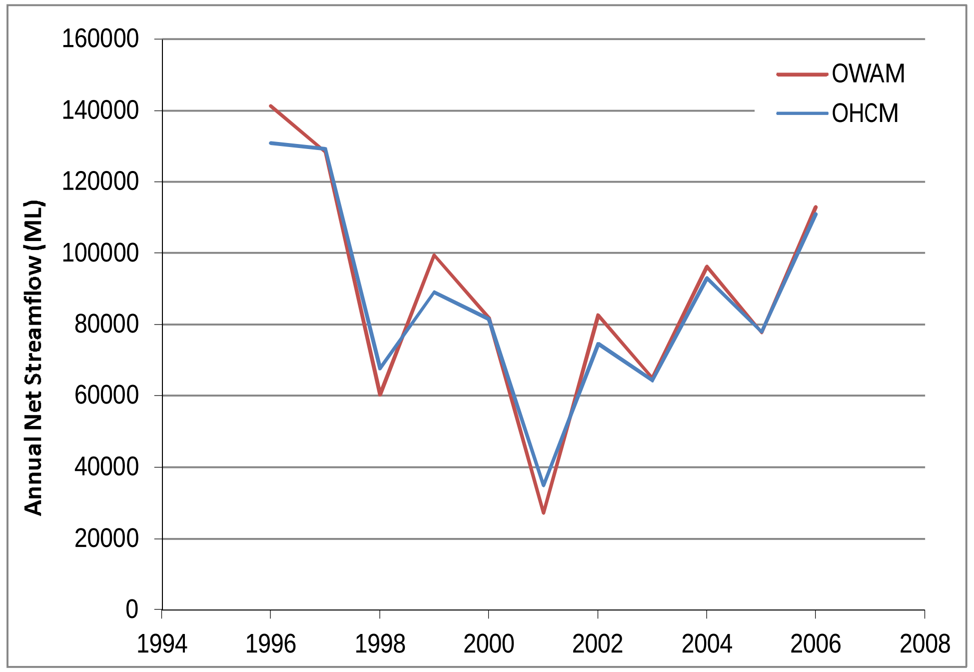


Figure B: Comparison of net annual streamflow at Trout Creek at the Mouth by OHCM and OWAM.

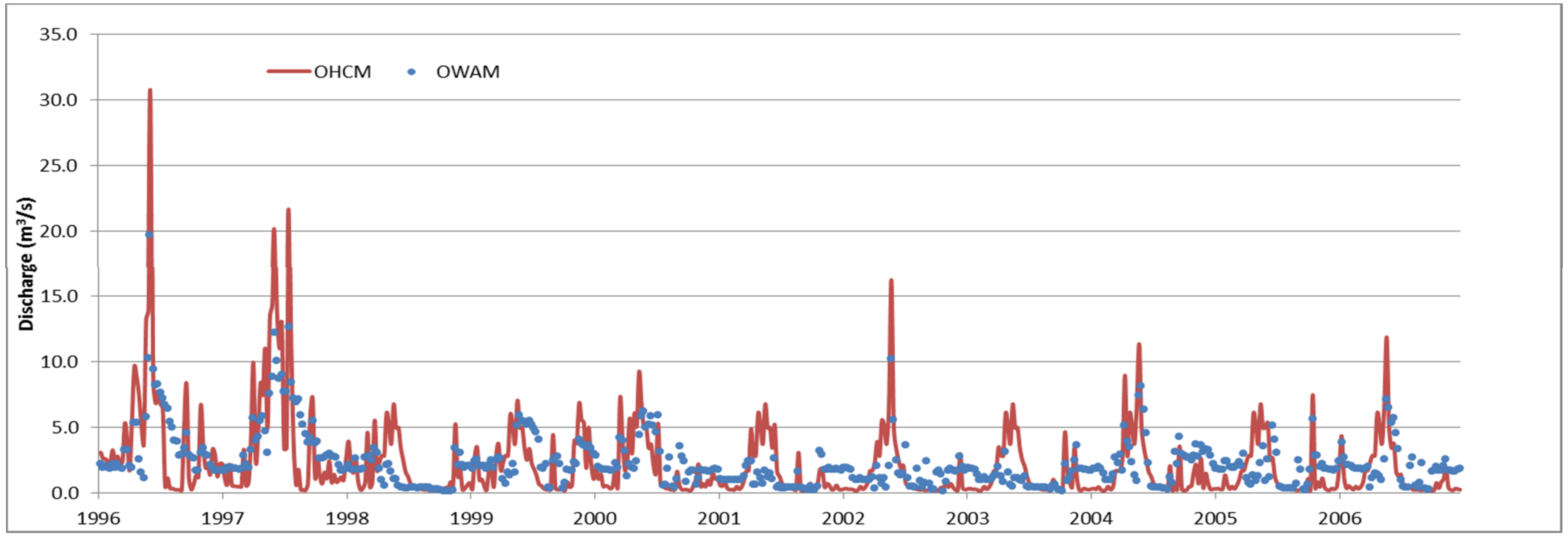


Figure C: Comparison of net weekly streamflow at Vernon Creek at the Mouth by OHCM and OWAM.

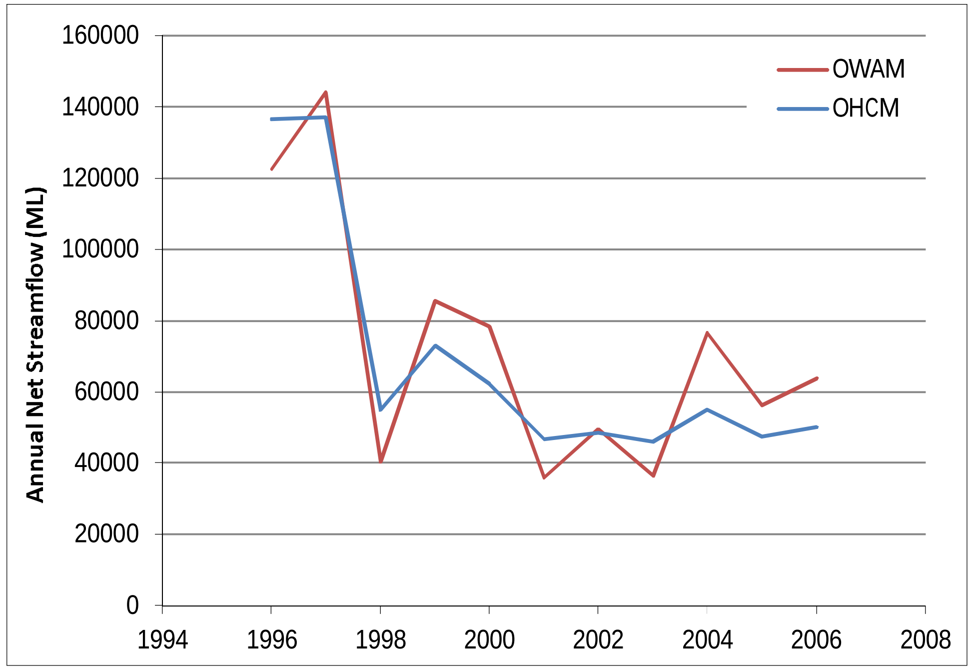


Figure D: Comparison of net annual streamflow at Vernon Creek at the Mouth by OHCM and OWAM.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**	
DRAWN BY: TN			
DATA SOURCE(S): OWAM and OHCM	PREPARED BY: SUMMIT Environmental Consultants Inc. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000	FIGURE A2-6: Annual and Weekly Net Streamflow Comparison
		DRAWNING NO. 6 of 6	
		FILE: Appendix A.cdr	

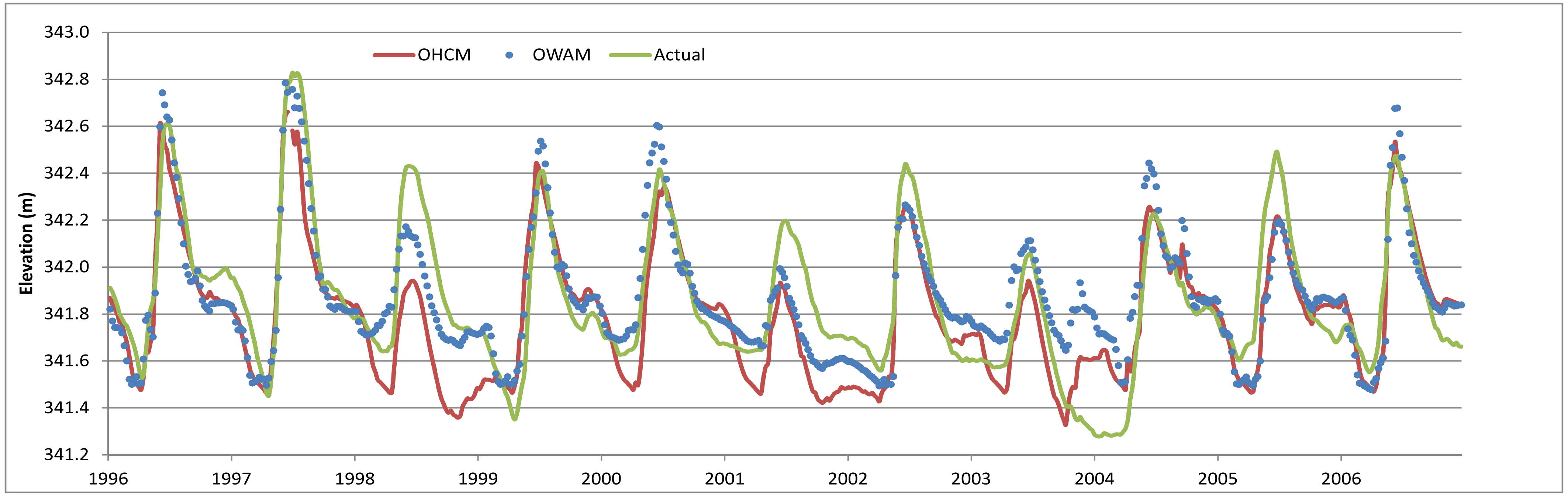


Figure A: Comparison of Calculated Okanagan Lake Levels by OHCM and OWAM.

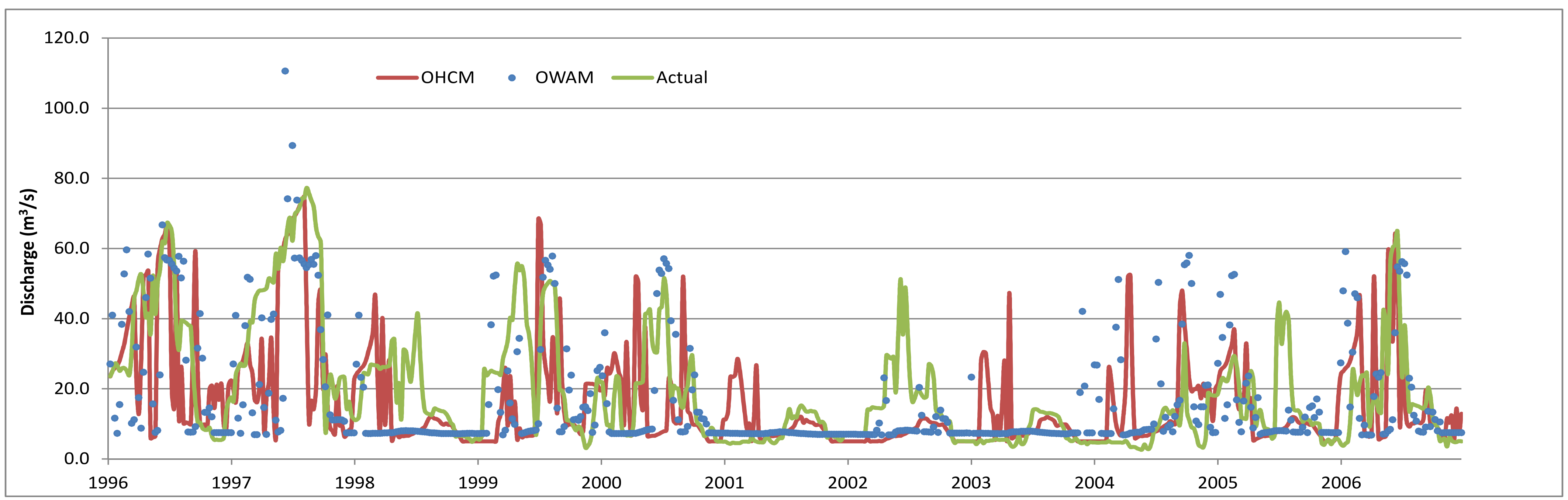


Figure B: Comparison of Calculated Okanagan Lake Outflows by OHCM and OWAM.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**	
DRAWN BY: TN			
DATA SOURCE(S): OWAM, OHCM, and WSC	PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000	FIGURE A2-7: Okanagan Lake Results
		DRAWNING NO. 1 of 1	
		FILE: Appendix A.cdr	

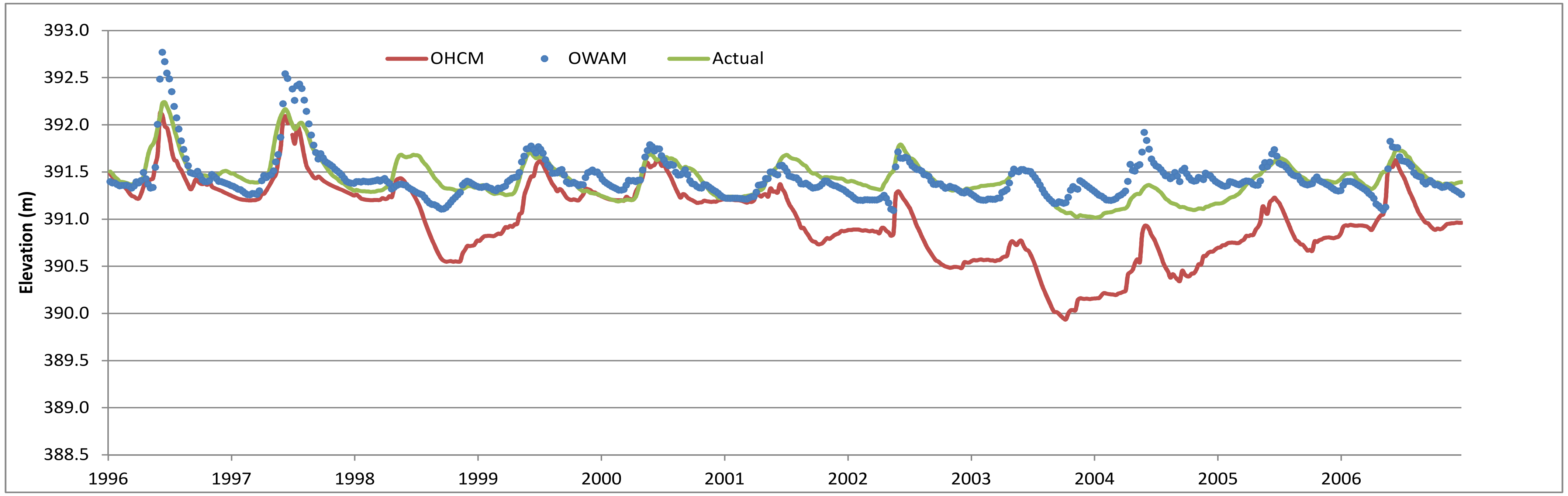


Figure A: Comparison of Calculated Kalamalka Lake Level by OHCM and OWAM to Actual Records.

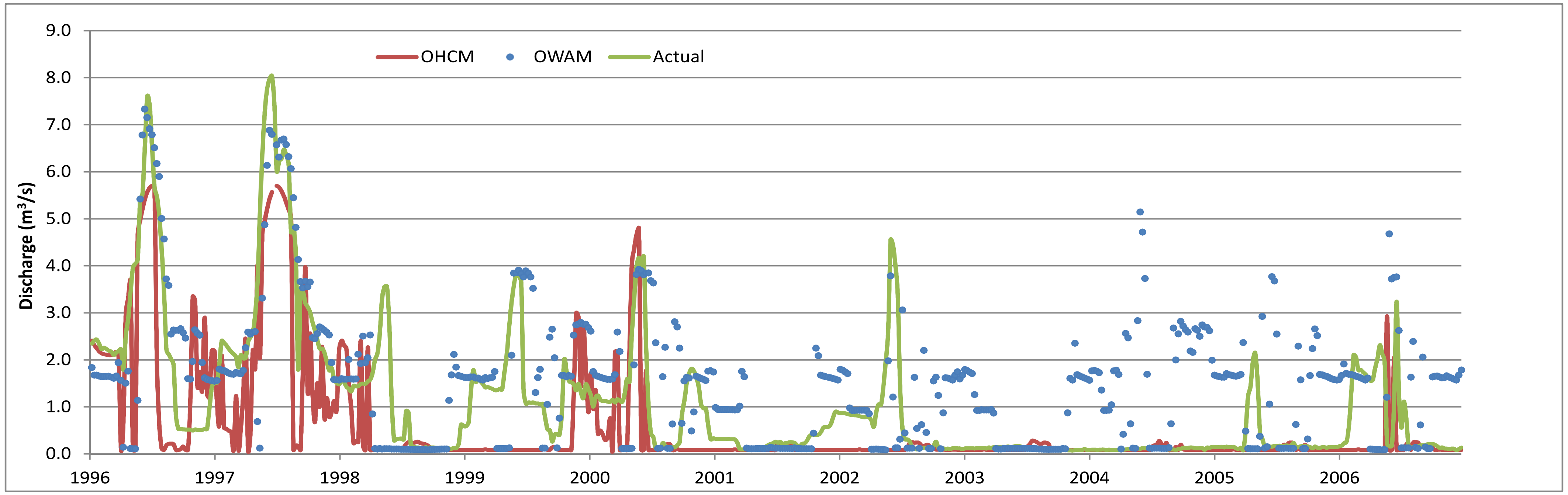


Figure B: Comparison of Calculated Kalamalka Lake Outflows by OHCM and OWAM to Actual Records.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**
DRAWN BY: TN		
DATA SOURCE(S): OWAM, OHCM, and WSC	PREPARED BY: SUMMIT Environmental Consultants Inc. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000
		DRAWNING NO. 1 of 1
		FILE: Appendix A.cdr
		FIGURE A2-8: Kalamalka Lake Results

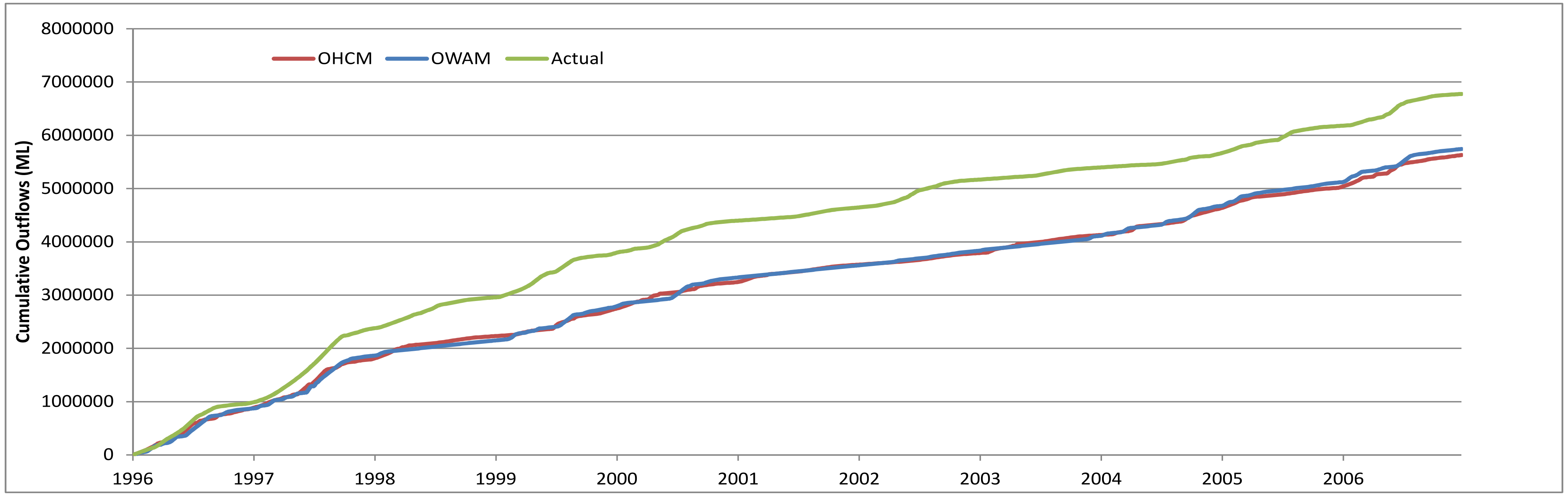


Figure A: Okanagan Lake Cumulative Outflow Comparison between OHCM, OWAM, and Actual Records.

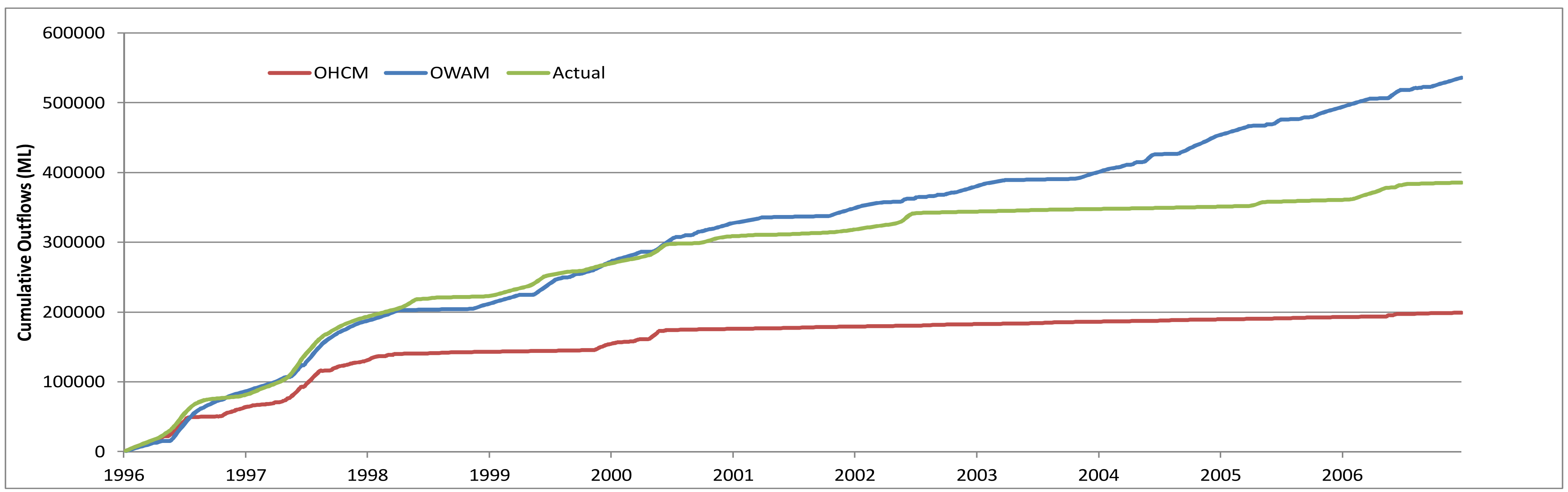


Figure B: Kalamalka Lake Cumulative Outflow Comparison between OHCM, OWAM, and Actual Records.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**	
DRAWN BY: TN			
DATA SOURCE(S): OWAM, OHCM, and WSC	PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000	FIGURE A2-9: Kalamalka and Okanagan Lake Cumulative Outflow Comparison
		DRAWNING NO. 1 of 1	
		FILE: Appendix A.cdr	

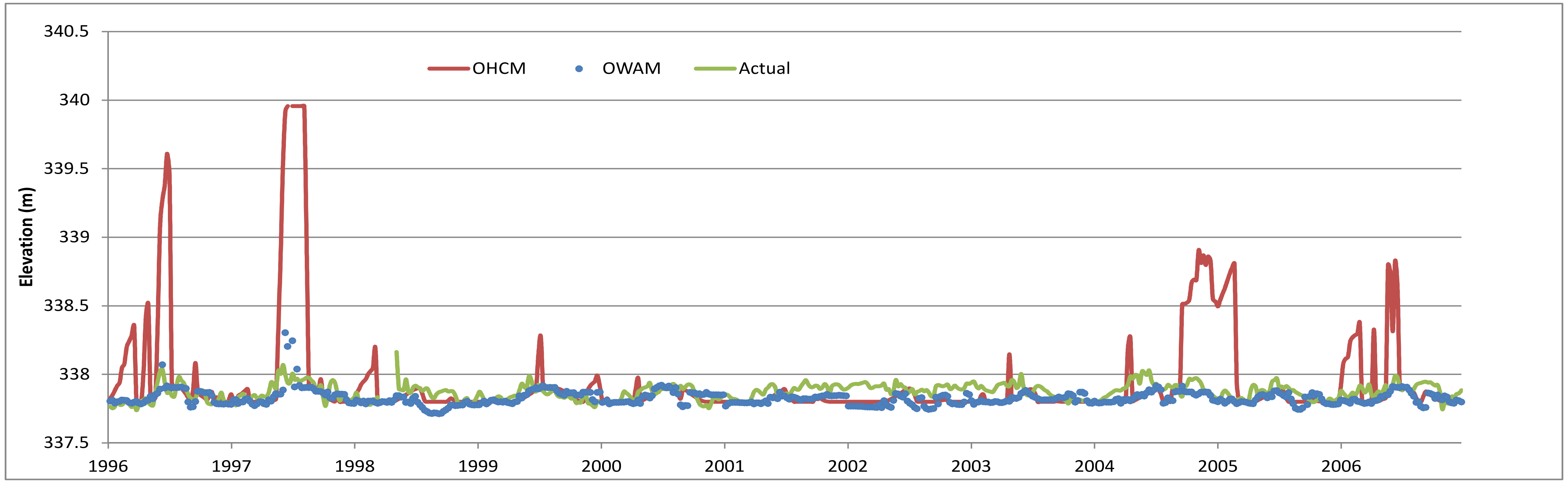


Figure A: Skaha Lake Level Comparison by OHCM and OWAM to Actual Records.

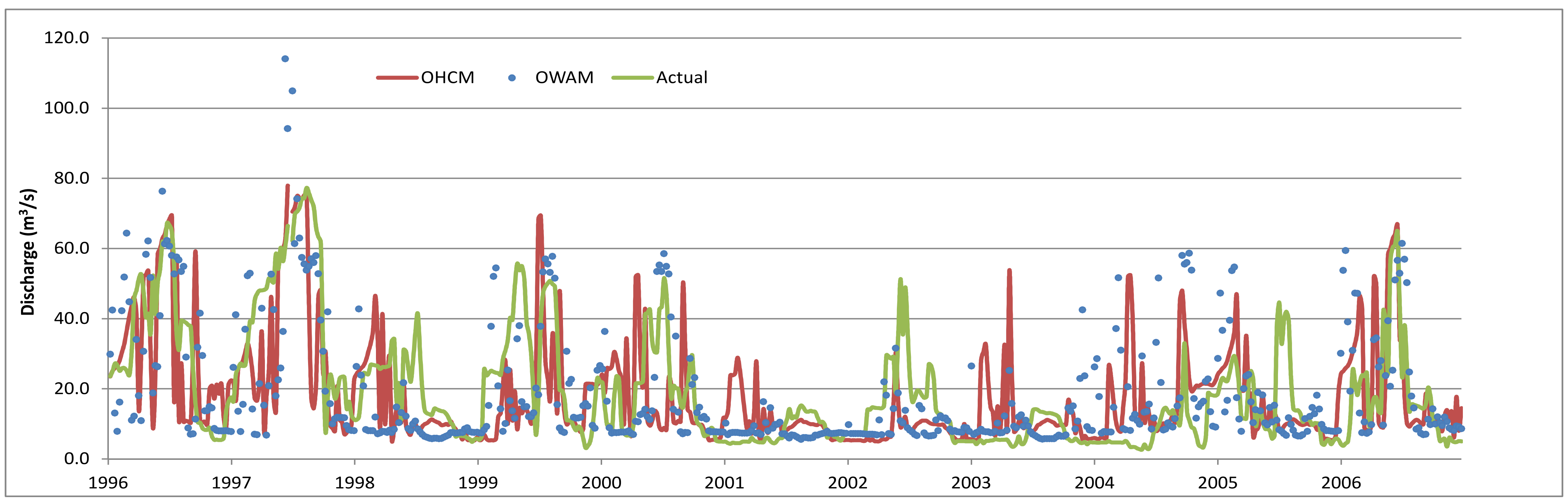


Figure B: Vaseux Lake Level Comparison by OHCM and OWAM to Actual Records.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**	
DRAWN BY: TN			
DATA SOURCE(S): OWAM, OHCM, and WSC	PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000 DRAWNING NO. 1 of 1 FILE: Appendix A.cdr	FIGURE A2-10: Skaha Lake Results

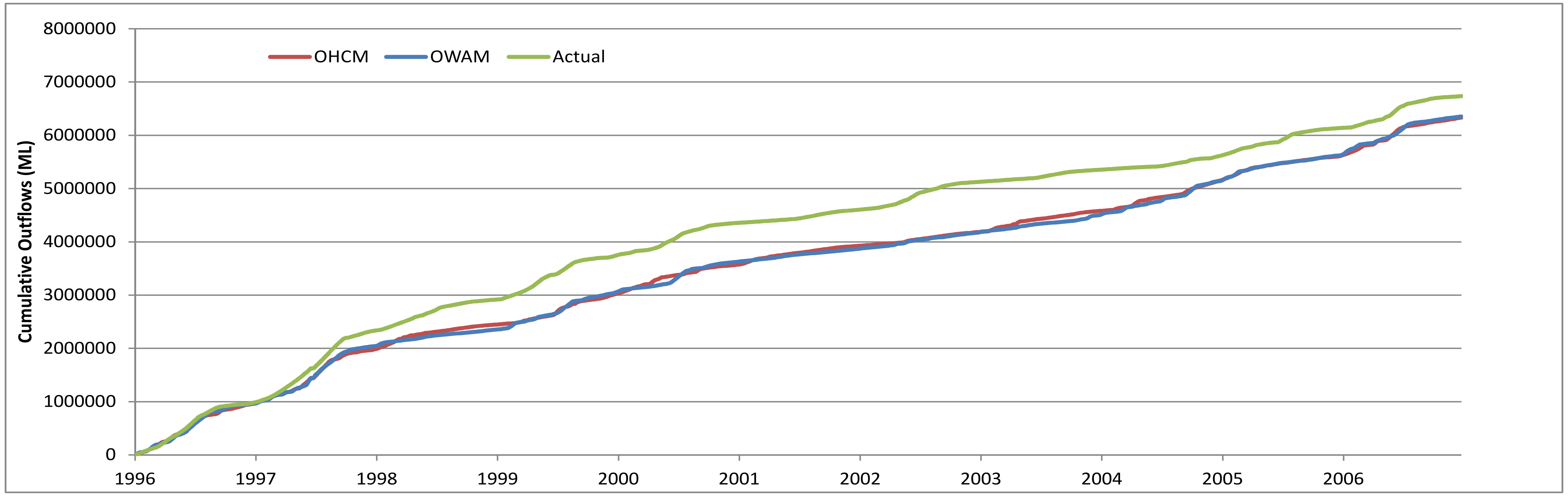


Figure A: Skaha Lake Cumulative Outflow Comparison between OHCM, OWAM, and Actual Records.

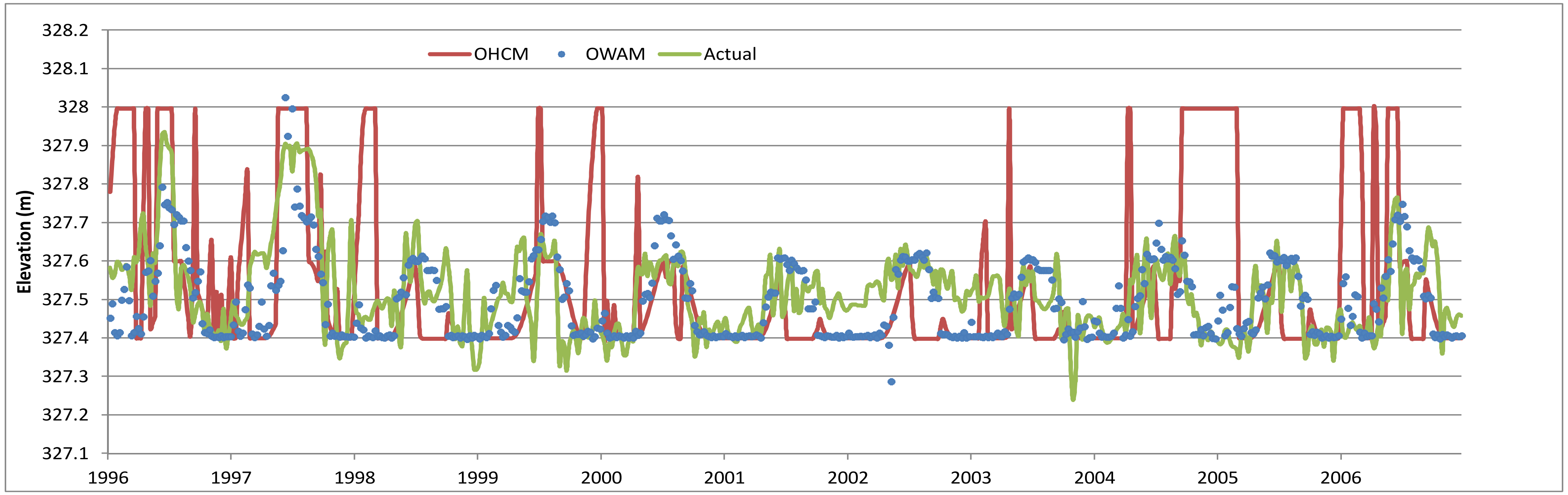


Figure B: Comparison of Calculated Vaseux Lake Level by OHCM and OWAM to Actual.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**	
DRAWN BY: TN			
DATA SOURCE(S): OWAM, OHCM, and WSC	PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000	FIGURE A2-11: Skaha Lake Cumulative Comparison and Vaseux Lake Results
		DRAWNING NO. 1 of 1	
		FILE: Appendix A.cdr	

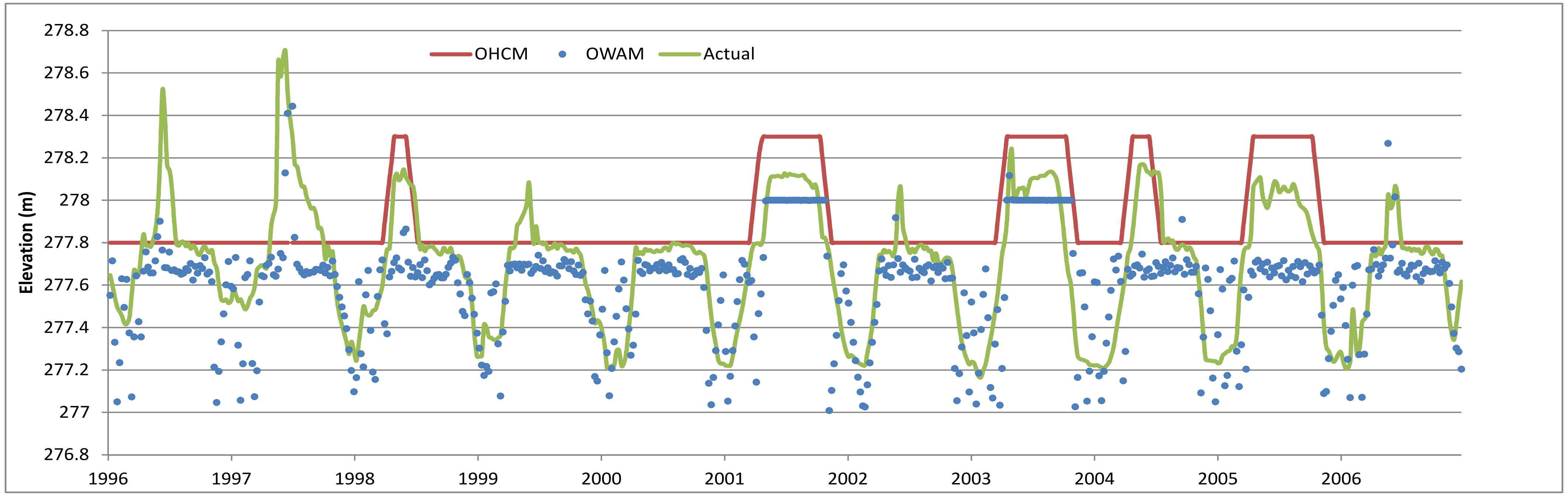


Figure A: Comparison of Calculated Osoyoos Lake Level by OHCM and OWAM to Actual Records.

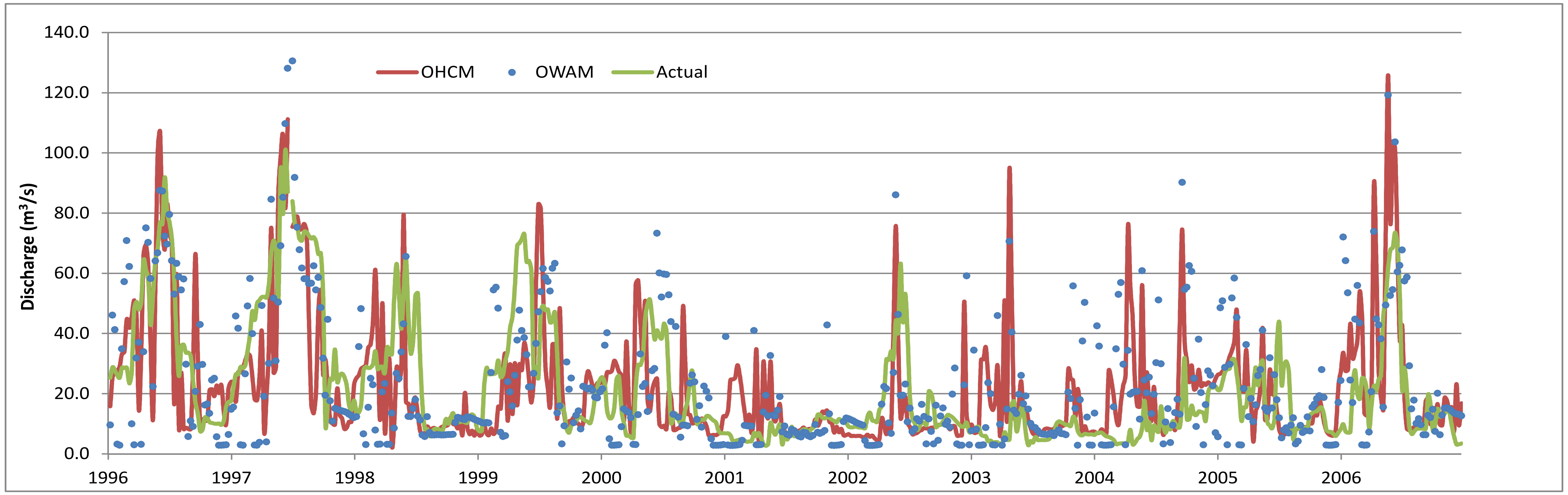


Figure B: Comparison of Calculated Osoyoos Lake Outflows by OHCM and OWAM to Actual Records.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**	
DRAWN BY: TN			
DATA SOURCE(S): OWAM, OHCM, and WSC	PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000	FIGURE A2-12: Osoyoos Lake Results
		DRAWNING NO. 1 of 1	
		FILE: Appendix A.cdr	

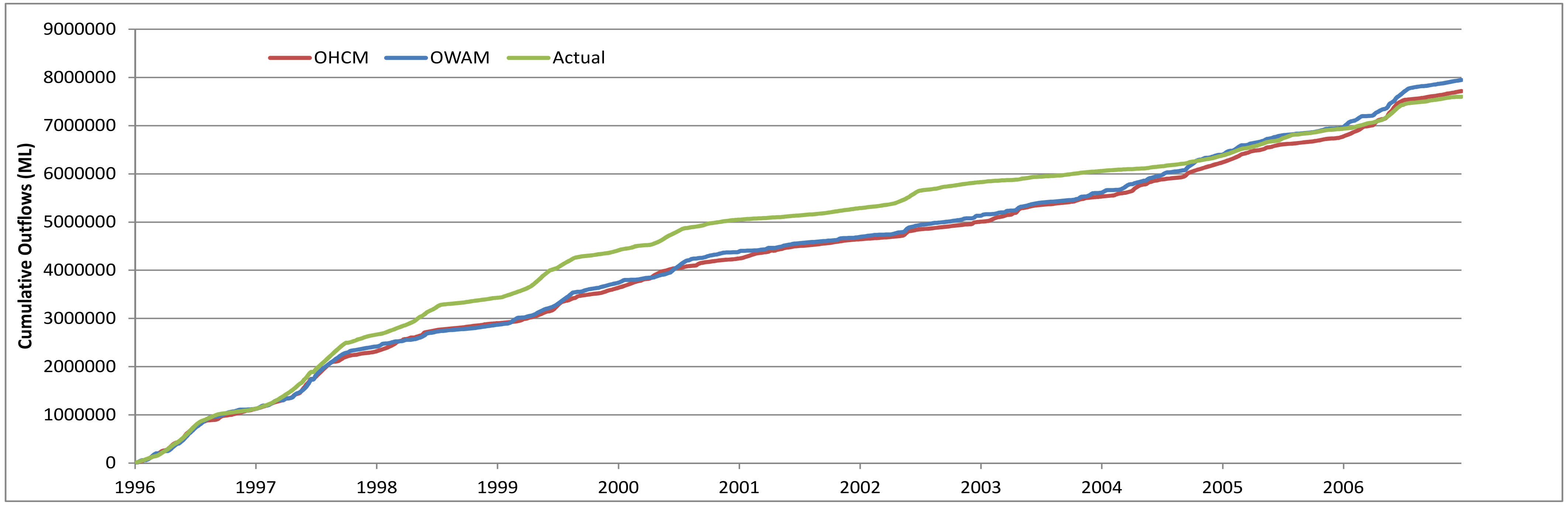


Figure A: Osoyoos Lake Cumulative Outflow Comparison between OHCM, OWAM, and Actual Records.

DATE: May 2013	PREPARED FOR: OKANAGAN BASIN WATER BOARD	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**	
DRAWN BY: TN			
DATA SOURCE(S): OWAM, OHCM, and WSC	PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS Inc. A Member of the Associated Engineering Group of Companies	PROJECT NO.: 2010-8005.000 DRAWNING NO. 1 of 1 FILE: Appendix A.cdr	FIGURE A2-13: Osoyoos Cumulative Outflow Comparison

B Appendix B - OHCM Data Extraction Memo

SUMMIT
ENVIRONMENTAL CONSULTANTS INC.
A Member of the Associated Engineering Group of Companies

MEMO

Date:	May 26, 2013
File:	2010-8005.000
To:	Okanagan Basin Water Board
From:	Brian Guy (Summit Environmental Consultants Inc.); Patrick Delaney (DHI Inc.)
Project:	Okanagan Hydrologic Connectivity Model
Subject:	**Appendix B**: Data Extraction Memo

This memorandum represents Appendix B of the final report "*Okanagan Hydrologic Connectivity Model: Summary Report*". This document was jointly prepared by Summit Environmental Consultants Inc. and DHI Inc.

1.1 INTRODUCTION

This Appendix describes how data is extracted from the Okanagan Water Accounting Model (OWAM) for use in the Okanagan Hydrologic Connectivity Model (OHCM). There are several types of data in the OWAM that are generally required as input to the OHCM. These include natural and net (i.e. accounting for water use and management) streamflows from all contributing areas within the Okanagan Basin, including those areas that contribute inflows to upland reservoir and mainstem lakes. Also required from the OWAM are data for streamflows at key points-of-interest, such as water intakes and below mainstem lakes. For areas (i.e. catchments) that are not explicitly modeled in OHCM, net streamflow from the OWAM is required.

This Appendix also outlines how the data, once extracted, is converted and translated so that it can be used by the OHCM. In addition, a folder called "*inflow_extraction*" containing all the relevant files required to prepare the inflow data for the OHCM has been provided to the Okanagan Basin Water Board (OBWB). Included within this folder are sub-folders for upland reservoirs, water intakes, mainstem lakes, the Okanagan River, and stream catchments, which include three types of files: *.pfs files, Excel spreadsheet (*.xls), and *.csv files.

1.2 DATA EXTRACTION TOOL

The extraction tool "*AFETDataExtractor.exe*" is used to extract streamflows from selected locations along the modelled river branches in the OWAM. In order to use the extraction tool, the user must create *.pfs files defining the following:

- Input file name and location/path (i.e. the MIKE 11 result file from the OWAM);
- Names of the river branches and chainage interval on each river branch where the flows are extracted; and
- Output file name and location/path where the extracted data will be saved.

The extraction tool reads the *.pfs file, extracts the relevant items at the specified points with the same time interval as the input and writes the extracted data into a DHI time series format file (*.dfs0). The *.dfs0 file can be loaded into Excel for post-processing, including intermediate calculation, weekly conversion, and .csv format conversion. A document that summarizes the extraction tool is provided in Appendix B1.

All relevant *.pfs files required for running the extraction tool have been provided to the OBWB. Ron Fretwell (RHF Systems Ltd.) has been retained by the OBWB for technical support of the OWAM and as such, has experience using the extraction tool.

1.3 DATA EXTRACTION FROM THE OKANAGAN WATER ACCOUNTING MODEL (OWAM)

The following section provides a summary of the process of extracting inflow data from the OWAM - for upland reservoirs, water intakes, mainstem lakes, Okanagan River, and stream catchments.

1.3.1 Stream Catchments

Both natural and net inflow data used in the OHCM are extracted from the OWAM for the main-stem lakes and major stream catchments. Natural inflow data is extracted for the major stream catchments that are specifically included within the OHCM (e.g. Mission Creek, Kelowna Creek). Within these major stream catchments, natural inflow data includes inflows to upland reservoirs and inflows to catchments between key points-of-interest (e.g. upland reservoirs, water intakes). A detailed explanation of the extraction process for each key point-of-interest is provided in Sections 1.3.2 to 1.3.6.

All natural inflows are extracted from two types of MIKE 11 result files from the OWAM. The first file is the standard MIKE 11 output file (*.res11) that contains discharge and water level calculated at alternating Q-Points (discharge) and H-Points (water level) along the river branch. The second MIKE 11 result file (*HDAdd.res11) contains three additional outputs that are relevant for OHCM data extraction. The additional output items in the *HDAdd.res11 file are:

1. LATERAL INFLOW SHE OVERLAND (overland flow);
2. LATERAL INFLOW SHE DRAIN (interflow); and
3. LATERAL INFLOW SHE BASEFLOW (baseflow).

These files represent the lateral inflows from the MIKE SHE hydrology model to the MIKE 11 river branches in the OWAM. MIKE 11 outputs are written to these result files at 6 hour time-steps and need to be converted to weekly values for use in the OHCM.

For the remaining stream catchments for which no explicit water supply-demand modeling was required in OHCM (i.e. those catchments that are not utilized by the major utilities), the inflows to the OHCM were extracted from a version of the OWAM that calculates the net flows (i.e. flows that already account for human use and management) (explained further in Section 1.3.6). This data reflects the total net inflow from these stream catchments to the mainstem lakes or the Okanagan River. This data is extracted at the mouth of each stream catchment in the OWAM. Alternatively, it can be obtained from the Ok Water Database. If the data is obtained directly from the OWAM, all net flows require converting to weekly values for use in the OHCM.

1.3.2 Upland Reservoirs

The OHCM includes forty-eight (48) upland reservoirs for which OWAM natural inflow data is required at locations both upstream and downstream of the reservoirs. Appendix B2 provides a summary of the Q-points for which data is required from the OWAM. For most reservoirs, natural inflows are extracted from standard MIKE 11 results files at the closest Q-point to where the reservoir is located. However, for Thirsk Lake, due to its unique situation as part of the mainstem of

Trout Creek, two *.pfs files are required for reservoir inflow extraction from OWAM. One of the files is for individual natural inflows into forty-seven (47) of the upland reservoirs and the second is for natural inflows into Thirsk Lake.

Since Thirsk Lake is located on upper Trout Creek (Figure B-1) it receives flows from reservoirs upstream, as well as flows from several tributaries and contributing areas. As a result, natural inflows to Thirsk Lake are calculated as the sum of overland flow, interflow, and baseflow from all contributing sources between Thirsk Lake and the upstream reservoirs. These contribution points include points along the reach of Crescent Creek below Crescent Lake, along the reach below Whitehead Lake, along the reach of Trout Creek below Headwater Reservoir No.1 (above Thirsk Lake), and along North Trout Creek, Empress Creek, and Kathleen Creek. All of the natural flow contributions to Thirsk Lake are included in three separate *.pfs files:

- Inflows_Upland_reservoirs_Thirsk_overland.pfs
- Inflows_Upland_reservoirs_Thirsk_interflow.pfs
- Inflows_Upland_reservoirs_Thirsk_baseflow.pfs

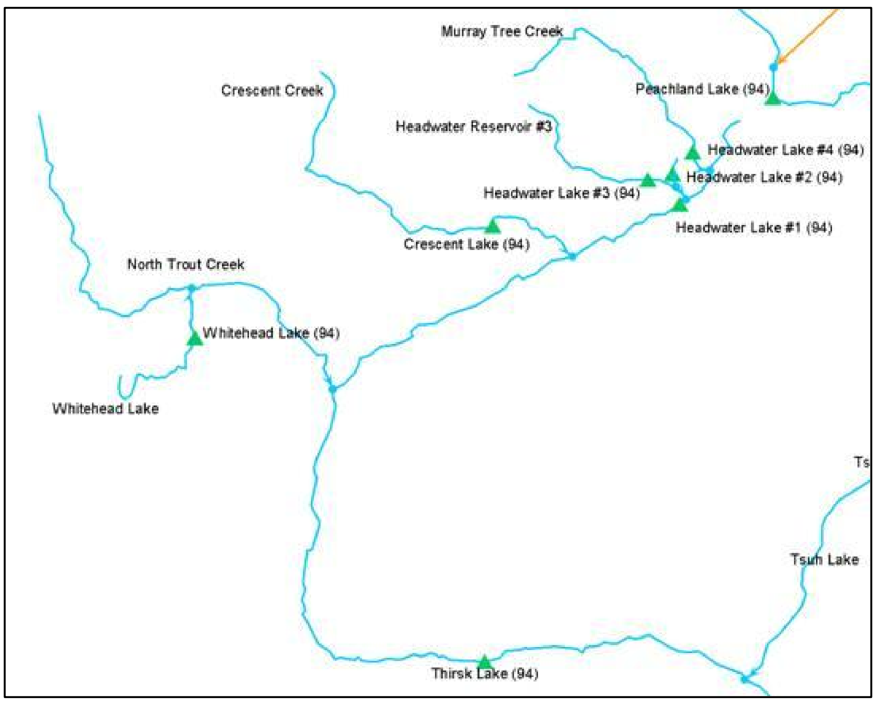


Figure B-1 Location of Thirsk Lake in the Trout Creek Watershed.

The information from the *.pfs files is extracted using the extraction tool to generate a *dfs0 file, which is then transposed into a separate file "*Inflows_Upland_Reservoirs_Thirsk_Lake.xls*", where the natural flow contribution to Thirsk Lake is calculated. Once the Thirsk Lake inflows are calculated, they are included within a *.csv file (*Inflows_upland_reservoirs.csv*) that represents all of the natural inflows to each upland reservoir within the OHCM.

Some reservoirs (e.g. Swalwell Lake, Swan Lake, Browne Lake, Dobbin Lake, Headwaters Lake No.1, Garnet Lakes, Eleanor Lake) are not located in the upper reaches of their respective stream catchment, while some have additional reservoirs upstream of them. As a result, inflows to the Q-point where these lakes are located may not represent the total inflow up to that point, so some intermediate calculations are required to provide inflows for these lakes. For example, for Headwater Reservoir No.1 located in upper Trout Creek, the reservoir receives inflows from Headwater Reservoir No.2, No.3, and No.4, as well as inflow from the mainstem of upper Trout Creek. However, since inflows to Headwater Reservoirs No.2, No.3 and No.4 have been accounted for in each of these reservoirs, the intermediate inflow between Headwater Reservoir No.1 and the other three Headwater Reservoirs needs to be accounted for within Headwater Reservoir No.1. The intermediate inflows are calculated as follows:

$$\text{Intermediate Inflow (No. 1)} = Q_{No.1} - Q_{No.2} - Q_{No.3} - Q_{No.4}$$

where "$Q_{No.1}$" refers to the discharge at the Q-point where Headwater Reservoir No.1 is located. A detailed explanation of the calculations for this type of situation is provided in the "Note" column of Table B2-1 in Appendix B2.

Finally, for Big Meadow Lake, Naramata Lake, King Edward Lake, and Swan Lake, there are no other reservoirs or extractions downstream. Accordingly, inflows below these two lakes are calculated as the discharge at the Q-point of the mouth of the respective stream catchment minus the discharge at the Q-point where the reservoir is located (i.e. $Q_{Mouth} - Q_{Reservoir}$). A *.pfs file named 'Flows_below_reservoirs.pfs' is included to extract flows at these locations and a *.csv file (*Flows_below_reservoir.csv*) is included in the OHCM to account for these natural flow contributions.

1.3.3 Intakes

For the OHCM, an 'intake' refers to an extraction point that feeds demand sites on modeled stream catchments. Natural inflows related to intakes on the mainstem lakes are treated differently and are discussed in Section 1.3.4.

Within the OWAM, natural inflows associated with intakes are extracted in two separate groups: (1) inflows above intakes and (2) inflows below intakes. The natural inflows are extracted from the standard MIKE 11 results file (*.res11) at the Q-points where the intakes are located. The inflows are organized by stream catchment and a *.pfs file is created that includes all relevant Q-points. All *.pfs files are organized using the stream catchment name (e.g. 'Flows_abv_Intakes_Ellis.pfs' refers to the Ellis Creek catchment).

Table B2-1 in Appendix B2 provides a summary of all intake locations (i.e. Q-points) and the formulas used to calculate inflows for reaches above and below the given intakes. For stream catchments where an intake is located close to the mouth of the catchment, all inflows in the catchment are accounted for by the *.pfs files "*Flow above intakes.pfs*"; however, for stream catchments where the last intake is a significant distance upstream of the mouth (e.g. Vernon Creek above Wood Lake, Mission Creek, Powers Creek, and Rose Valley Lake), the inflow below the last intake is accounted for by individual *.pfs files, which are included in individual *.csv files within the OHCM.

Example Extraction and Associated Calculations (Mission Creek)

The following provides an example of the extraction process and subsequent calculations for the Mission Creek stream catchment; the general process is applied in the other major stream catchments for the OHCM. Within the Mission Creek stream catchment, there are three principal intakes (Figure B-2):

1. BMID1;
2. SEKID1; and
3. Mission Other Licenses.

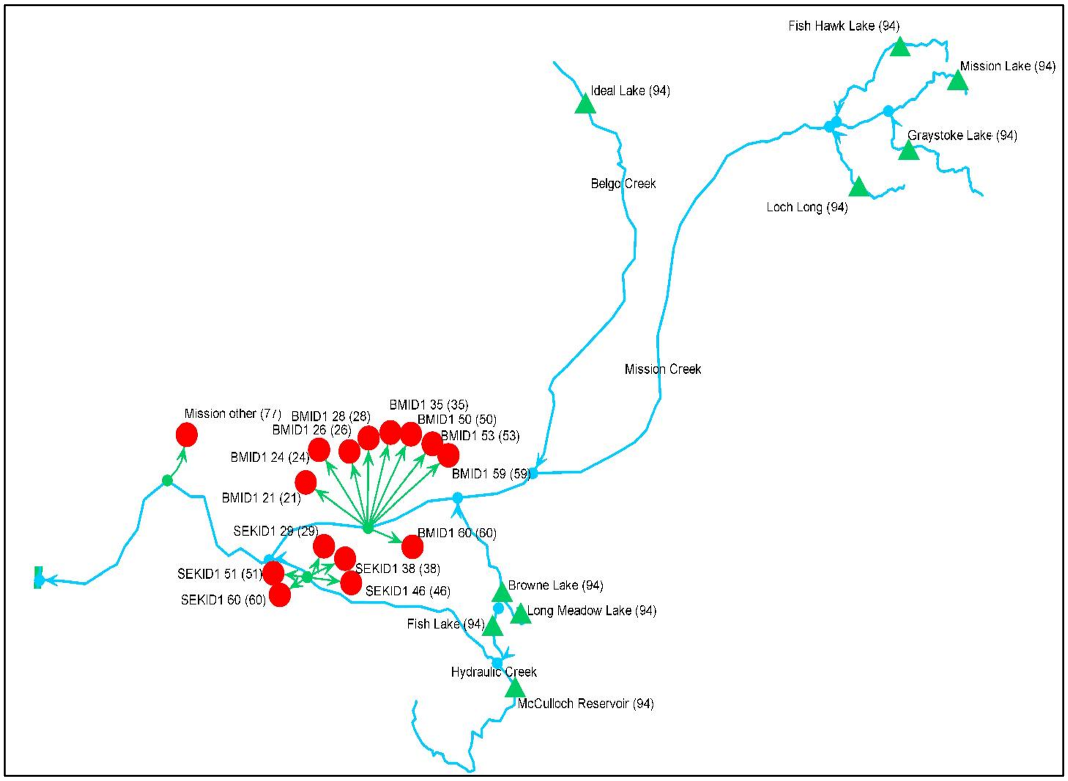


Figure B-2 General Layout of the Mission Creek Catchment within the OHCM.

Since the 'Mission Other Licences' intake is a significant distance upstream from the mouth of the catchment, inflows for the reach below this intake are accounted for in a *.pfs file named "*Flows_below_Intakes_Mission.pfs*". The formula for this inflow calculation is $Q_{Inflow} = Q_{mission\ outlet}$[1] - Q_{other}, where inflows in the reach below the 'Mission Other licences" intake (Q_{Inflow}) is equal to the discharge at the Q-Point at the mouth of Mission Creek ($Q_{mission\ outlet}$) minus the discharge at the Q-point where the 'Mission Other Licences' intake is located (Q_{other}). The same approach is applied to other catchments where the last intake is located a significant distance upstream from the mouth of the catchment.

[1] $Q_{mission\ outlet}$ =discharge at the outlet of Mission Creek (at river branch chainage 69,203.1 m).

For inflows to the other intakes in the Mission Creek stream catchment (i.e. BMID1 and SEKID1), inflows above the intakes are required. These inflows include: (1) inflows in the reach below upland reservoirs (i.e. Ideal Lake, Fishhawk Lake, Mission Lake, Graystoke Lake, Loch Long Lake, and Browne Lake) and above intake 'BMID1', (2) inflows in the reach below McCulloch Lake and Fish Lake and above the intake 'SEKID1', and (3) flows in the reach between the intakes 'BMID1', 'SEKID 1', and 'Mission Other Licences'. The following provides a detailed description of how these inflows are calculated. The same approach is used in other catchments for calculation of inflows above intakes.

(1) *Flows in the reach below the upland reservoirs and above intake 'BMID1'*

The inflow at 'BMID1' is calculated as the total inflow up to the intake, which includes all inflows upstream of the intake minus all the other calculated inflows accounted for in upstream Q-points. Since inflows to the upland reservoirs have already been considered (Section 1.3.2), the inflow between the upland reservoirs and intake 'BMID1' is calculated as:

$$Q_{\text{Inflow}} = Q_{\text{BMID1}} - Q_{\text{Ideal Lake}} - Q_{\text{Fishhawk Lake}} - Q_{\text{Mission Lake}} - Q_{\text{Graystoke Lake}} - Q_{\text{LochlLong Lake}} - Q_{\text{Browne Lake}}$$

where Q_{BMID1} is the inflow at the 'BMID1' Q-point, and $Q_{\text{Name of Lake}}$ is the inflow at the Q-point where each lake is located.

(2) Flows in the reach below McCulloch Reservoir and Fish Lake and above 'SEKID1' intake

The inflow at the 'SEKID1' intake is the total inflow up to this point, which includes all flows above the intake minus all the other calculated inflows accounted for by upstream Q-points. Since inflows to the upland reservoirs have been considered, the inflow between upland reservoirs and intake 'SEKID1' is calculated as:

$$Q_{\text{Inflow}} = Q_{\text{SEKID1}} - Q_{\text{McCulloch Reservoir}} - Q_{\text{Fish Lake}}$$

where Q_{SEKID1} is the inflow at the 'SEKID1' Q-point, and $Q_{\text{Name of Lake}}$ is the inflow at the Q-point where each lake is located.

(3) Flow in the reach between 'BMID1', 'SEKID1', and 'Mission Other Licences'

The inflow at the intake 'Mission Other Licences' is the total inflow up to this intake including all flows above this point minus all the other calculated inflows accounted for by upstream Q-points. Since inflows up to intakes 'BMID1' and 'SEKID1' have been considered (see above), the inflow between intakes 'BMID1', 'SEKID1', and 'Mission Other Licences' is calculated as:

$$Q_{\text{Inflow}} = Q_{\text{Mission Other Licences}} - Q_{\text{BMID1}} - Q_{\text{SEKID1}}.$$

where $Q_{\text{Mission Other Licences}}$ is the inflow at the 'Mission Other Licences' Q-point, and $Q_{\text{Name of Intake}}$ is the inflow at the Q-point where each intake is located.

1.3.4 Mainstem Lakes

The mainstem lakes within the OHCM, are Kalamalka, Okanagan, Skaha, Vaseux, and Osoyoos Lakes; and data extractions from the OWAM are organized based on each lake. Inflows into the mainstem lakes include contributions from modeled and non-modeled stream catchments, as well as natural lateral flows from the OWAM not accounted for by the stream catchments. Inflows from modeled/non-modeled stream catchments to the mainstem lakes are included directly (Section 1.3.1), while natural lateral flows are accounted for separately. These additional lateral flows include overland flow, interflow, and baseflow (i.e. the deeper groundwater flow component in the OWAM).

For each mainstem lake, except Okanagan Lake, the total natural inflow is the sum of the three lateral flows at all points along the full length of the lake. For each lake, a *.pfs file was created that extracts the lateral inflows from the additional MIKE 11 results files (*HDADD.res11) discussed earlier (Section 1.3.1). For Okanagan Lake, due to the size of the lake and number of Q-Points, *.pfs files were required for each of the three lateral flows. By using three *.pfs files, the extracted files are more manageable. Once the data is extracted from the OWAM, all of the natural lateral inflows for the mainstem lakes are included in *.csv files within the OHCM.

1.3.5 Okanagan River

Within the OHCM, the Okanagan River is divided into four (4) segments:

1. Okanagan River below Okanagan Lake;
2. Okanagan River below Skaha Lake;
3. Okanagan River below Vaseux Lake; and
4. Okanagan River near Oroville.

Similar to the mainstem lakes, inflows to the Okanagan River include contributions from modeled and non-modeled stream catchments, as well as natural lateral flows from the OWAM not accounted for by the stream catchments. Inflows from modeled/non-modeled stream catchments to the Okanagan River are included directly (Section 1.3.1 and 1.3.6), while natural lateral flows are accounted for separately. The total natural lateral inflow is the sum of the three lateral flows (overland flow, interflow and baseflow) at all points along each reach of the Okanagan River. For each reach, a *.pfs file was created to extract all three lateral inflows from the additional MIKE 11 results file (*HDADD.res11). Once the data is extracted from the OWAM, all of the natural lateral inflows for the Okanagan River reaches are included in *.csv files within the OHCM.

1.3.6 Non-modeled Stream Catchments

As noted earlier (Section 1.3.1), only the stream catchments with major water utility intakes and upland reservoirs were explicitly modeled in the OHCM. The extraction of inflows from these catchments has previously been described. Inflows to the mainstem lakes and Okanagan River, for those catchments without major intakes or upland reservoirs (i.e. non-modeled tributaries), were included in the OHCM by using the net flows at their mouths (as calculated in the OWAM). The net flows were extracted from the OWAM (including water extractions and reservoir operations) using the standard MIKE 11 results file.

For each mainstem lake, the sum of the net inflows of catchments that flow into the lake was calculated and associated with a single branch flowing into a mainstem lake or a reach of Okanagan River or Vernon Creek. Table B-1 provides the names of the branch/reach to which the net inflows are associated within the OHCM and the branches in MIKE 11 where the sum of the net inflows is calculated for each mainstem lake.

Table B-1 Summary of Branches with which the Net Inflows of Non-Modeled Catchments are Associated.

Lake Name	Branch in the OHCM	Branches in MIKE 11 (where sum of net flows are calculated)
Kalamalka Lake	Vernon Creek Below Oyama Creek Inflow	Boltres Creek, Cosens Creek, Kalamalka West
	Vernon Creek Below Ellison Lake Inflow	Ribbleworth Creek
Okanagan Lake	Okanagan River Below Penticton Creek Inflow	Deep Creek, Nashwito Creek, Equesis Creek, Whitemans Creek, Shorts Creek, Bellevue Creek, McDougall Creek, Naramata Creek, Turnbull Creek, Residual areas W-1 to W-13, Residual Areas E-1 to E-9
Skaha Lake	Marron River	Shingle Creek, Marron River, Residual Area W-14 to W-17, Residual Area E-10 to E-11
Vaseux Lake	E-12 Reach	Shuttleworth Creek, Residual Area W-18 to W-19, Residual Area E-12
Osoyoos Lake	Inkaneep Creek	Vaseux Creek, Park Rill, Wolfcub Creek, Testlinden Creek, Inkaneep Creek, Residua Area W-20 to W-23, Residual Area E-13 to E-17

Two *.pfs files were created for extracting net inflows from the MIKE 11 results file for the OWAM. One file is for the catchments on the mainstem lakes along the Okanagan River (‘*Tributaries_Nodes.pfs*’), the other is for catchments on Kalamalka Lake along Vernon Creek (‘*Inflows_Kalamalka.pfs*’). In addition to these two *pfs files, another *.pfs file for B.X. and Coldstream Creeks (in the Vernon Creek watershed) was created to extract the natural inflows from the standard MIKE 11 results in the OWAM. However, since King Edward Lake is a tributary of Coldstream Creek, whose inflow is already taken into consideration in the upland reservoir inflows (Section 1.3.2), the inflows below this lake and above the mouth of Coldstream Creek are included as follows: $Q_{Inflow} = Q_{outlet} – Q_{King\ Edward\ Lake}$.

Another way to obtain the net inflows for the non-modeled tributaries is to extract the data from the Ok Water Database.

1.4 FILE FORMATING FOR THE OHCM

1.4.1 .pfs Extraction File Format

The *.pfs files are the key files for extracting inflow information from the MIKE 11 results files, as these files define the input, output, data type, and locations of where data is extracted. The *.pfs file is in an ASCII text file format.

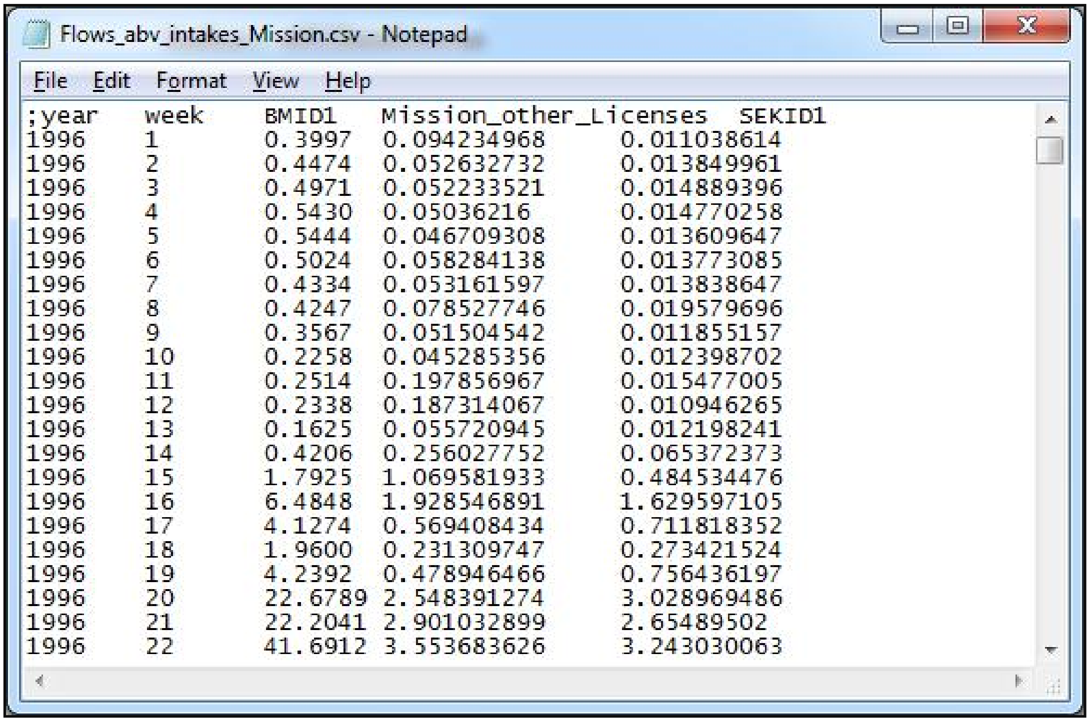
The following provides an example of a *.pfs file that is read by the *AFETDataExtractor* tool for extracting the overland flow into Okanagan Lake. The file path for the Input File must be the full path of the MIKE 11 results file (i.e. *.res11 or *HDADD.res11), where inflow data is extracted. The file path for the Output File must be the full path and file name from where the extracted data (*.dfs0) is saved.

```
 [AFETDataExtractor]
  SIUnits = true
  [DataExtraction]
   InputFile = |F:\OBWB_MSHE_Model_Natural\MIKE11\OKWaterBalance_FV_011HDAdd.res11|
   OutputFile = |F:\OBWB_HCM\Inflow_extraction\Major_Lakes\Okanagan\Okanagan_overflow.dfs0|
   [Item]
     Name = 'Okanagan Lake'
     Branch = 'Okanagan Lake'
     SpecifiedRange = true
     Chainage = 0
     ChainageEnd = 113686.332
     DataType = 'LATERAL INFLOW SHE OVERLAND'
     SpecifiedOperator = false
     Operator = 'AVERAGE'
     units = 'meter'
   EndSect // Item
   EndSect // DataExtraction
EndSect // AFETDataExtractor
```

1.4.2 OHCM Input File Format

The OHCM (i.e. WEAP modeling platform) only accepts input in *.csv file format in a weekly time-step (for this phase of model development). This means that all extracted data from the MIKE 11 results files must be saved to a *.csv format and converted from a 6 hour output time-step to an equivalent weekly value.

Figure B-3 provides an example of the required *.csv input file format. The first two columns represent the year and the week number (i.e. 1 to 52), respectively, while the remaining columns represent the associated data (typically inflow information) for each time-step. The first row of each file contains the header for explanation of each column. The header is not necessary, but if it is present, then it must start with a semi-colon in the beginning of the row. However, in spite of the file requiring a *.csv extension, the columns must be separated by a tab. Accordingly, the file must be 'tab' delimited and not 'comma' delimited, and it must carry the *.csv extension for it to be used in the OHCM. This is accomplished by saving the file as a 'tab' delimited text file in Excel, and then converting the file extension from *.txt to *.csv manually (see next section).


Flows_abv_intakes_Mission.csv - Notepad

File Edit Format View Help

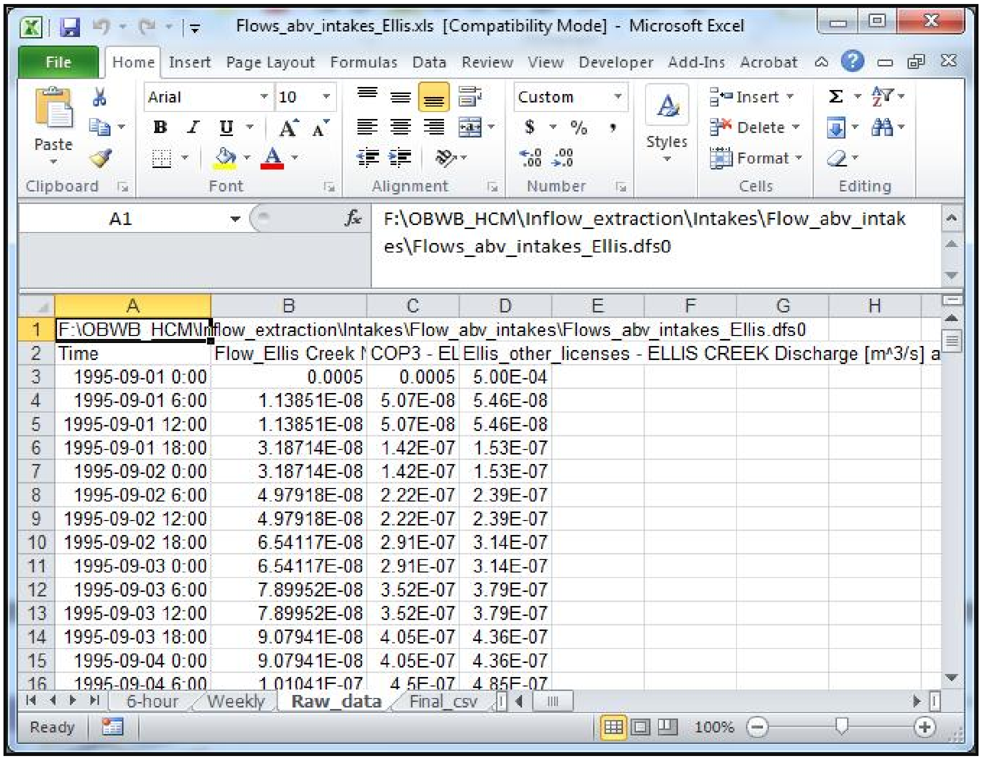
;year	week	BMID1	Mission_other_Licenses	SEKID1
1996	1	0.3997	0.094234968	0.011038614
1996	2	0.4474	0.052632732	0.013849961
1996	3	0.4971	0.052233521	0.014889396
1996	4	0.5430	0.05036216	0.014770258
1996	5	0.5444	0.046709308	0.013609647
1996	6	0.5024	0.058284138	0.013773085
1996	7	0.4334	0.053161597	0.013838647
1996	8	0.4247	0.078527746	0.019579696
1996	9	0.3567	0.051504542	0.011855157
1996	10	0.2258	0.045285356	0.012398702
1996	11	0.2514	0.197856967	0.015477005
1996	12	0.2338	0.187314067	0.010946265
1996	13	0.1625	0.055720945	0.012198241
1996	14	0.4206	0.256027752	0.065372373
1996	15	1.7925	1.069581933	0.484534476
1996	16	6.4848	1.928546891	1.629597105
1996	17	4.1274	0.569408434	0.711818352
1996	18	1.9600	0.231309747	0.273421524
1996	19	4.2392	0.478946466	0.756436197
1996	20	22.6789	2.548391274	3.028969486
1996	21	22.2041	2.901032899	2.65489502
1996	22	41.6912	3.553683626	3.243030063

Figure B-3 An Example of the .csv File Format for the OHCM.

1.4.3 Data Processing

This section details the steps of how data is processed, from extracting it from the OWAM *.dfs0 file generated by the extraction tool to generating the final *.csv file that is read by the OHCM.

The data processing is done using Microsoft Excel. One Excel workbook (e.g. '*Flows_below_Reservoirs.xls*' from the '*inflow_extraction*' folder provided to the OBWB) is used for each *.dfs0 file and each Excel workbook has at least 4 separate worksheets (Figure B-4). These worksheets include: (1) Raw data, (2) 6-hour, (3) Weekly, and (4) Final_csv. The purpose and function of each worksheet is described below.



	A	B	C	D	E	F	G	H
1	F:\OBWB_HCM\Inflow_extraction\Intakes\Flow_abv_intakes\Flows_abv_intakes_Ellis.dfs0							
2	Time	Flow_Ellis Creek I	COP3 - EL	Ellis_other_licenses - ELLIS CREEK Discharge [m^3/s] a				
3	1995-09-01 0:00	0.0005	0.0005	5.00E-04				
4	1995-09-01 6:00	1.13851E-08	5.07E-08	5.46E-08				
5	1995-09-01 12:00	1.13851E-08	5.07E-08	5.46E-08				
6	1995-09-01 18:00	3.18714E-08	1.42E-07	1.53E-07				
7	1995-09-02 0:00	3.18714E-08	1.42E-07	1.53E-07				
8	1995-09-02 6:00	4.97918E-08	2.22E-07	2.39E-07				
9	1995-09-02 12:00	4.97918E-08	2.22E-07	2.39E-07				
10	1995-09-02 18:00	6.54117E-08	2.91E-07	3.14E-07				
11	1995-09-03 0:00	6.54117E-08	2.91E-07	3.14E-07				
12	1995-09-03 6:00	7.89952E-08	3.52E-07	3.79E-07				
13	1995-09-03 12:00	7.89952E-08	3.52E-07	3.79E-07				
14	1995-09-03 18:00	9.07941E-08	4.05E-07	4.36E-07				
15	1995-09-04 0:00	9.07941E-08	4.05E-07	4.36E-07				
16	1995-09-04 6:00	1.01041E-07	4.5E-07	4.85E-07				

Figure B-4 An example of an Excel Spreadsheet used for Data Processing.

Raw Data

This worksheet is where time-series data from the *.dfs0 file is generated by the extraction tool and is brought into Excel using the 'DHI DFS0 Tool[2]'. The 'DHI DFS0 Tool' is a Microsoft Excel Add-in program that is specifically developed for reading .dfs0 data into a spreadsheet.

This worksheet has links with the worksheet labeled '6-hour' so it is important to follow the current format. If there is any modification to this worksheet, make sure to update the other three tabs based on the relationship sequence.

6-Hour Data

Extracted data in the Raw_data worksheet starts from 01/09/1995, but the simulation period in the OHCM starts from 01/01/1996, so this worksheet is used to read data from the Raw_data worksheet, which starts from 01/01/1996. The

[2] The 'DHI DFS0 Tool' can be obtained from DHI Inc. or the OBWB. The DHI DFS0 Tool requires installation of the DHI DFSO Tool.xlam Add-In in Microsoft Excel. Once installed, to ensure the *.dfs0 file is loaded properly, choose cell A1 in a new blank worksheet. Check 'Read DFS0 File' on the tool and click on the 'Open & Read DFS0' button; then choose the *.dfs0 file you want to load. The tool writes the *.dfs0 file path on the first row, and column headers on the second row and then data values starting from the third row. The first column is typically the time-stamp, followed by data values starting from the second column. The column number in the spreadsheet should be the same as that in *.dfs0 file.

other purpose of this worksheet is to do the intermediate calculations required to produce single inflow time series (Section 1.3.3). Data in this worksheet has a 6-hour time-step.

Weekly Data

This worksheet contains an Excel macro that is used to convert the 6-hour time-step data in the '6-hour' worksheet to weekly values. In the 'weekly' worksheet the data column starts in the third column (i.e. column C), as the first column is the time-stamp and the second column is the week interval. These first two columns should never be changed.

The Macro can be accessed from the top menu Developer/Macro. The Macro is described below and if a column number and row number are changed, then two numbers in Macro need to be changed (explained in the green text below).

```
For Col = 3 To 4 'This is the data column number in the Weekly tab (first data column number to last data column number). The last column number needs to be changed if data column number is modified.
initRow = 2
  For Row = 2 To 573 'this is the row number in the Weekly tab (first data row number to last data row number). The last row number needs to be changed if data row number is modified (i.e. time axis is modified).
    Count = Worksheets("Weekly").Cells(Row, 2).Value
    tot = 0#
      For cnt = 0 To ((Count * 4) - 1)
        tot = tot + Worksheets("6-hour").Cells(initRow + cnt, Col - 1).Value
       Next cnt
    Worksheets("Weekly").Cells(Row, Col).Value = tot / (Count * 4)
  initRow = initRow + (Count * 4)
 Next Row
Next Col
```

*Final *.csv Data*

In this worksheet, the first row is the header with data values starting in the second row. The first column is the year and the second column is the week number (i.e. 1 to 52). The data values start in the third column and should be the same as those in 'weekly' worksheet. The data values can be copied from the 'weekly' worksheet or can be linked directly from the 'weekly' worksheet.

Once the input data is in the correct format (Figure B-5), the data is now ready to be converted to the *.csv format that the WEAP modeling platform and the OHCM can accept (Section 1.4.2). First, convert the 'Final_csv' worksheet active to text (tab delimited) format (*.txt). Once complete, open the text file (using Wordpad or equivalent) and insert a semi-color (;) in front of the first word "year" in the header; this indicates to the OHCM that the first row is the header row. Once saved, the *.txt must be changed to *.csv by simply changing the *.txt extension to *.csv in Windows Explorer. Finally, please note that if any *.csv file names are changed, the associated link in the OHCM will also require updating.

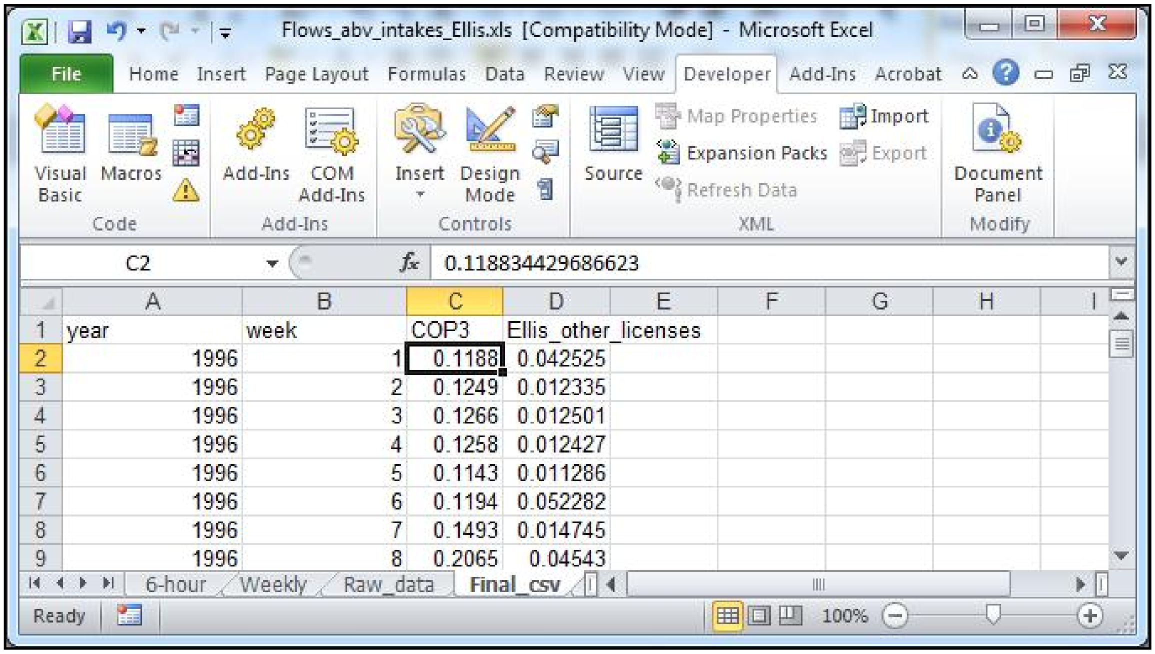


Figure B-5 Example of Final_csv Data for Conversion to OHCM File Format.

B

Appendix B1 - Data Extraction Tool

AFET Data Extractor – Input, output, and program execution instructions

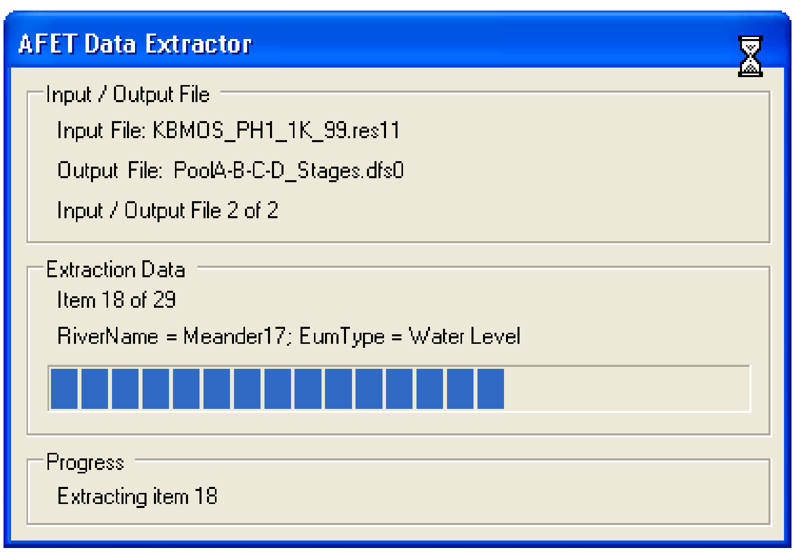
The AFETDataExtractor program is written in C# and uses a DHI pfs file to specify input parameters. A DHI pfs file is similar to an xml file but was selected for this executable because of the availability of a COM pfs library that could be accessed from C#. Similar to xml files, all data tags in the AFETDataExtractor input pfs file are CASE SENSITIVE.

The AFETDataExtractor program can be run from the command line, run by double-clicking on the AFETDataExtractor.exe binary file, or using the Run option in Windows. The AFETDataExtractor program can accept the name of the input pfs file as a command line argument using the following syntax:

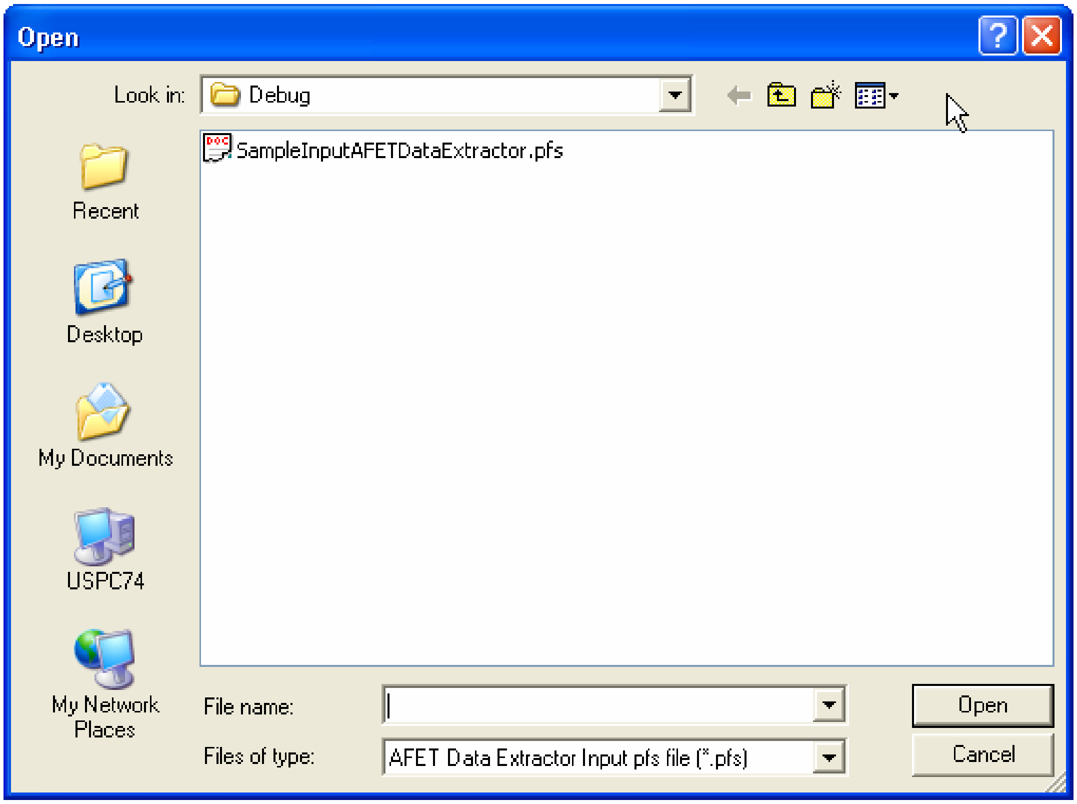
```
AFETDataExtractor.exe –d –s SampleInputAFETDataExtractor.pfs
```

The –d command line argument is OPTIONAL and if omitted, prevents creation of a log file that summarizes program inputs, progress, and errors encountered during execution. The OPTIONAL log file has the same name as the AFETDataExtractor input pfs file with a *.sum file extension.

The –s command line argument is OPTIONAL and causes the program to run in silent mode without a progress bar showing how many extractions from individual MIKE SHE / MIKE 11 files have been made. An example of the progress bar that is displayed when the –s command line argument is not specified is shown below.



If the AFETDataExtractor program is run by double-clicking on the AFETDataExtractor.exe binary file or without the AFETDataExtractor input pfs file as a command line argument a standard Open File Dialog will open and allow the user to navigate to and select the desired AFETDataExtractor input pfs file. An example of the Open File Dialog is shown below.



An example of a DHI pfs file for the AFETDataExtractor program is given below. The example pfs file is configured to extract one item from an existing dfs0 file and write the results in another dfs0 file.

```
[AFETDataExtractor]
   SIUnits = true
   [DataExtraction]
      InputFile = |.\Test.dfs0|
      OutputFile = |.\S-65_DTSFlow.dfs0|
      [Item]
         Name = 'S-65 From dfs0'
         item = 1
         x = 1000.21
         y = 5021.35
         layer = 2
         Branch = 'C-38'
         SpecifiedRange = false
         Chainage = 1000.0
         ChainageEnd = 2000.0
         DataType = 'DISCHARGE'
         SpecifiedOperator = false
         Operator = 'SUM'
         units = ‘meter’
      EndSect  // Item

   EndSect  // DataExtraction

EndSect  // AFETDataExtractor
```

AFETDataExtractor input pfs file keyword data types.

There are several keyword data types that have specific requirements. Failure to meet the requirements for keyword data types will result in the program returning an error condition (which is reported to the debug file, if created) and failure to perform extractions from a MIKE SHE / MIKE 11 result file or extract an individual item from a specified MIKE SHE / MIKE 11 result file.

(BOOLEAN)	Valid values are **true** and **false**. BOOLEAN data should not be enclosed in quotes.
(FILENAME)	Input and output filenames need to be enclosed between two | characters (*e.g.,* |c:\temp\Test.dfs0|). Filenames can be specified using absolute or relative paths. If relative file names (relative to the input pfs file) are used, standard Windows command line syntax is used to locate directories within (.\) and outside (..\) of the directory containing the input pfs file.
(STRING)	STRING data must be enclosed in quotes (*e.g.,* 'DISCHARGE').
(INTEGER)	INTEGER data must be represented in integer (*e.g.,* 1, 2, 3, *etc.*). INTEGER data should not be enclosed in quotes.
(FLOAT)	FLOAT data must be represented in real (*e.g.,* 1.25) or exponential (1.25e+00) format. FLOAT data should not be enclosed in quotes.

Specific instructions for AFETDataExtractor input pfs file sections and keywords.

The following sections and keywords need to be specified in the input pfs file and meet the keyword data constraints indicated above. Sections and keywords are identified with blue and green text, respectively, in the following section. Specific keywords required for a data extraction item are a function of the MIKE SHE / MIKE 11 result file specified as the input file.

[AFETDataExtractor]	The AFETDataExtractor section is the main tag in AFETDataExtractor input pfs file. Each AFETDataExtractor input pfs file need to have only one AFETDataExtractor section.
SIUnits	SIUnits parameter defines whether results from the AFETDataExtractor program should be reported in SI or English units. Results will be in SI units if parameter is true and in English units if parameter is false. (BOOLEAN)

Repeat [DataExtraction] section for each MIKE SHE and/or MIKE 11 output file to process.

[DataExtraction]	A DataExtraction section defines a series of extractions that will be performed on a specified existing data file. Any number of DataExtraction sections can be included in the AFETDataExtractor pfs file. For example you could include two (2) DataExtraction sections to extract data from a dfs0 file and a dfs3 file.
InputFile	The name of the file to extract data from. Valid file types include *.dfs0, *.dfs2, *.dfs3, and *.res11. The file type determines the data (dfs0, dfs2, dfs3, and res11 files) required in each Item section in a DataExtraction section. (FILENAME)
OutputFile	User specified output file name. The OutputFiles can either be *.dfs0, *.csv files, or *.dat file. The format of the AFETExtractor output files are summarized in the Output File Formats section below. The OutputFile parameter is required for each DataExtraction section. (FILENAME)

Repeat [Item] section for each item to extract from the MIKE SHE and/or MIKE 11 output file (InputFile) identified in the [DataExtraction] section.

[Item]	Each Item section defined the data that will be extracted from the InputFile defined in the DataExtraction section. Any number of Item sections can be included in the DataExtraction section. For example, you could include two (2) Item sections to extract data from two item (columns) in a dfs0 file.
Name	User specified name of extracted time series. The Name is written to the output file to identify the data item. The Name parameter is required for all InputFile types. (STRING)
item	The item to extract from the specified InputFile. The item parameter only needs to be specified for *.dfs0, *.dfs2, and *.dfs3 files. All typical MIKE SHE output data types are supported. (INTEGER)
x	Actual x coordinate of the point to extract result data. The x coordinate value should be consistent with the defined units for the item. Data will not me extracted for the Item if the x coordinate is outside of the domain defined by the dfs2 or dfs3 file. The x coordinate parameter only needs to be specified for *.dfs2 and *.dfs3 files. (FLOAT)
y	Actual y coordinate of the point to extract result data. The y coordinate parameter value should be consistent with the defined units for the item. Data will not me extracted for the Item if the y

	coordinate is outside of the domain defined by the dfs2 or dfs3 file. The y coordinate parameter only needs to be specified for *.dfs2 and *.dfs3 files. (FLOAT)
layer	Layer of the point to extract result data. Valid layer values range from one (1) for the upper MIKE SHE layer to the maximum number of layers in the MIKE SHE setup. Data will not be extracted for the Item if the specified layer parameter exceeds the dimensions of the MIKE SHE model (layer <= 0, number of layers + 1, *etc.*). The layer parameter only needs to be specified for *.dfs3 files. (INTEGER)
Branch	Exact name of the MIKE 11 branch to extract data for. The Branch parameter is case in-sensitive and only needs to be specified for *.res11 files. (STRING)
SpecifiedRange	SpecifiedRange parameter defines whether MIKE 11 results will be extracted for a range of chainage values in the defined MIKE 11 Branch. The SpecifiedRange parameter only needs to be specified for *.res11 files. (BOOLEAN)
Chainage	Chainage value to extract data from the user specified MIKE 11 Branch. The program will find the closest chainage to the specified value. If the SpecifiedRange parameter is true the Chainage parameter represents the starting chainage value. The Chainage parameter value should be consistent with the defined units for the item. Data will not me extracted for the Item if the Chainage parameter is outside of the range of chainage values stored in the *res11 file for the Branch. The Chainage parameter only needs to be specified for *.res11 files. (FLOAT)
ChainageEnd	Ending chainage value of the defined range to extract data from the user specified MIKE 11 Branch. The program will find the closest chainage to the specified value. The ChainageEnd parameter value should be consistent with the defined units for the item. Data will not me extracted for the Item if the ChainageEnd parameter is outside of the range of chainage values stored in the *res11 file for the Branch. The ChainageEnd parameter only needs to be specified for *.res11 files and when the SpecifiedRange parameter is true. (FLOAT)
DataType	DataType to extract from the specified chainage (or range of chainage values) of the specified MIKE 11 branch. Valid options are “WATER LEVEL”, “DISCHARGE”, “VOLUME”, “VELOCITY”, “MASS ERROR”, “GATE LEVEL”, “STRUCTURE VELOCITY”, “STRUCTURE AREA”, “STRUCTURE DISCHARGE”, “LATERAL INFLOW SHE OVERLAND”, “LATERAL INFLOW SHE DRAIN”, and “LATERAL INFLOW SHE BASEFLOW”. For structure data (“GATE LEVEL”, “STRUCTURE VELOCITY”, “STRUCTURE

	AREA", and "STRUCTURE DISCHARGE"), the structure ID defined in the MIKE 11 network file also needs to be specified for the DataType (*e.g.,* GATE LEVEL S65_ZONEA). Because storage of structure data in the res11 file is different than data storage for data stored at H and Q points (*e.g.,* "WATER LEVEL", "DISCHARGE", "VELOCITY", *etc.*) the entire res11 file is read into memory prior to processing and may cause the AFETDataExtractor program to fail on large MIKE 11 result files (> 500 MB). The DataType parameter only needs to be specified for *.res11 files. (STRING)
SpecifiedOperator	SpecifiedOperator parameter defines whether MIKE 11 results will be operated on. The SpecifiedOperator parameter only needs to be specified for *.res11 files. (BOOLEAN)
Operator	Operator parameter defines whether MIKE 11 results will be operated on. Valid Operator parameters are "SUM", "AVERAGE", "MINIMUM", and "MAXIMUM". The "SUM" Operator sums all of the values over the defined range of chainage values for the specified MIKE 11 branch. The "AVERAGE" Operator averages all of the values over the defined range of chainage values for the specified MIKE 11 branch. The "MINIMUM" and "MAXIMUM" Operators determines the minimum and maximum values, respectively, in the defined range of chainage values for the specified MIKE 11 branch. The SpecifiedRange parameter only needs to be specified for *.res11 files, when the SpecifiedRange is true, and when the SpecifiedOperator parameter is true. (STRING)
units	units of the x and y locations or Chainage values of the point to extract data for. The unit parameter only needs to be specified for *.dfs2, *.dfs3, and *.res11 files. Valid options are 'meter' for meters and 'feet' for feet. (STRING)

<u>Output File Formats</u>

The formats of the output files created by the AFETDataExtractor program are summarized below. The output file created by the AFETDataExtractor program is determined by the file extension of file identified by the OutputFile parameter in the [DataExtraction] section.

***.dfs0**	A standard binary DHI *.dfs0 file is created.

***.csv** A comma spaced value ASCII file with the following format is created.

```
Date,KARUP RIVER Water Level [m] at 28450 m,KARUP RIVER Discharge [m^3/s] at 28550
  m,KARUP RIVER AVERAGE of Discharge [m^3/s] from 28475 to 30528 m,KARUP RIVER SUM of
  Discharge [m^3/s] from 0 to 52000 m
2/1/1970 00:00:00,30.44643,0,0,0
2/13/1970 00:00:00,31.1626,6.150805,5.443101,75.80505
2/25/1970 00:00:00,31.10328,5.170284,4.595663,62.90651
3/9/1970 00:00:00,31.06908,4.629899,4.130964,56.05199
3/21/1970 00:00:00,31.07765,4.615868,4.144041,56.78234
4/2/1970 00:00:00,31.08772,4.657446,4.200656,58.22448
4/14/1970 00:00:00,31.07845,4.523661,4.087785,57.00141
4/26/1970 00:00:00,31.08721,4.582464,4.154398,58.70578
5/8/1970 00:00:00,31.05706,4.217819,3.821274,53.08071
5/20/1970 00:00:00,31.03399,3.931323,3.562574,49.07699
                                             .
                                             .
                                             .
```

***.dat** A tab-delimited ASCII file with the following format is created.

```
YEAR
MONTH
DAY
HOUR
MINUTE
SECOND
KARUP RIVER SUM of Lateral Inflow SHE Drain [m^3/s] from 0 to 52000 m
KARUP RIVER AVERAGE of Lateral Inflow SHE Overland [m^3/s] from 0 to 52000 m
DATA
1970	2	1	0	0	0	0	0
1970	2	12	18	0	0	0.5442975	0
1970	2	24	18	0	0	0.3439001	0
1970	3	8	18	0	0	0.2816568	0
1970	3	20	18	0	0	0.4987281	0
1970	4	1	18	0	0	0.7043925	0
1970	4	13	18	0	0	0.719947	0
1970	4	25	18	0	0	0.8947854	0
1970	5	7	18	0	0	0.5863445	0
1970	5	19	18	0	0	0.4476901	0
                                             .
                                             .
                                             .
```

B

Appendix B2 - Inflow Extraction Points

Table B2-1 Summary of Inflow Extraction Points (Q-Points) at the 48 Upland Reservoirs.

Reservoir	Watershed	Water Supplier	Branch Name	Q-point (m)	Note
Moore Lake	Kelowna (Mill) Creek	GEID	Moore Lake	3233.92	
South Lake	Kelowna (Mill) Creek	GEID	South Lake	5868.46	
Postill Lake	Kelowna (Mill) Creek	GEID	Mill Creek	5171.58	
Peachland Lake	Peachland Creek	District of Peachland	Peachland Creek	9376.67	
Crooked Lake	Vernon Creek	District of Lake Country	Vernon Creek Above Wood Lake	10765.98	
Swalwell Lake	Vernon Creek	District of Lake Country	Vernon Creek Above Wood Lake	15072.37	Crooked Lake is directly above Swalwell Lake (H-point in between) (=$Q_{Swalwell}$ - $Q_{Crooked}$)
Oyama Lake	Vernon Creek	District of Lake Country	Oyama Creek	4574.13	
Ellison Lake	Vernon Creek		Ellison Lake	4311.65	
King Edward Lake	Vernon Creek	Greater Vernon Water	King Edward Lake	6343.28	
Swan Lake	Vernon Creek		Greenhow Creek	10606.05	Goose Lake is directly above Swan Lake (=Q_{Swan} - Q_{Goose})
Goose Lake	Vernon Creek	Greater Vernon Water	Goose Lake	2577.71	
Long Meadow Lake	Mission Creek	SEKID	Grouse Creek	447.25	
Browne Lake	Mission Creek	SEKID	Grouse Creek	2236.26	Long Meadow Lake is directly above Browne Lake (Q =Q_{Browne} - $Q_{LongMeadow}$)
Fish Lake	Mission Creek	SEKID	Fish Lake	707.96	
McCulloch	Mission Creek	SEKID	Hydraulic Creek	11189.17	
James Lake	Kelowna (Mill) Creek	BMID	James Lake	2490.49	
Fish Hawk	Mission Creek	BMID	Fish Hawk Creek	3469.09	
Graystoke Lake	Mission Creek	BMID	Loch Katrine Creek	6650.29	
Mission Lake	Mission Creek	BMID	Mission Creek	1514.98	
Ideal Lake	Mission Creek	BMID	Belgo Creek	2319.12	
Loch Long	Mission Creek	BMID	Stanley Creek	2340.67	
Ellis Creek No. 4	Ellis Creek	City of Penticton	Ellis Creek	10059.55	
Greyback	Penticton Creek	City of Penticton	Penticton Creek	6866.1	
Rose Valley Lake	Diversion from Lambly Creek	LID	Rose Valley Lake	3575.76	
Big Horn Reservoir	Lambly Creek	LID	Terrace Creek	6129.7	
Tadpole Lake	Lambly Creek	WID	North Lambly Creek	693.02	
Paynter Lake	Powers Creek	WID	Paynter Lake	3971.61	
Lambly Lake	Powers Creek	WID	Lambly Lake	9008.95	
Jackpine Lake	Powers Creek	WID	Jackpine Lake	1913.49	
West Lake	Powers Creek	WID	West Lake	182.1	
Dobbin Lake	Powers Creek	WID	Powers Creek	1006.54	Q=Q_{Dobbin} - Q_{West}
Islaht Lake	Powers Creek	WID	Islaht Lake	1990.93	
Headwaters Lake No. 4	Trout Creek	District of Summerland	Murray Tree Creek	6628.62	

Table B2-1 Cont'd.

Reservoir	Watershed	Water Supplier	Branch Name	Q-point (m)	Note
Headwaters Lake No. 3	Trout Creek	District of Summerland	Headwater Reservoir #3	4171.96	
Headwaters Lake No. 2	Trout Creek	District of Summerland	Headwater Reservoir #2	369.81	
Headwaters Lake No. 1	Trout Creek	District of Summerland	Trout Creek	2260.7	$Q = Q_{No.1} - Q_{No.3} - Q_{No.2} - Q_{No.4}$ (Note: Number beside Q refers to Headwater Reservoir number)
Munro Lake	Eneas Creek	District of Summerland	Munro Lake	511.5	
Whitehead Lake	Trout Creek	District of Summerland	Whitehead Lake	4068.26	
Tsuh Lake	Trout Creek	District of Summerland	Tsuh Lake	845.23	
Isintok Lake	Trout Creek	District of Summerland	Isintok Creek	4644.25	
Darke Lake	Trout Creek	Meadow Valley Irrigation District	Darke Lake	4857.45	
Crescent Lake	Trout Creek	District of Summerland	Crescent Creek	8111.77	
Big Eneas Lake	Eneas Creek	District of Summerland	Eneas Lake	2023.15	
Garnet Lakes	Eneas Creek	District of Summerland	Eneas Creek	12932.71	Eneas Lake is directly above Garnet Lake ($=Q_{Garnet} - Q_{Eneas}$)
Big Meadow Lake	Chute Creek	Regional District Okanagan-Similkameen	Chute Creek	2102.95	
Eleanor Lake	Robinson Creek	Regional District Okanagan-Similkameen	Robinson Creek	467.01	
Naramata Lake	Robinson Creek	Regional District Okanagan-Similkameen	Robinson Creek	1401.03	Eleanor Lake is directly above Naramata Lake ($=Q_{Naramata} - Q_{Eleanor}$)
Thirsk	Trout Creek	District of Summerland	Trout Creek	26682.02	Natural flows from MIKE SHE plus tributary inflows

Table B2-2 Summary of Inflow Extraction Points (Q-Points) at Intakes.

Intake ID	Stream Name	Q-point (m)	Flow Above Intakes	Flow Below Intakes
BMID1	Mission Creek	47317	$Q = Q_{BMID1} - Q_{Mission\ Lake} - Q_{Ideal\ Lake} - Q_{Fishhawk\ Lake} - Q_{Graystroke\ Lake} - Q_{LochLong\ Lake} - Q_{Browne\ Lake}$	
BMID2	James Lake	12452.5	$Q = Q_{BMID2} - Q_{James\ Lake}$	
COP1	Penticton Creek	20900.7	$Q = Q_{COP1} - Q_{Greyback\ Lake}$	
COP3	Ellis Creek	23500.3	$Q = Q_{COP3} - Q_{Ellis\ Lake\ No.4}$	
DLC1	Vernon Creek above Wood Lake	23685.2	$Q = Q_{DLC1} - Q_{Swalwell\ Lake}$	$Q = (Q_{Vernon\ Creek\ abv\ Wood\ Lake\ Mouth})$[3] $- Q_{DLC1} - Q_{Ellison\ Lake}$
DLC2	Oyama Creek	11892.7	$Q = Q_{DLC2} - Q_{Oyama\ Lake}$	
DOP1	Peachland Creek	27963.7	$Q = Q_{DOP1} - Q_{Peachland\ Lake}$	
DOP2	Trepanier Creek	22028.1	$Q = Q_{DOP2}$	
DOS1	Trout Creek	62205.2	$Q = Q_{DOS1} - Q_{MVID1} - Q_{Thirsk\ Lake} - Q_{Isintok\ Lake} - Q_{Tsuh\ Lake}$	
DOS2	Eneas Creek	27583.3	$Q = Q_{DOS2} - Q_{Garnet\ Lake}$	
ELLIS_OTHER LICENCES	Ellis Creek	27263.2	$Q = Q_{Other} - Q_{COP3}$	
ENEAS_OTHER LICENCES	Eneas Creek	27583.3	$Q = Q_{DOS2} - Q_{Garnet\ Lake}$	
GEID1	Mill Creek	20521.6	$Q = Q_{GEID1} - Q_{Moore\ Lake} - Q_{Postill\ Lake} - Q_{South\ Lake}$	
GID1	Irish Creek	3009.97	$Q = Q_{GID1}$	
IRISH_OTHER LICENCES	Irish Creek	9029.92	$Q= Q_{Other} - Q_{GID1}$	
KELOWNA_OTHER LICENCES	Mill Creek	38585.8	$Q = Q_{Other} - Q_{BMID2} - Q_{GEID1}$	
LAMBLY_OTHER LICENCES	Lambly Creek	17364.6	$Q = Q_{Other} - Q_{Big\ Horn\ Lake} - Q_{Tadpole\ Lake}$	

[3] $Q_{Vernon\ Creek\ abv\ Wook\ Lake\ Mouth}$ is discharge at the mouth of Vernon Creek above Wook Lake at chainage 31420.8 m.

Table B2-2 Cont'd.

Intake ID	Stream Name	Q-point (m)	Flow Above Intakes	Flow Below Intakes
LID1	Rose Valley Lake	5959.6	$Q = Q_{LID1} – Q_{Rose\ Valley\ Lake}$	$Q = (Q_{W\text{-}7\ Reach1\ Outlet})^{4} - Q_{LID1}$
MISSION_OTHER LICENCES	Mission Creek	61124.3	$Q = Q_{Other} - Q_{BMID1} - Q_{SEKID1}$	$Q = (Q_{Mission\ outlet})^{5} - Q_{Other}$
MVID1	Darke Creek	13353.6	$Q = Q_{MVID1} - Q_{Darke\ Lake} - Q_{Munro\ Lake}$	
PEACHLAND_OTHER LICENCES	Peachland Creek	30576.2	$Q = Q_{Other} - Q_{DOP1}$	
PENTICTON_OTHER LICENCES	Penticton Creek	28832.2	$Q = Q_{Other} - Q_{COP1}$	
POWERS_OTHER LICENCES	Powers Creek	27949.5	$Q = Q_{Other} - Q_{WID1}$	$Q = (Q_{Powers\ outlet})^{6} - Q_{Other}$
SEKID1	Hydraulic Creek	24992.1	$Q = Q_{SEKID1} - Q_{McCulloch\ Lake}$	
TREPANIER_OTHER LICENCES	Trepanier Creek	27888.9	$Q = Q_{Other} - Q_{DOP2}$	
TROUT_OTHER LICENCES	Trout Creek	73860.8	$Q = Q_{Other} - Q_{DOS1}$	
VERNMOUTH_OTHER LICENCES	Vernon Creek at outlet	14222.4	$Q = Q_{Other} - Q_{Swan\ Lake} – (Q_{Kalamalka\ Outlet})^{7}$	
WID1	Powers Creek	22098.9	$Q = Q_{WID1} - Q_{Dobbin\ Lake} - Q_{Lambly\ Lake} - Q_{Jackpine\ Lake} - Q_{Paynter\ Lake} - Q_{Islaht\ Lake}$	

[4] $Q_{W\text{-}7\ Reach1\ Outlet}$ is the discharge at the outlet of W-7 Reach1 at chainage 2955.72 m.
[5] $Q_{Mission\ Outlet}$ is the discharge at the outlet of Mission Creek at chainage 69203.1 m.
[6] $Q_{Powers\ Outlet}$ is the discharge at the outlet of Powers Creek at chainage 29899.7 m.
[7] $Q_{Kalamalka\ Outlet}$ is the discharge at Kalamalka Lake outlet at Q-point of 15935.6 m.

C Appendix C - Selected OHCM Results

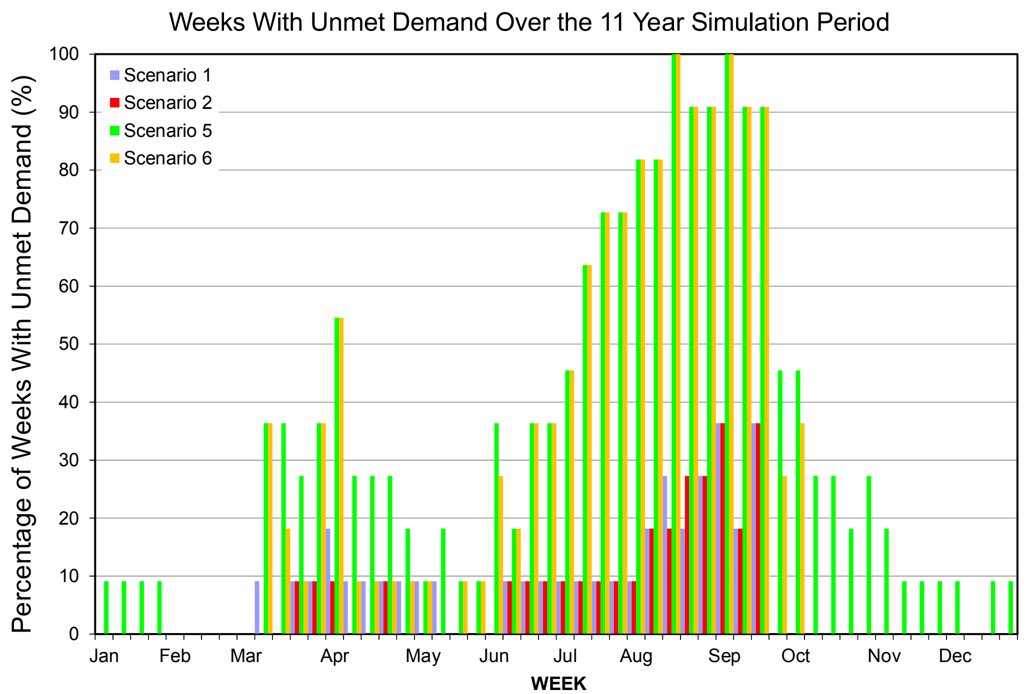


Figure A: Unmet Demand for BMID for Scenarios 1, 2, 5, and 6

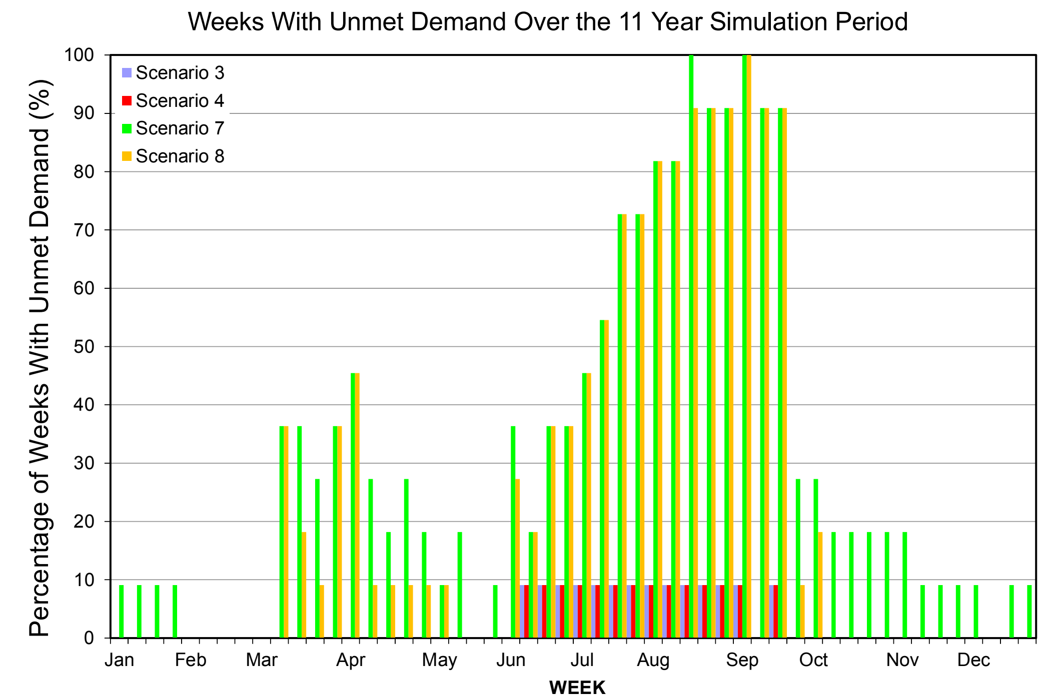


Figure B: Unmet Demand for BMID for Scenarios 3, 4, 7, and 8

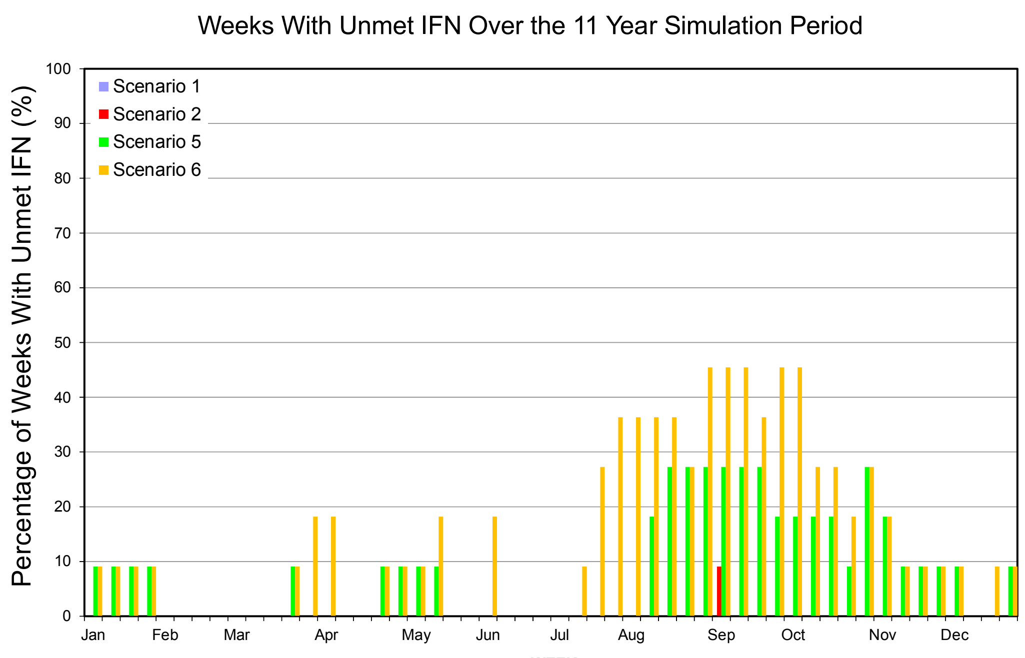


Figure C: Unmet IFN in Mission Creek for Scenarios 1, 2, 5, and 6

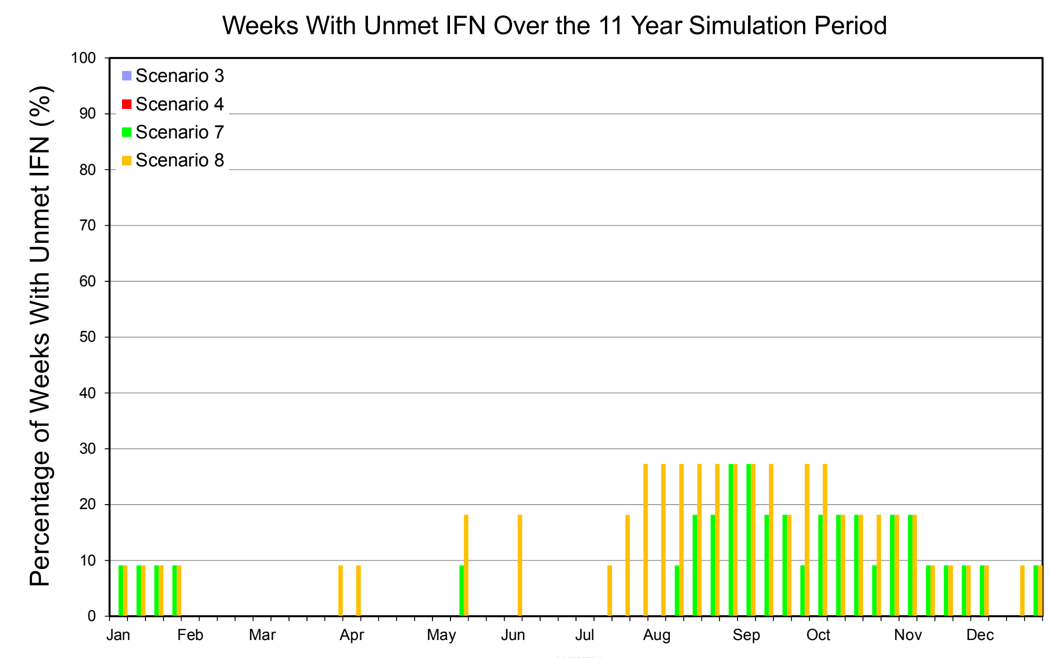


Figure D: Unmet IFN in Mission Creek for Scenarios 3, 4, 7, and 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC.
A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO: 2010-8005.000
FILE: BMID Unmet.mxd

Figure C-1: BMID Unmet Demand and Mission Creek Unmet IFN for OHCM Scenarios 1-8

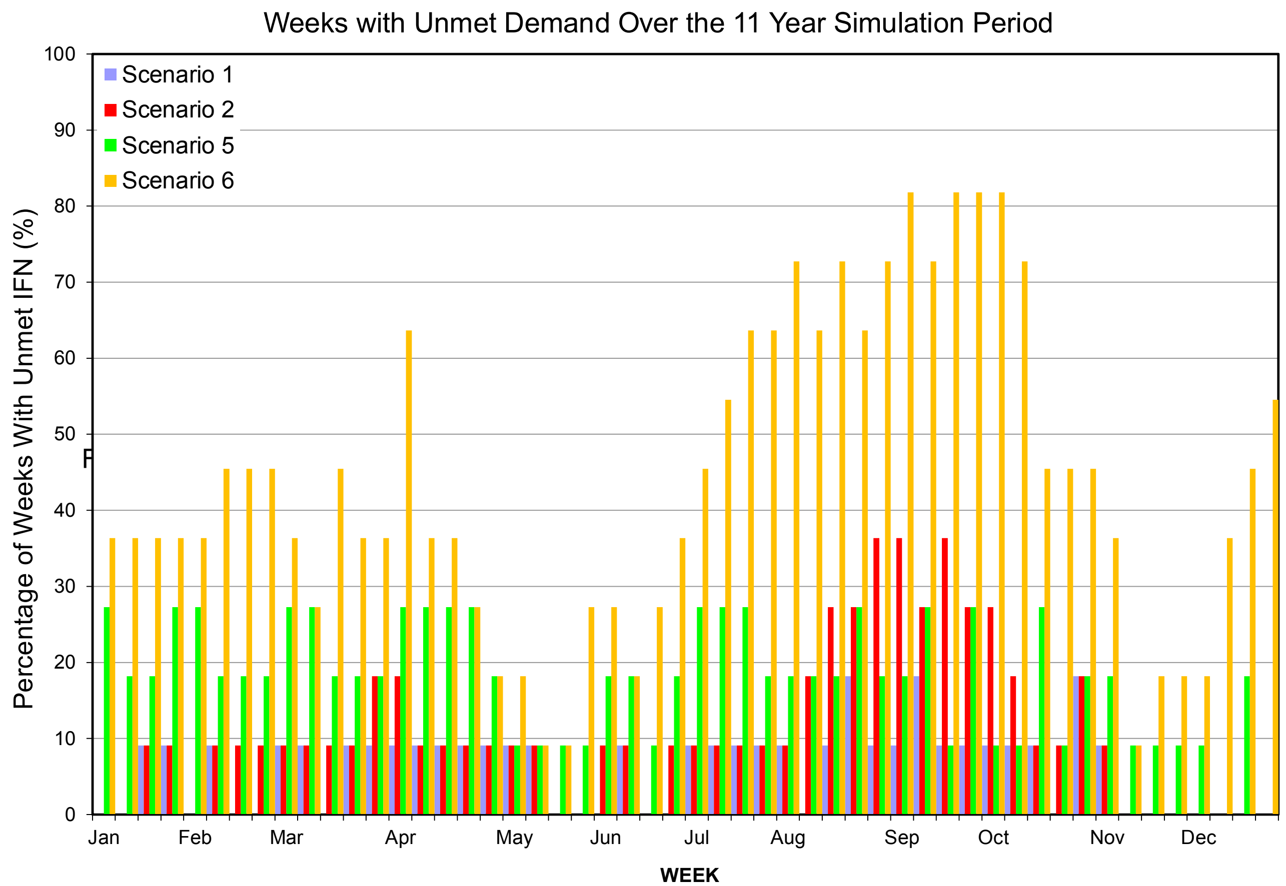


Figure A: Unmet IFN in Kelowna (Mill) Creek for Scenarios 1, 2, 5, and 6

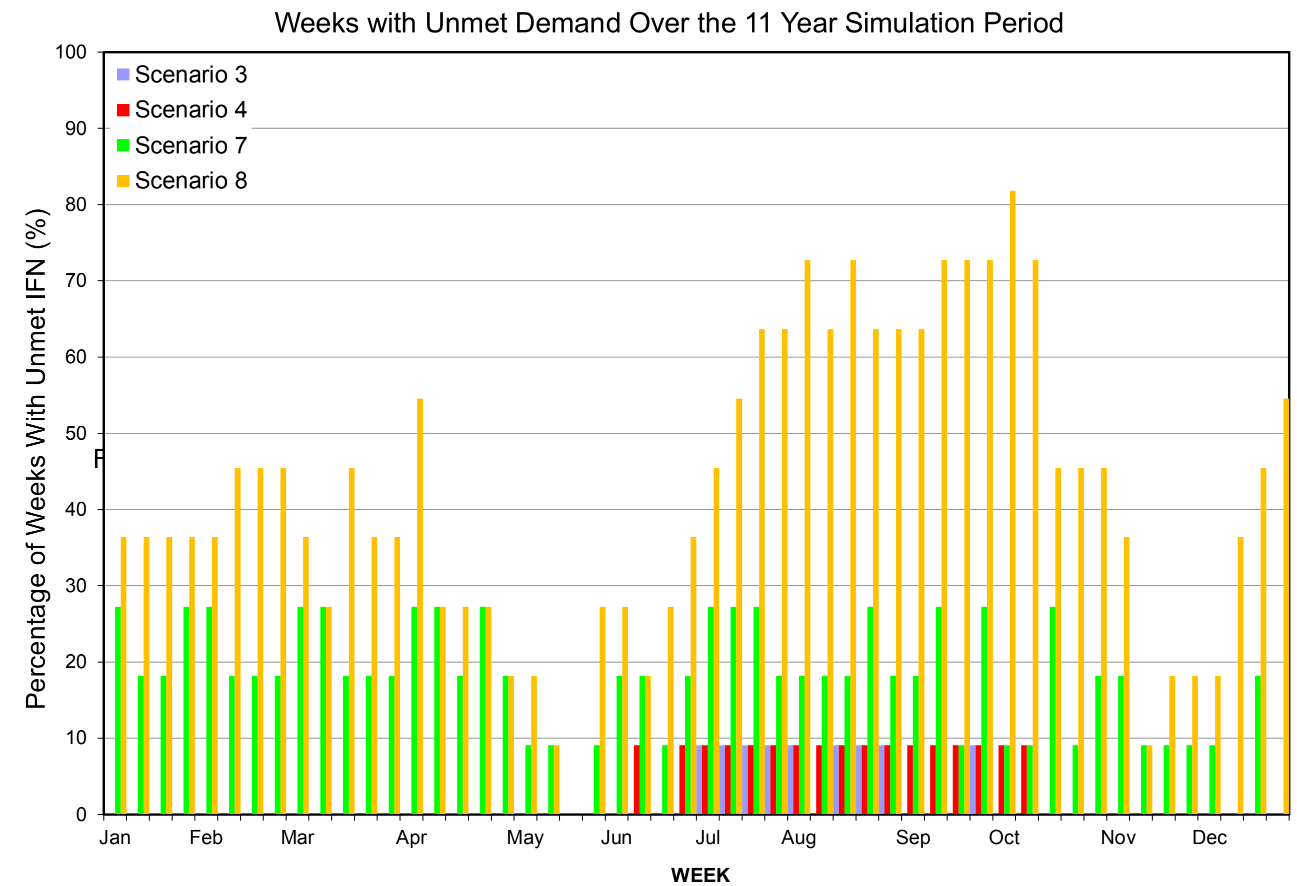


Figure D: Unmet IFN in Kelowna (Mill) Creek for Scenarios 3, 4, 7, and 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actualdemand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO: 2010-8005.000
FILE: Mill Creek Cons.mxd

Figure C-2: Kelowna (Mill) Creek Unmet IFN for OHCM Scenarios 1-8

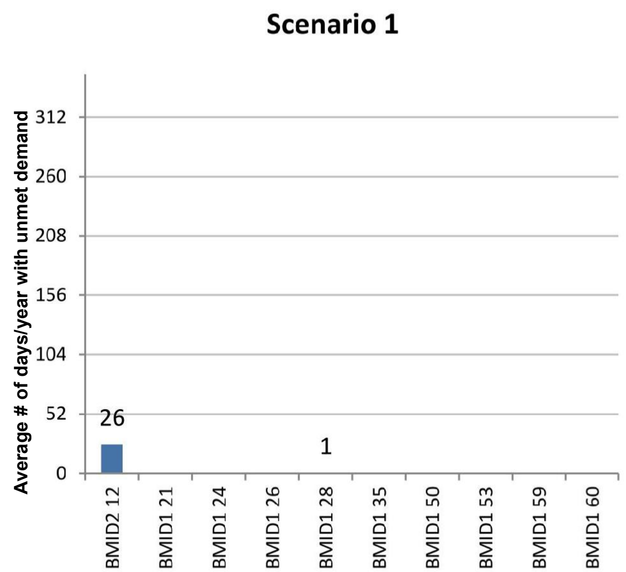


Figure A: The average number of days per year the demand is not satisifed for BMID - Scenario 1

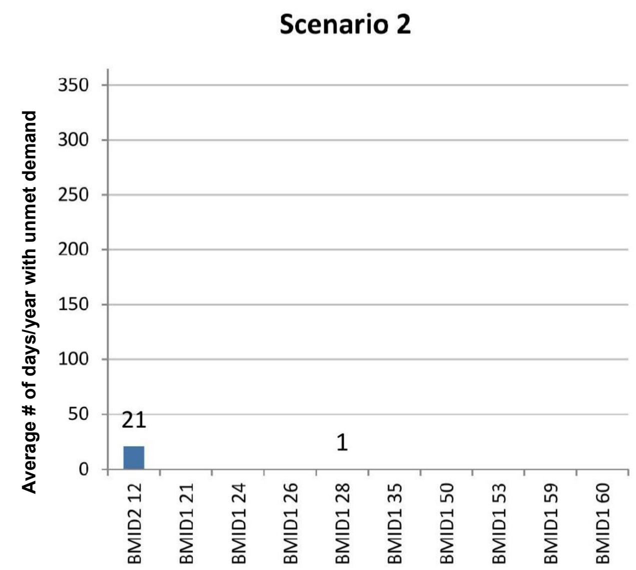


Figure B: The average number of days per year the demand is not satisifed for BMID - Scenario 2

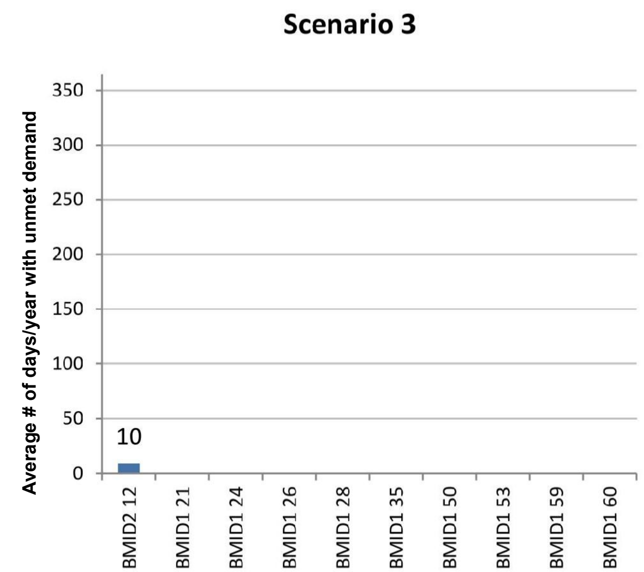


Figure C: The average number of days per year the demand is not satisifed for BMID - Scenario 3

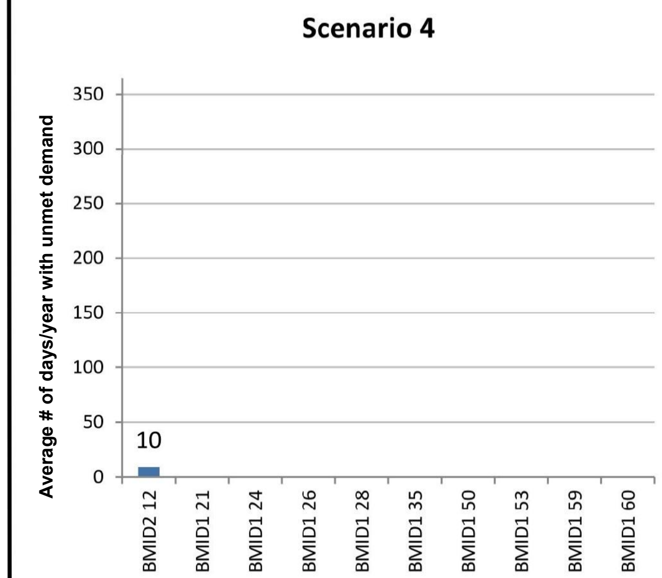


Figure D: The average number of days per year the demand is not satisifed for BMID - Scenario 4

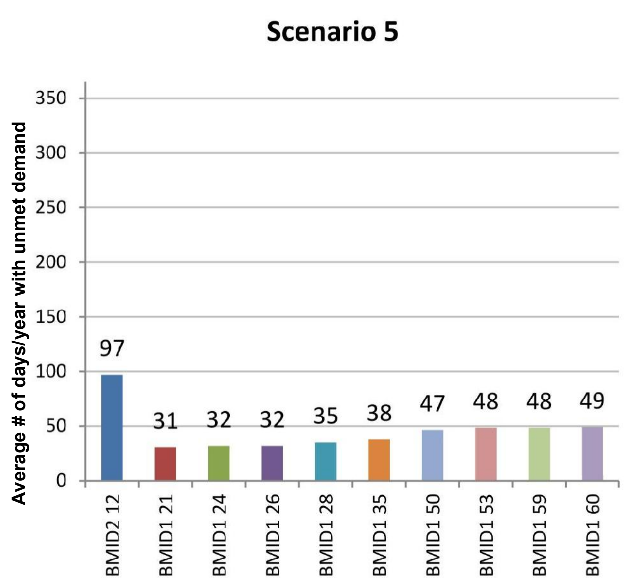


Figure E: The average number of days per year the demand is not satisifed for BMID - Scenario 5

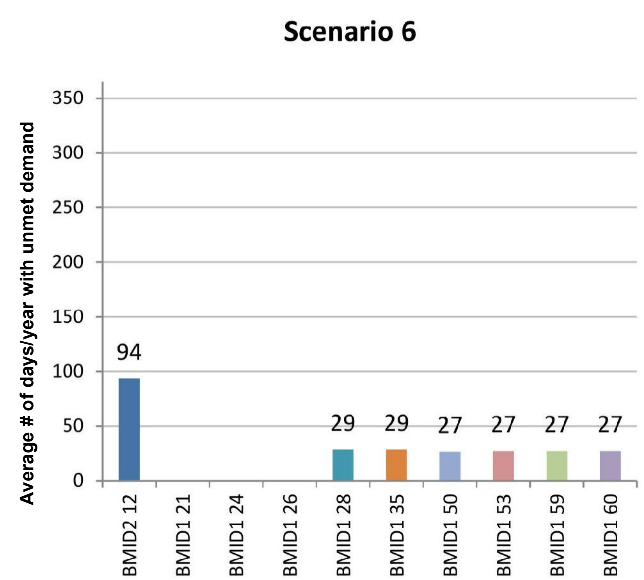


Figure F: The average number of days per year the demand is not satisifed for BMID - Scenario 6

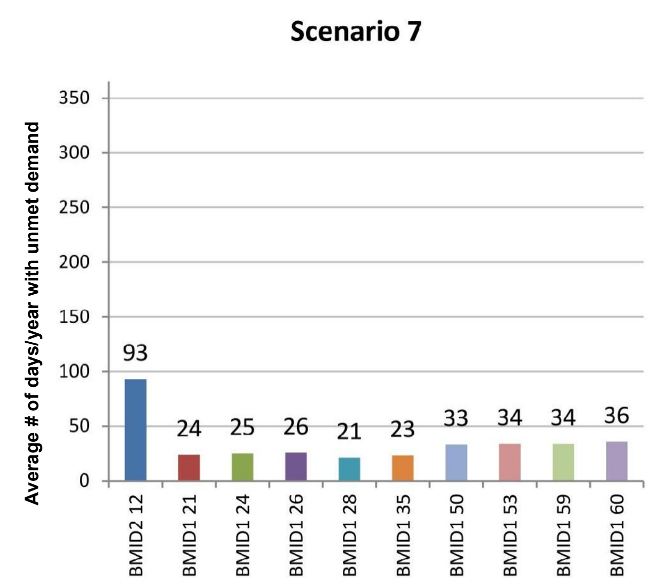


Figure G: The average number of days per year the demand is not satisifed for BMID - Scenario 7

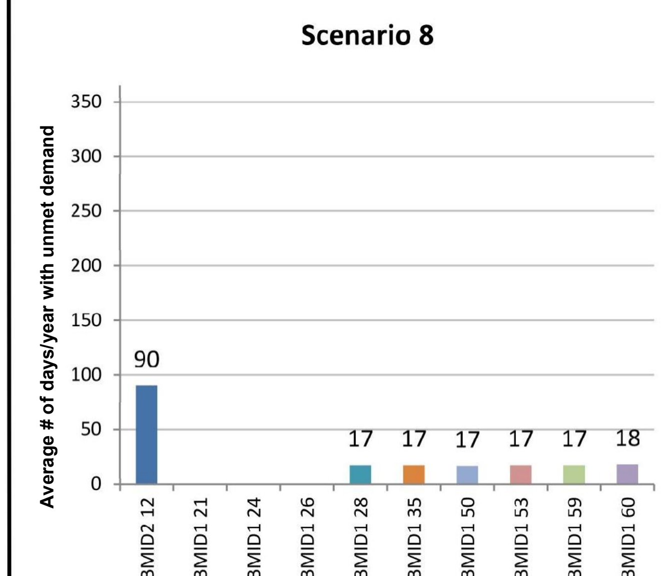


Figure H: The average number of days per year the demand is not satisifed for BMID - Scenario 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013

DRAWN BY: DA/TN/DL

DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO: 2010-8005.000

FILE: BMID UN_Reliability.mxd

Figure C-3: BMID Demand Site Unreliability Results for OHCM Scenarios 1-8

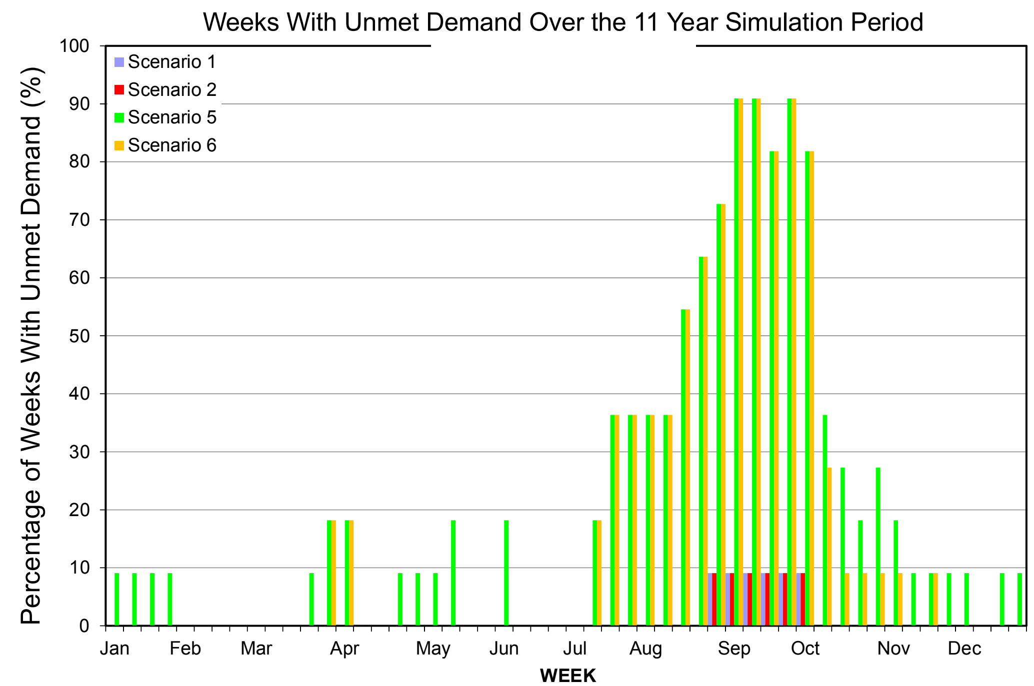


Figure A: Unmet Demand for SEKID for Scenarios 1, 2, 5, and 6

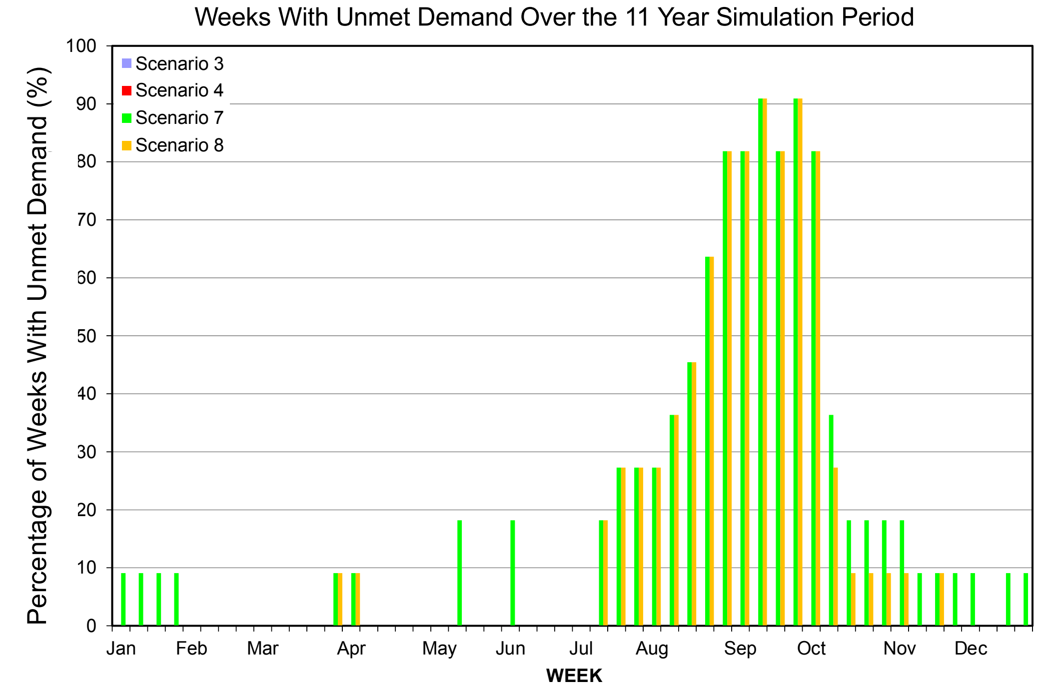


Figure B: Unmet Demand for SEKID for Scenarios 3, 4, 7, and 8

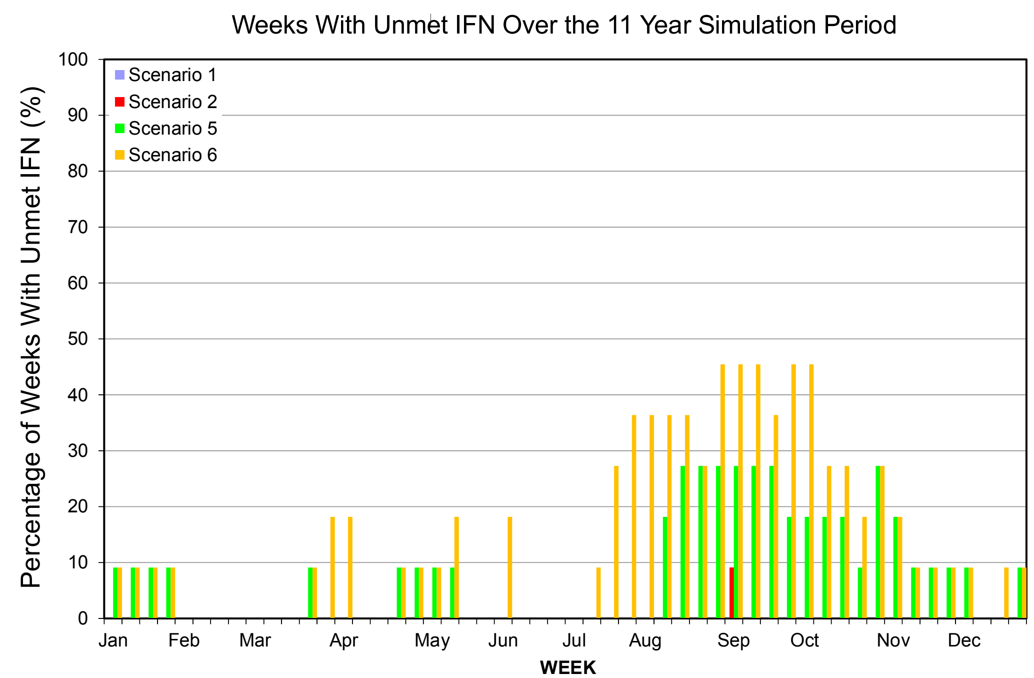


Figure C: Unmet IFN in Mission Creek for Scenarios 1, 2, 5, and 6

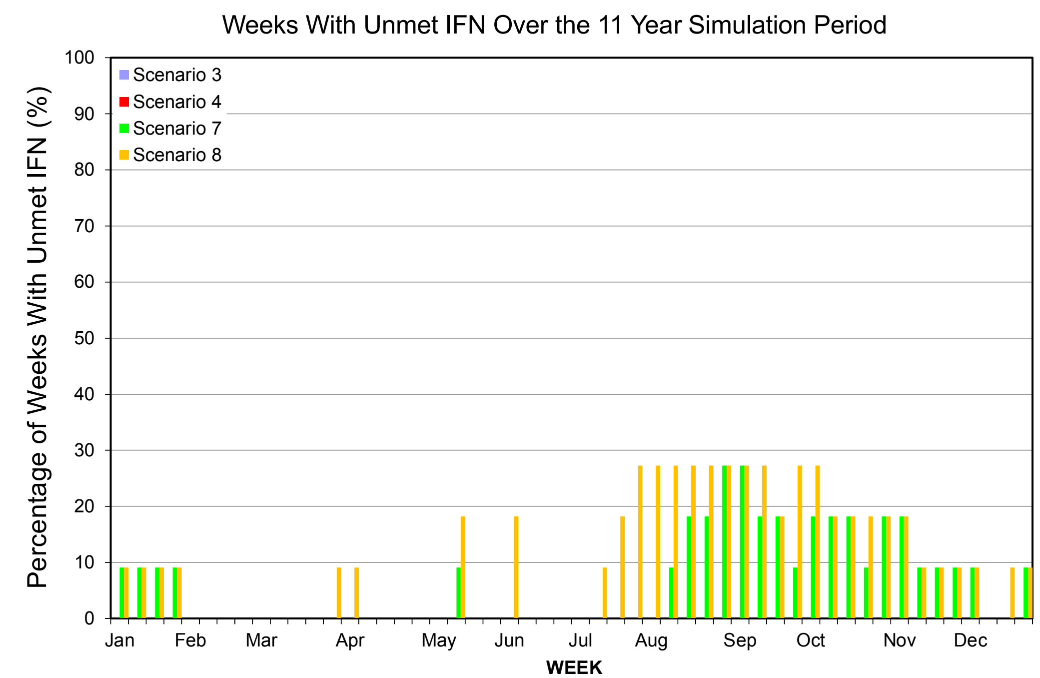


Figure D: Unmet IFN in Mission Creek for Scenarios 3, 4, 7, and 8

Scenario Description: 1) Actual demand, existing storage, highest IFN priority 2) Actual demand, existing storage, lowest IFN priority 3) Actual demand, potential storage, highest IFN priority 4) Actual demand, potential storage, lowest IFN priority 5) Max demand, existing storage, highest IFN priority 6) Max demand, existing storage, lowest IFN priority 7) Max demand, potential storage, highest IFN priority 8) Max demand, potential storage, lowest IFN priority	DATE: May 2013 DRAWN BY: DA/TN/DL DATA SOURCE(S): OHCM	PREPARED FOR: OKANAGAN BASIN WATER BOARD PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL** PROJECT NO: 2010-8005.000 FILE: SEKID Unmet.mxd Figure C-4: SEKID Unmet Demand and Mission Creek Unmet IFN for OHCM Scenarios 1-8

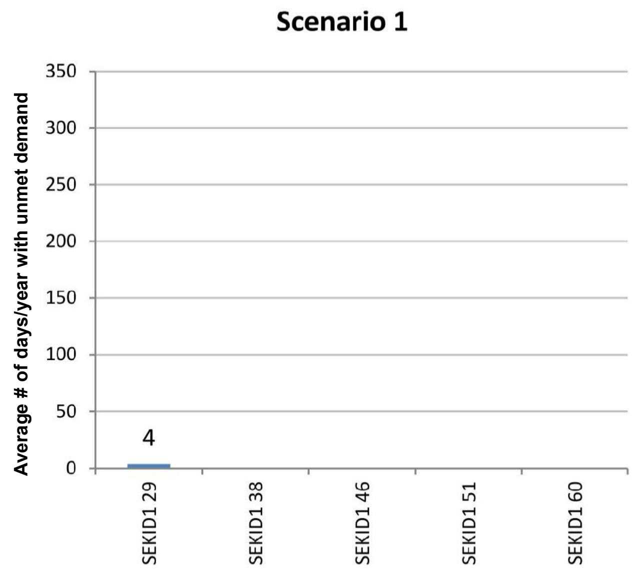


Figure A: The average number of days per year the demand is not satisifed for SEKID - Scenario 1

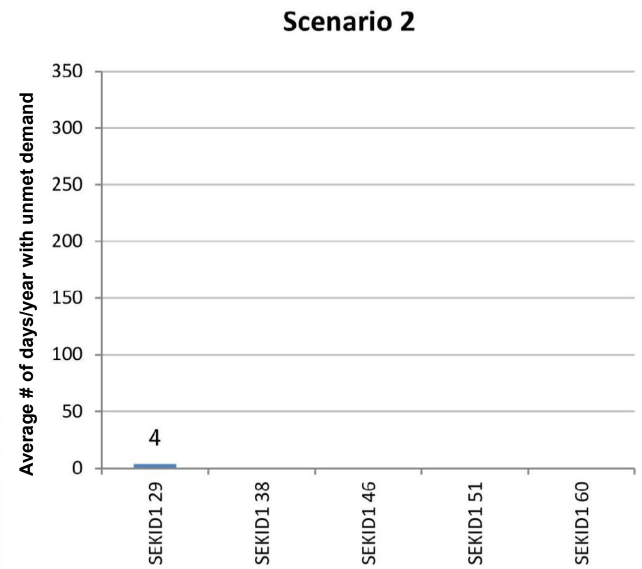


Figure B: The average number of days per year the demand is not satisifed for SEKID - Scenario 2

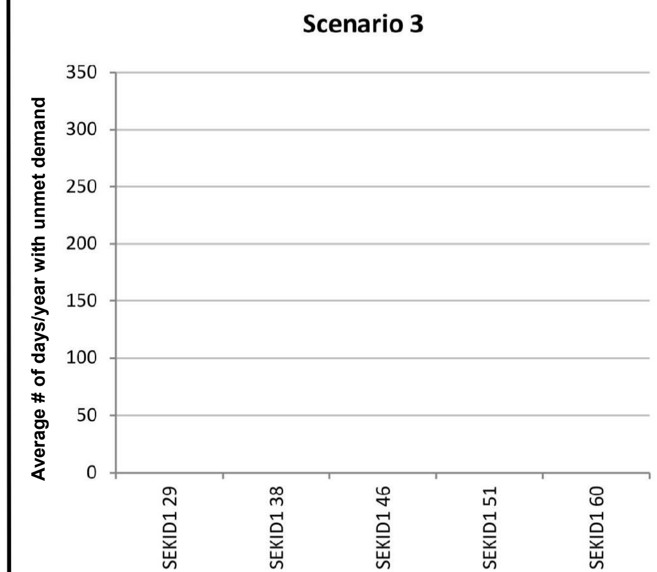


Figure C: The average number of days per year the demand is not satisifed for SEKID - Scenario 3

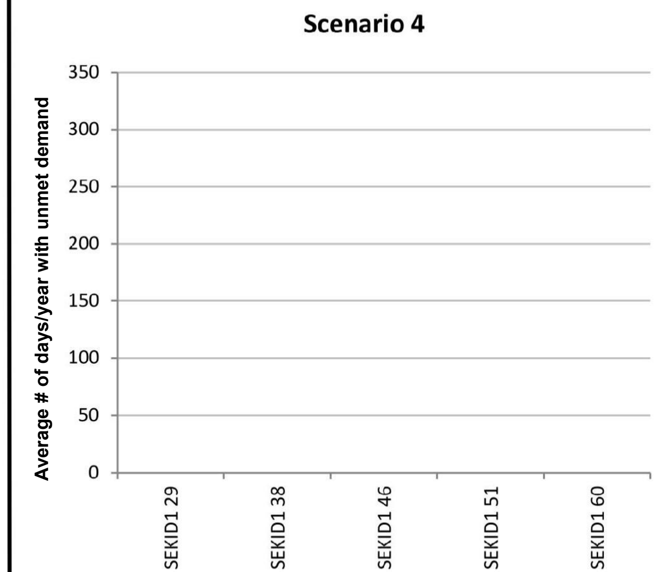


Figure D: The average number of days per year the demand is not satisifed for SEKID - Scenario 4

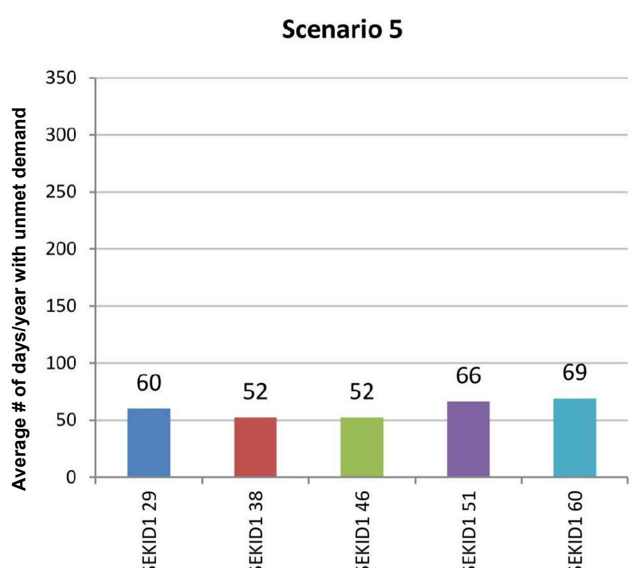


Figure E: The average number of days per year the demand is not satisifed for SEKID - Scenario 5

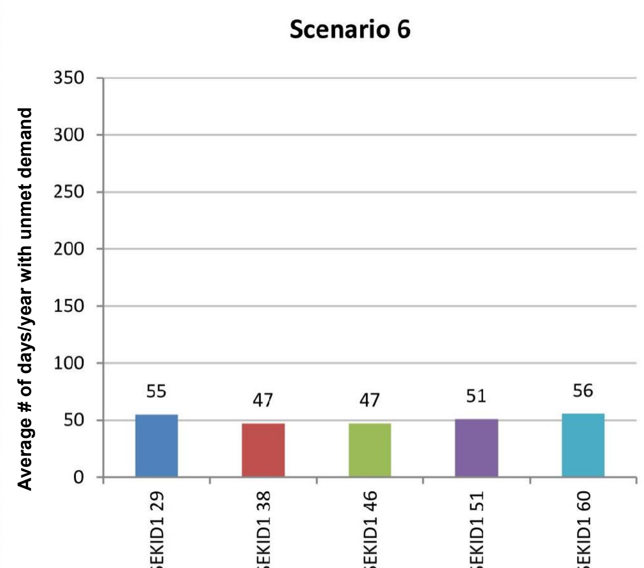


Figure F: The average number of days per year the demand is not satisifed for SEKID - Scenario 6

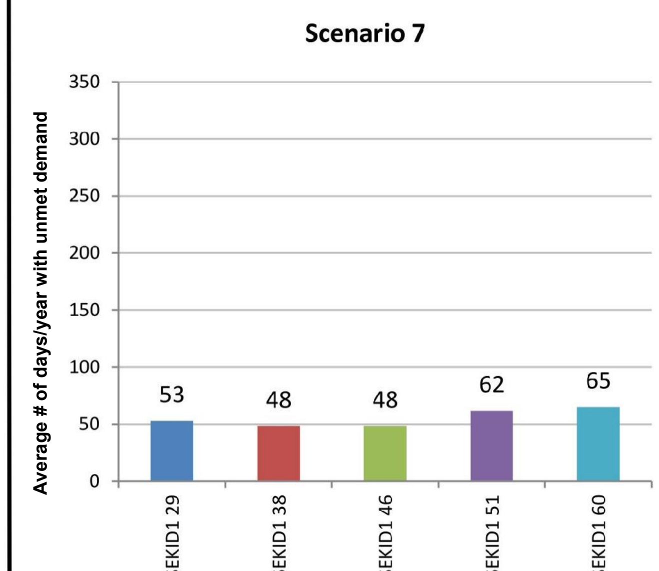


Figure G: The average number of days per year the demand is not satisifed for SEKID - Scenario 7

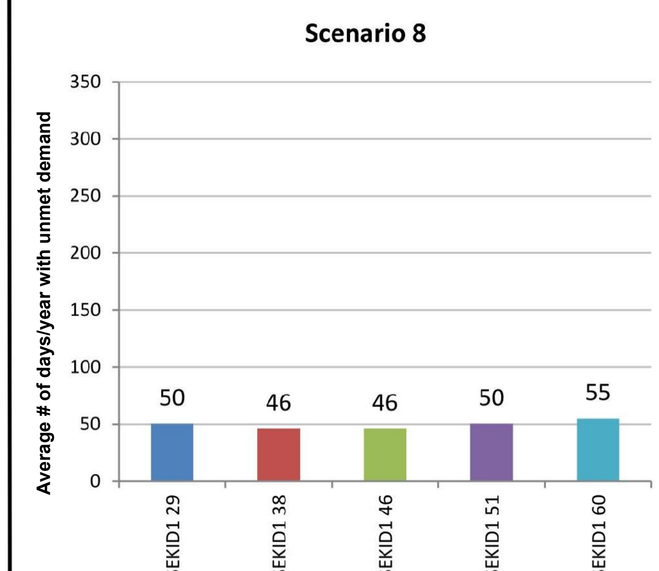


Figure H: The average number of days per year the demand is not satisifed for SEKID - Scenario 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actualdemand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC.
A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO: 2010-8005.000
FILE: SEKID Reliability.mxd

Figure C-5: SEKID Demand Site Unreliability Results for OHCM Scenarios 1-8

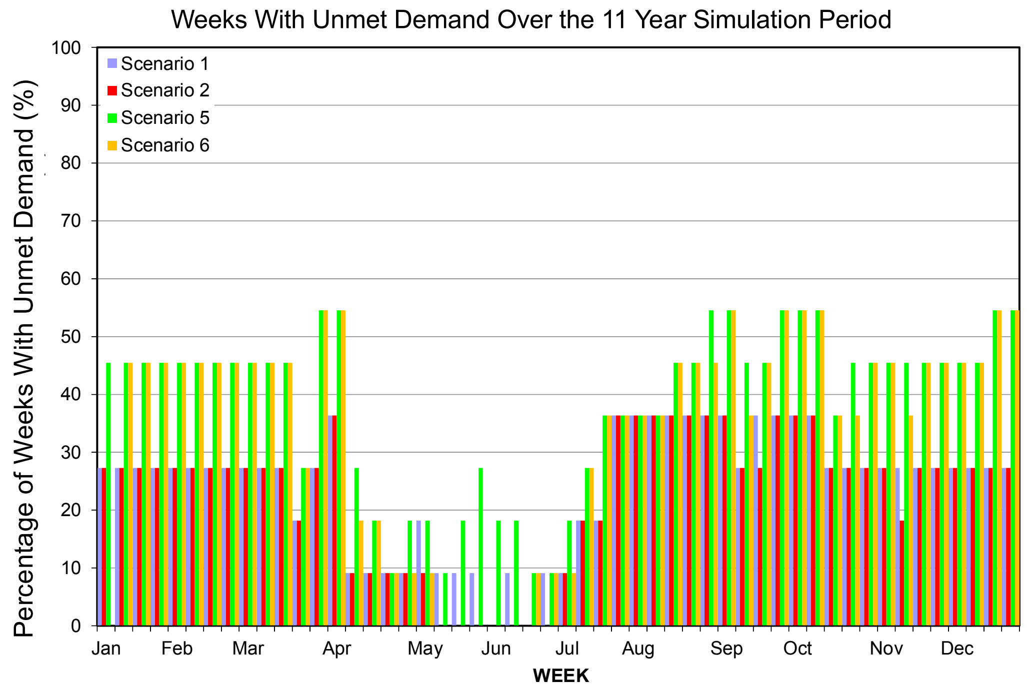


Figure A: Unmet Demand for COP 1 and 2 for Scenarios 1, 2, 5, and 6

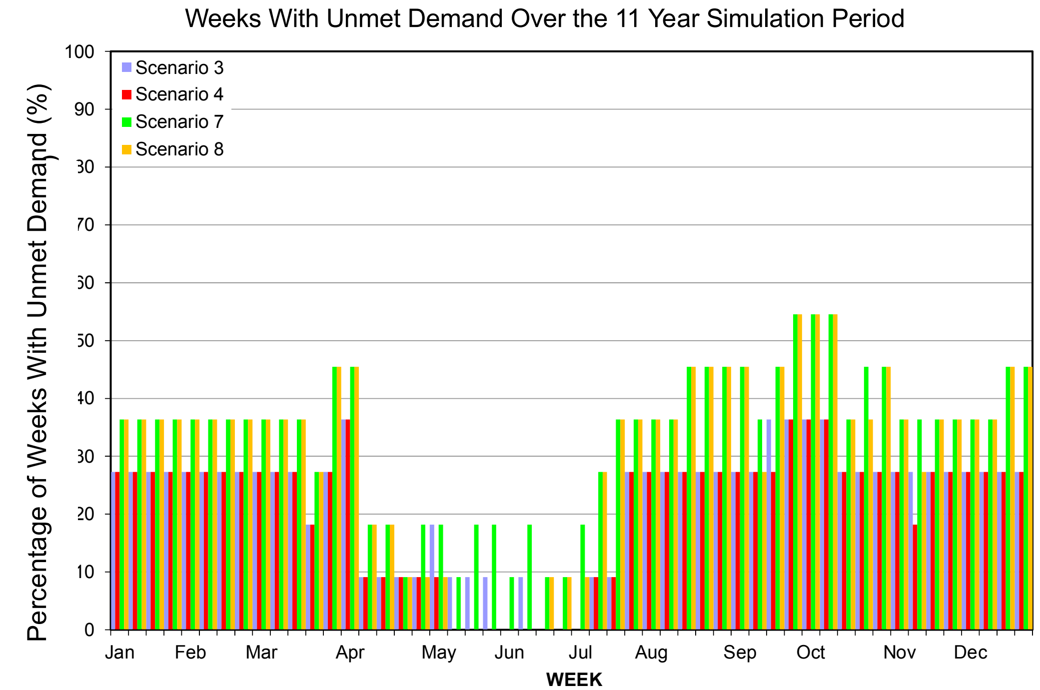


Figure B: Unmet Demand for COP 1 and 2 for Scenarios 3, 4, 7, and 8

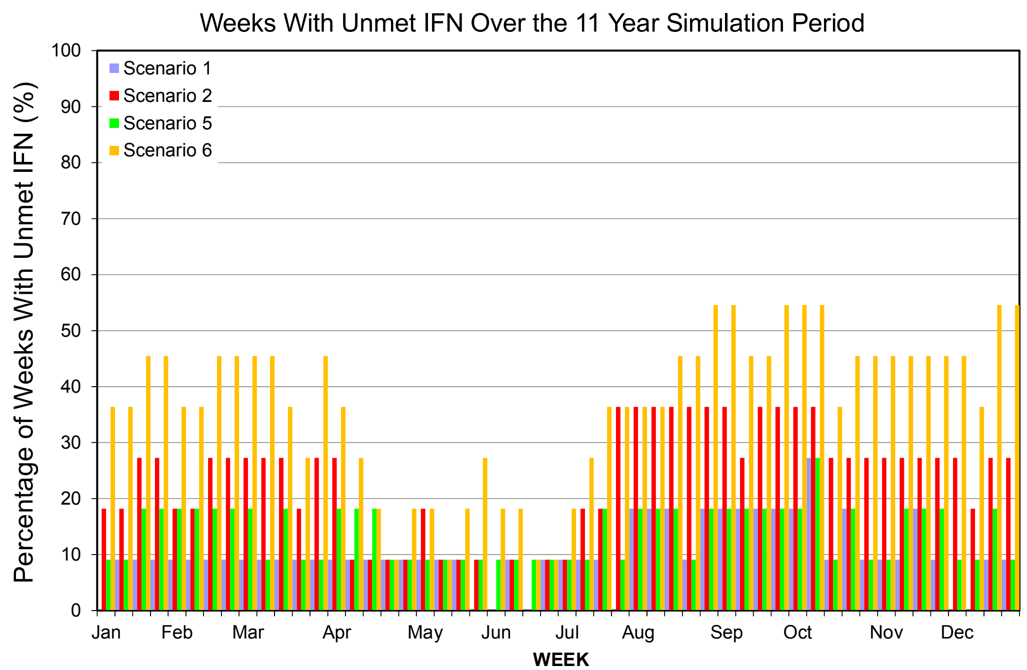


Figure C: Unmet IFN in Penticton Creek for Scenarios 1, 2, 5, and 6

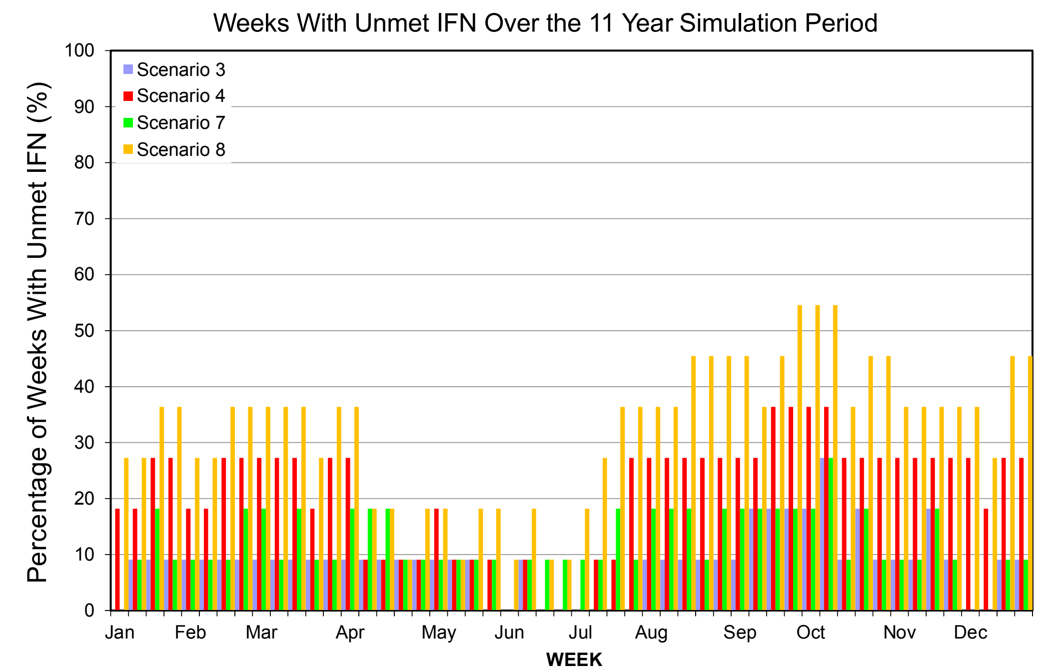


Figure D: Unmet IFN for Penticton Creek for Scenarios 3, 4, 7, and 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC.
A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO: 2010-8005.000
FILE: COP 1-2 Unmet.mxd

Figure C-6: COP 1 and 2 Unmet Demand and Penticton Creek Unmet IFN for OHCM Scenarios 1-8

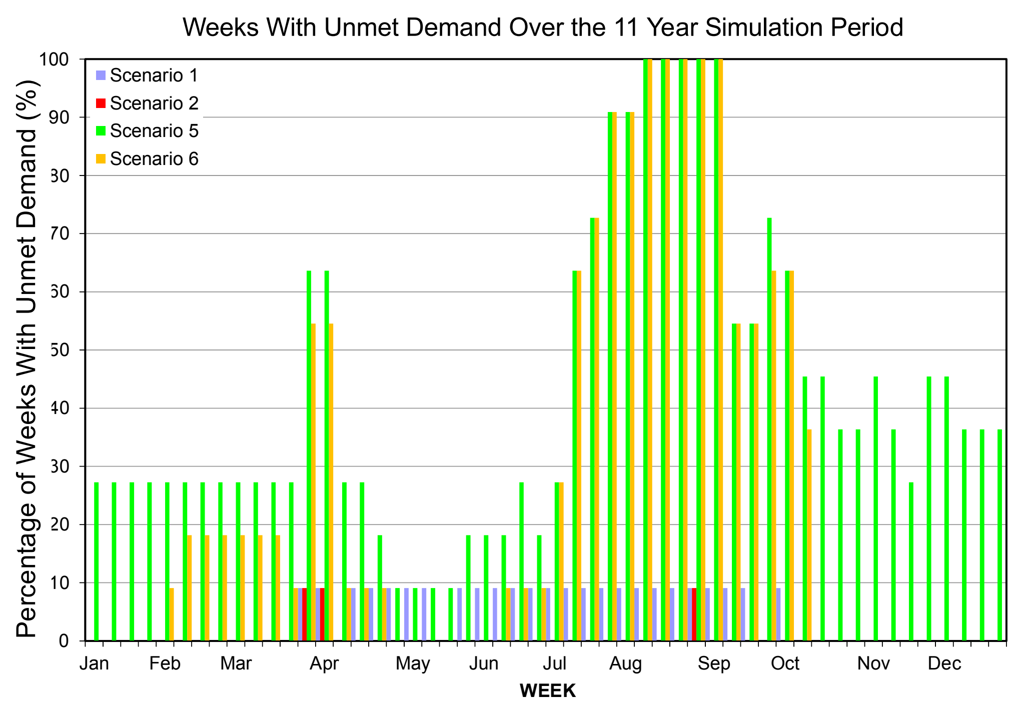


Figure A: Unmet Demand for COP 3 for Scenarios 1, 2, 5, and 6

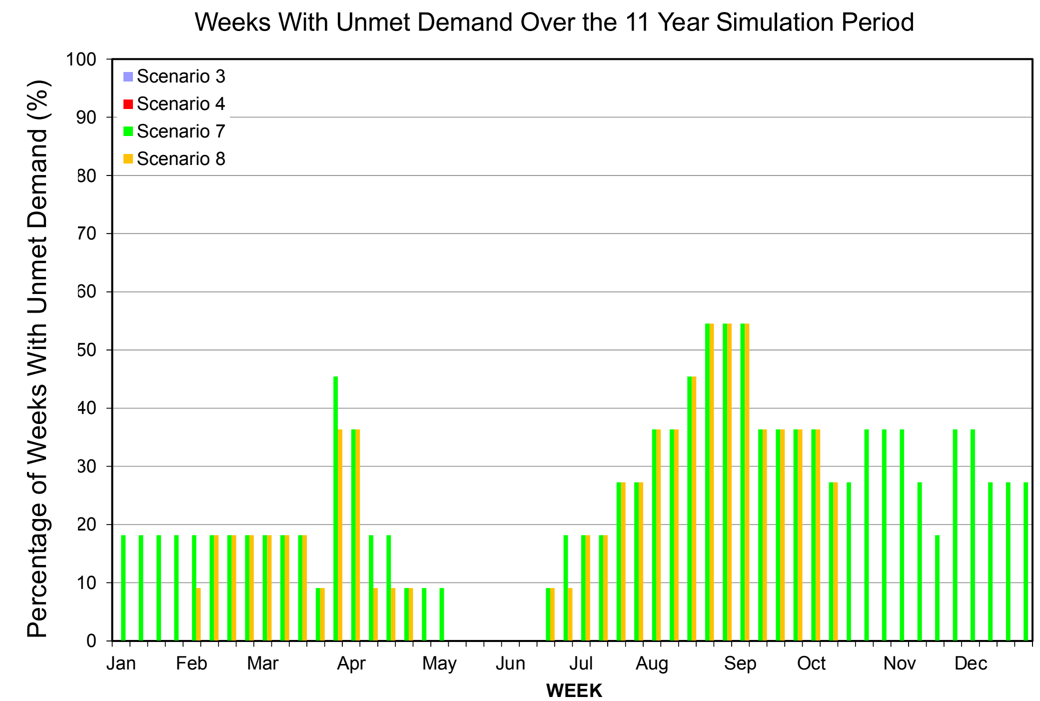


Figure B: Unmet Demand for COP 3 for Scenarios 3, 4, 7, and 8

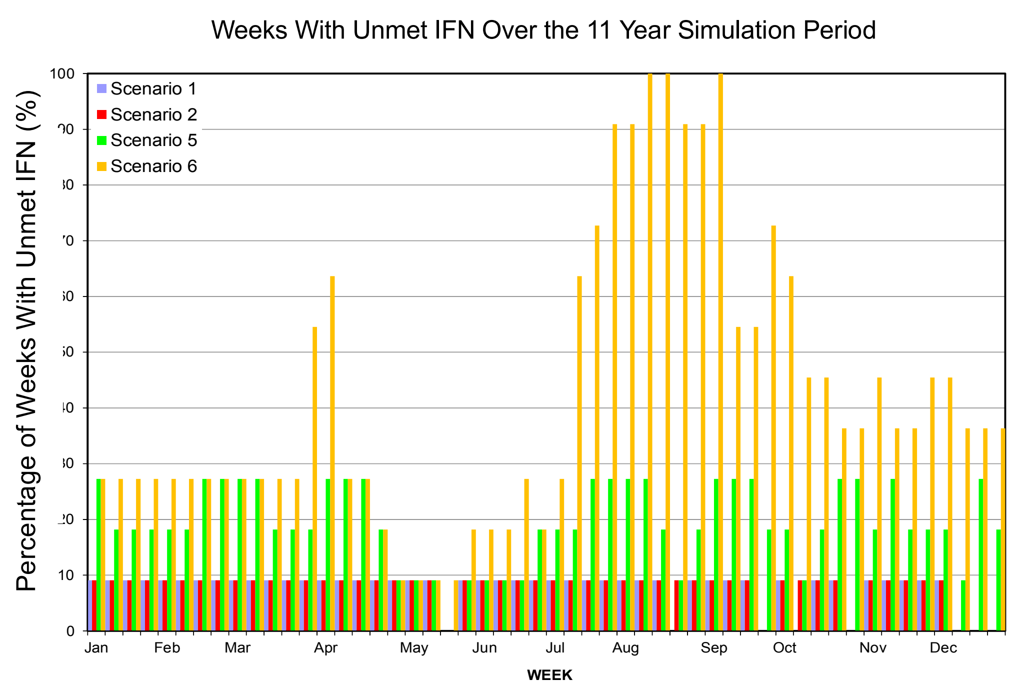


Figure C: Unmet IFN in Ellis Creek for Scenarios 1, 2, 5, and 6

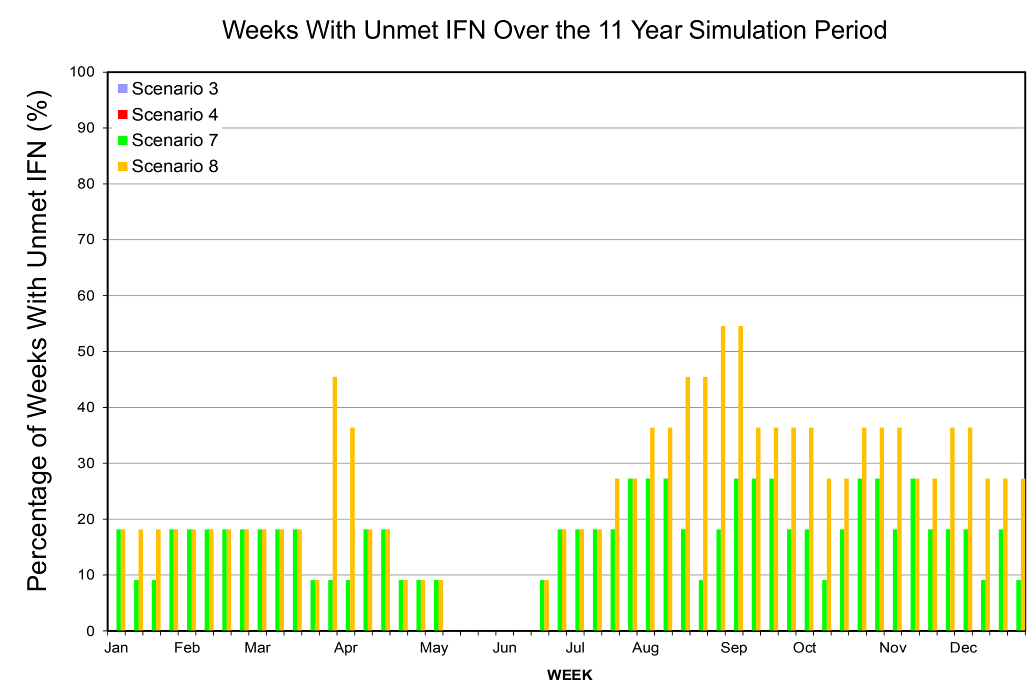


Figure D: Unmet IFN in Ellis Creek for Scenarios 3, 4, 7, and 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO: 2010-8005.000

FILE: COP 3 Unmet.mxd

Figure C-7: COP 3 Unmet Demand and Ellis Creek Unmet IFN for OHCM Scenarios 1-8

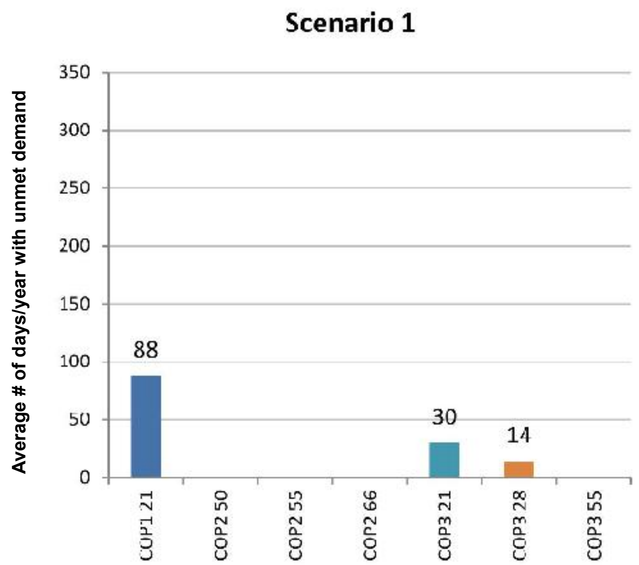


Figure A: The average number of days per year the demand is not satisifed for COP - Scenario 1

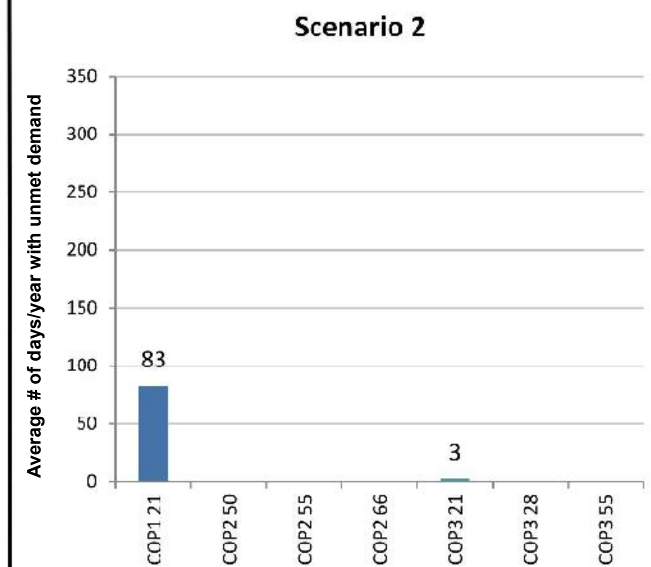


Figure B: The average number of days per year the demand is not satisifed for COP - Scenario 2

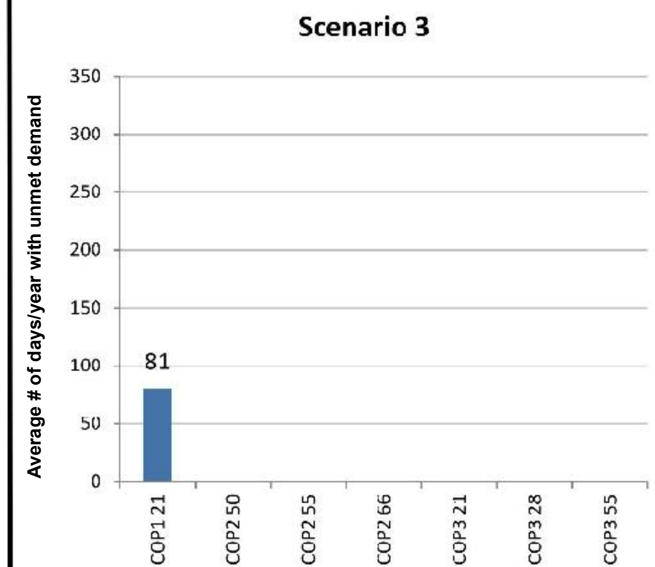


Figure C: The average number of days per year the demand is not satisifed for COP - Scenario 3

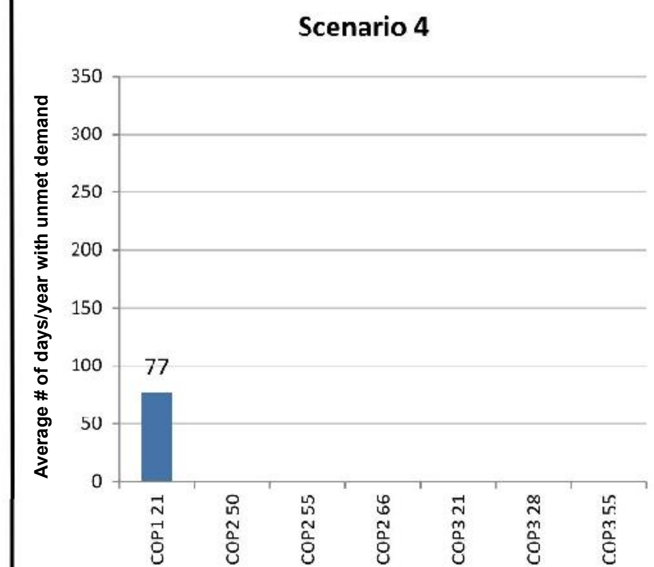


Figure D: The average number of days per year the demand is not satisifed for COP - Scenario 4

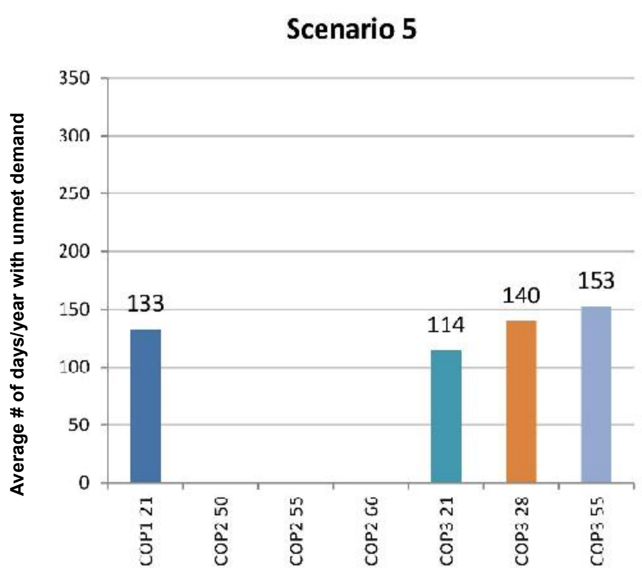


Figure E: The average number of days per year the demand is not satisifed for COP - Scenario 5

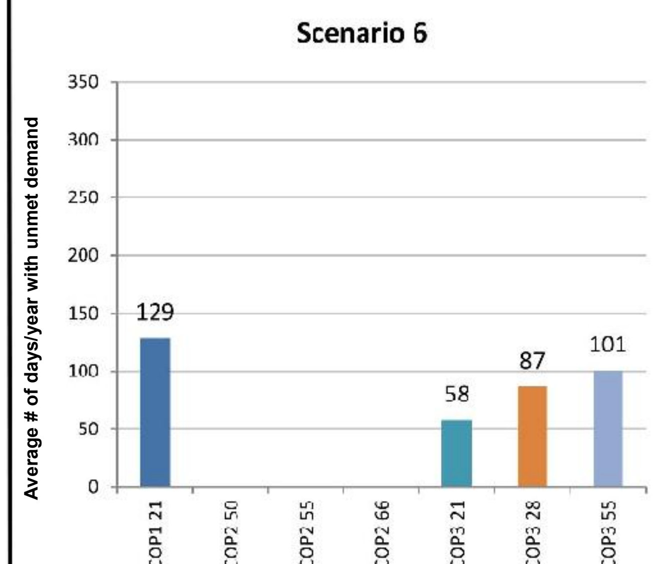


Figure F: The average number of days per year the demand is not satisifed for COP - Scenario 6

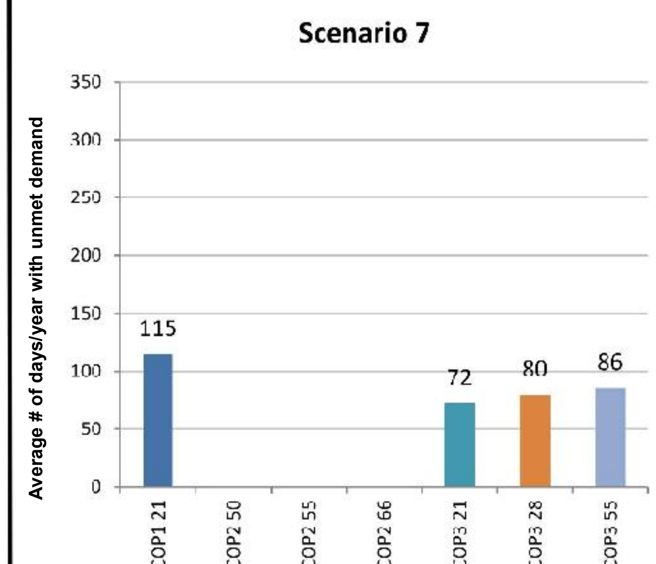


Figure G: The average number of days per year the demand is not satisifed for COP - Scenario 7

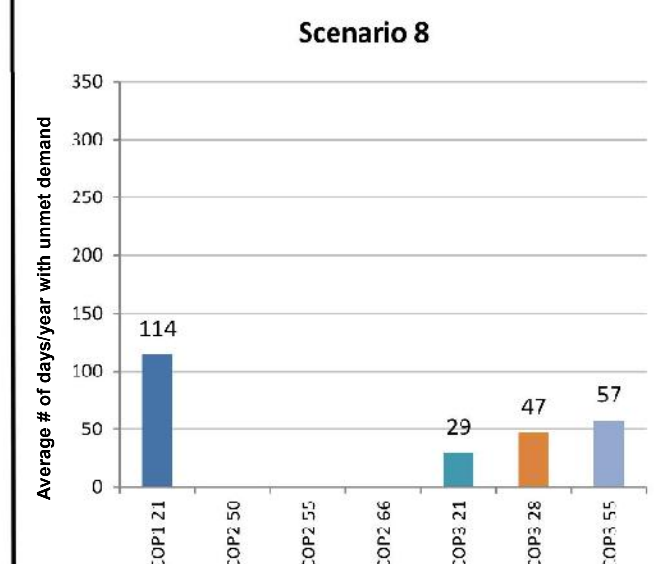


Figure H: The average number of days per year the demand is not satisifed for COP - Scenario 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO: 2010-8005.000
FILE: COP UN_Reliability.mxd

Figure C-8: COP Demand Site Unreliability Results for OHCM Scenarios 1-8

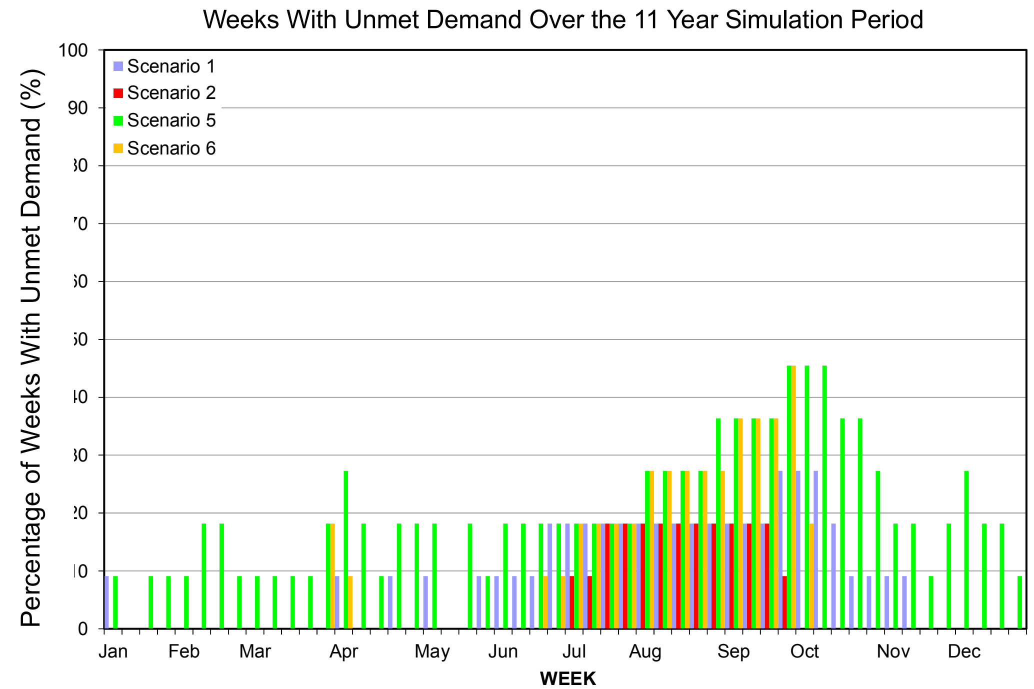


Figure A: Unmet Demand for DOS 1 for Scenarios 1, 2, 5, and 6

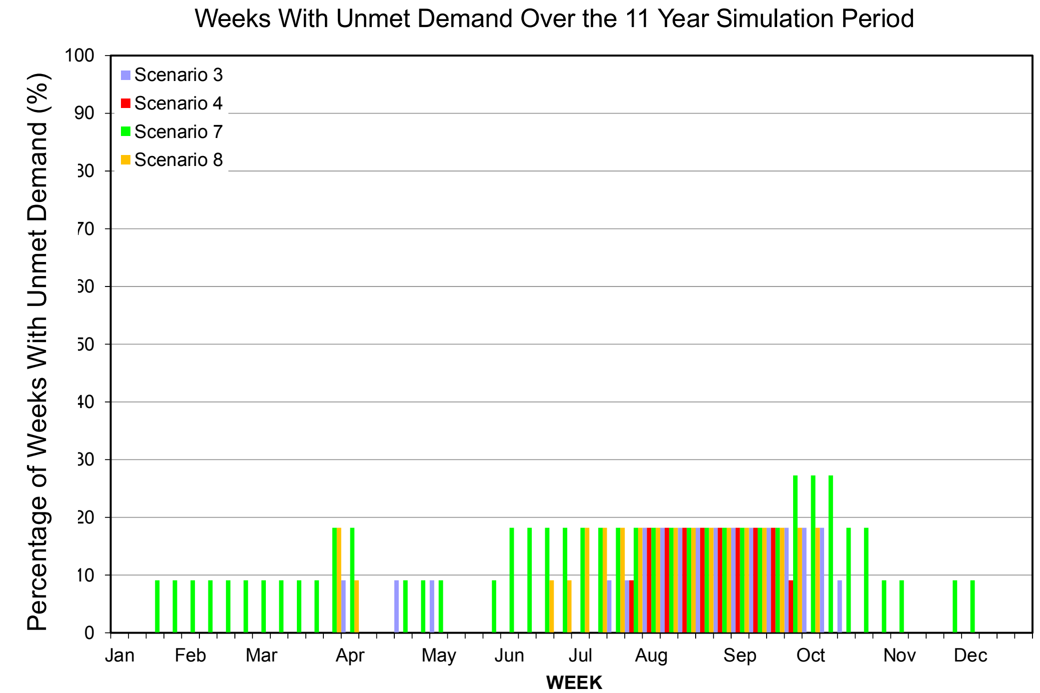


Figure B: Unmet Demand for DOS 1 for Scenarios 3, 4, 7, and 8

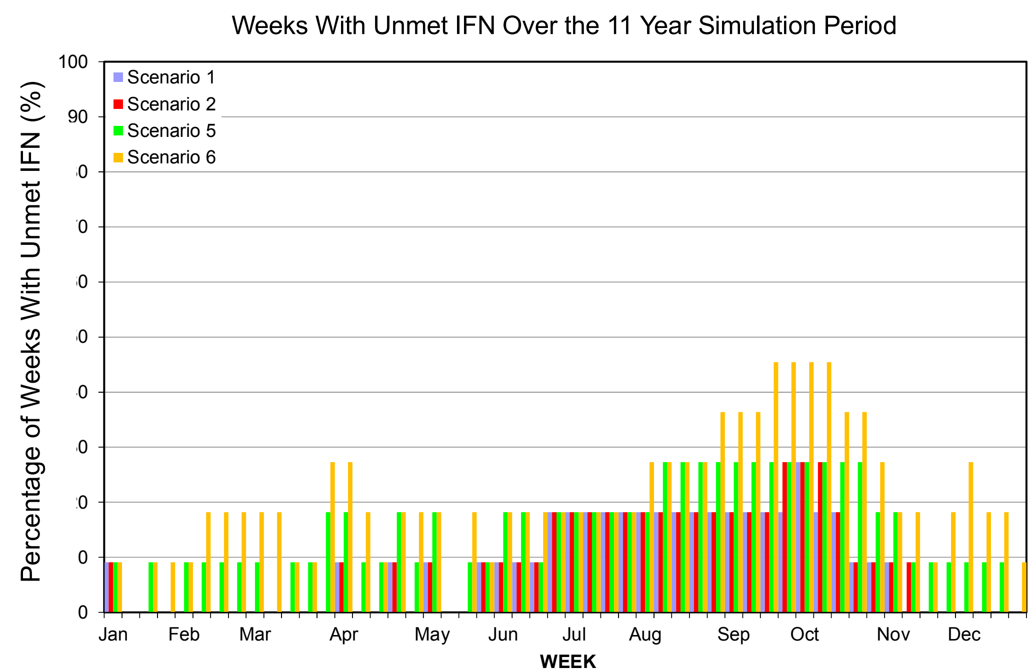


Figure C: Unmet IFN in Trout Creek for Scenarios 1, 2, 5, and 6

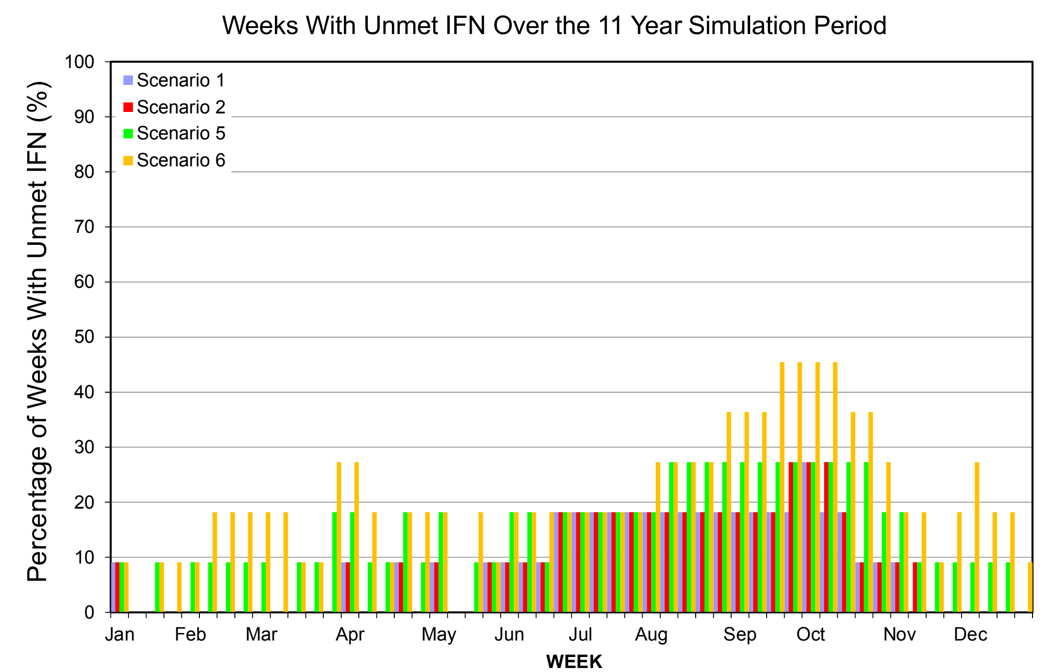


Figure D: Unmet IFN in Trout Creek for Scenarios 3, 4, 7, and 8

<u>Scenario Description:</u>
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD
PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**
PROJECT NO: 2010-8005.000
FILE: DOS 1 Unmet.mxd

Figure C-9: DOS 1 Unmet Demand and Trout Creek Unmet IFN for OHCM Scenarios 1-8

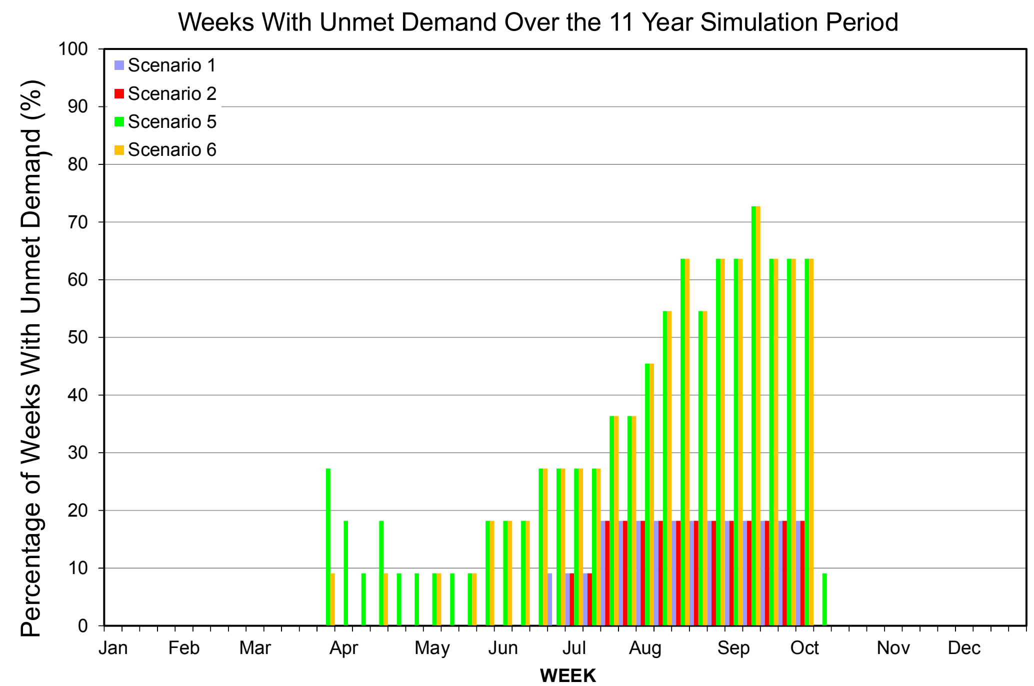


Figure A: Unmet Demand for DOS 2 for Scenarios 1, 2, 5, and 6

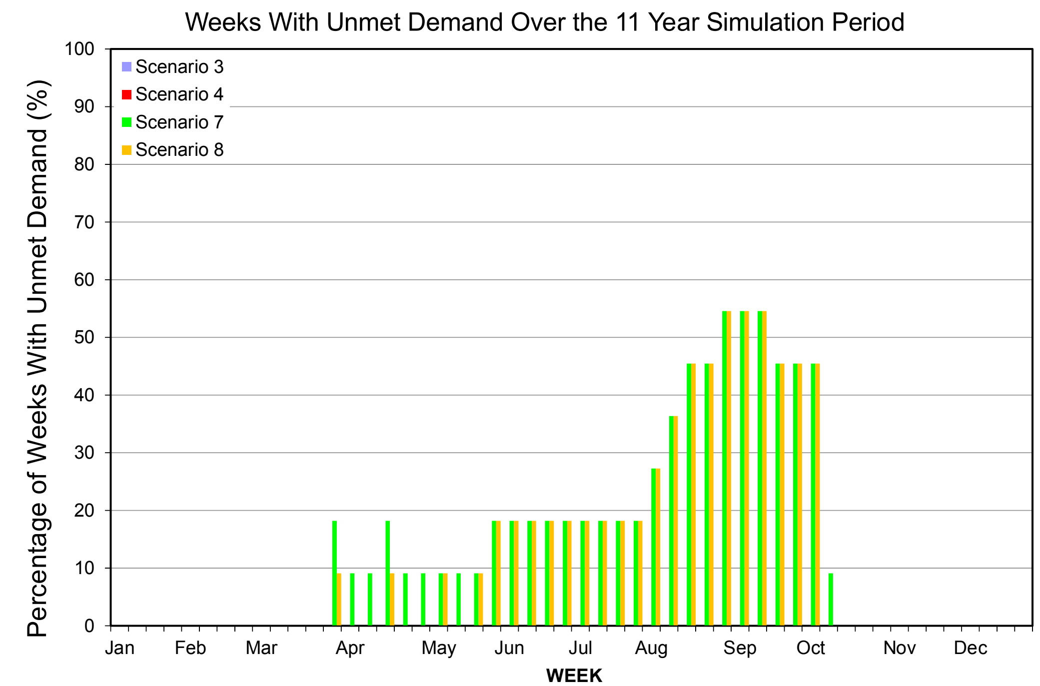


Figure B: Unmet Demand for DOS 2 for Scenarios 3, 4, 7, and 8

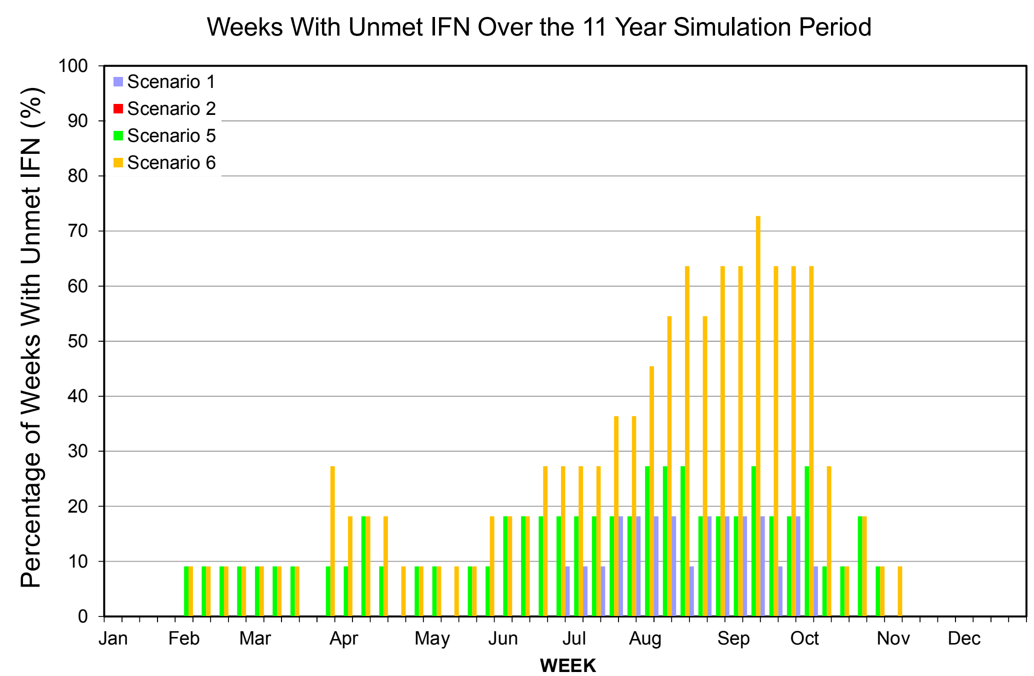


Figure C: Unmet IFN in Eneas Creek for Scenarios 1, 2, 5, and 6

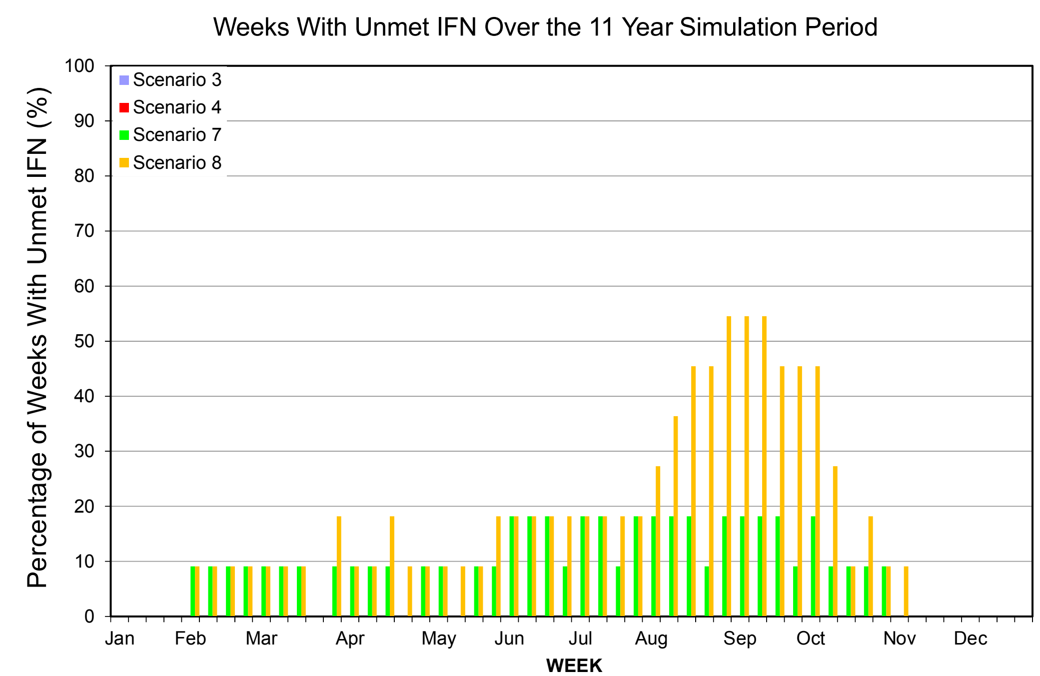


Figure D: Unmet IFN in Eneas Creek for Scenarios 3, 4, 7, and 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO: 2010-8005.000
FILE: DOS 2 Unmet.mxd

Figure C-10: DOS 2 Unmet Demand and Eneas Creek Unmet IFN for OHCM Scenarios 1-8

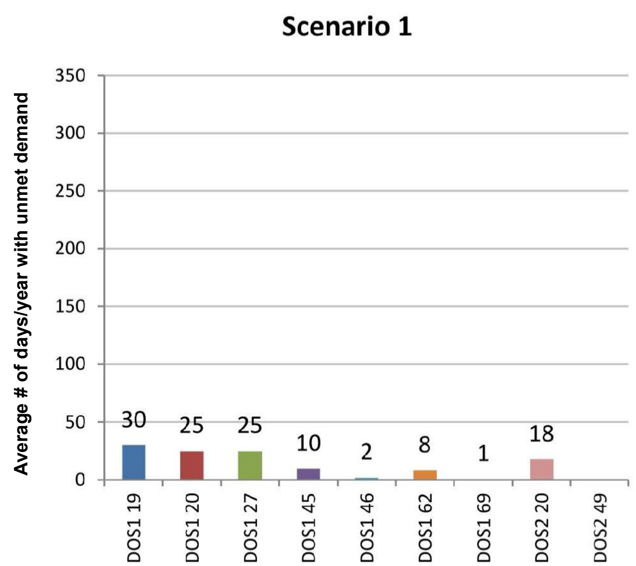


Figure A: The average number of days per year the demand is not satisifed for DOS - Scenario 1

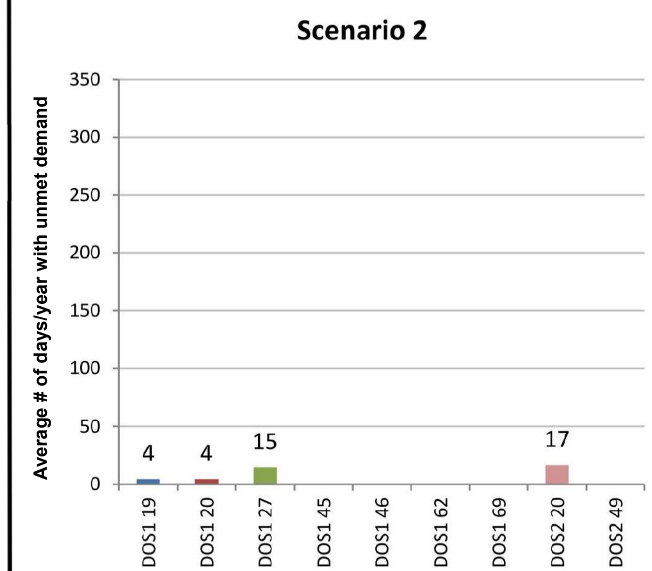


Figure B: The average number of days per year the demand is not satisifed for DOS - Scenario 2

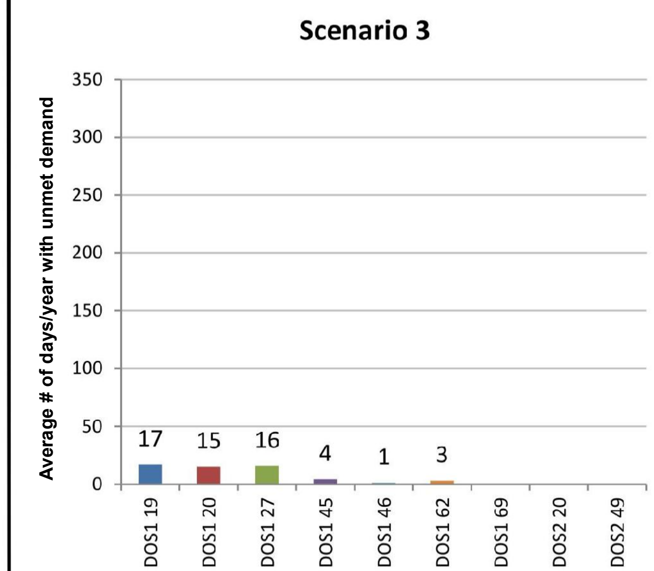


Figure C: The average number of days per year the demand is not satisifed for DOS - Scenario 3

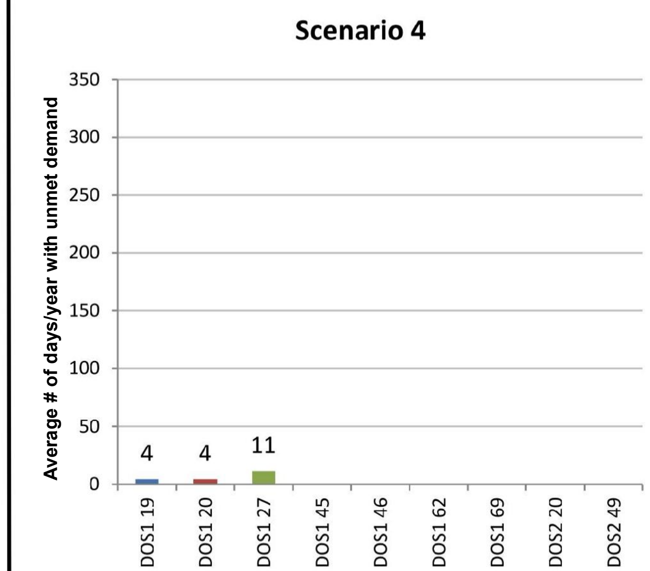


Figure D: The average number of days per year the demand is not satisifed for DOS - Scenario 4

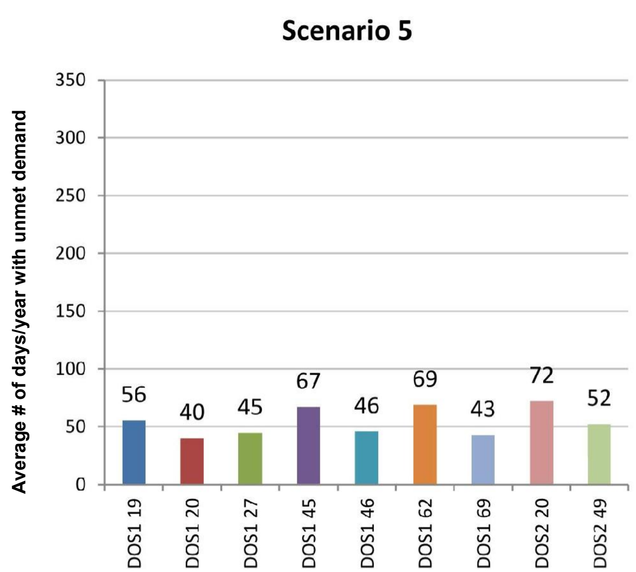


Figure E: The average number of days per year the demand is not satisifed for DOS - Scenario 5

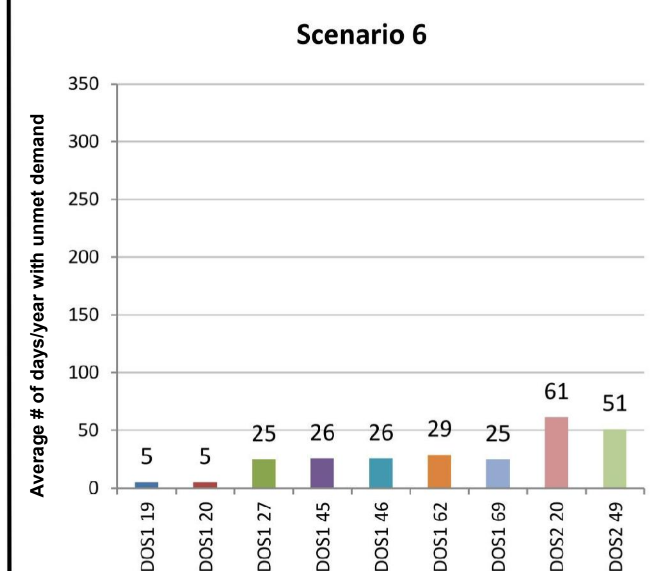


Figure F: The average number of days per year the demand is not satisifed for DOS - Scenario 6

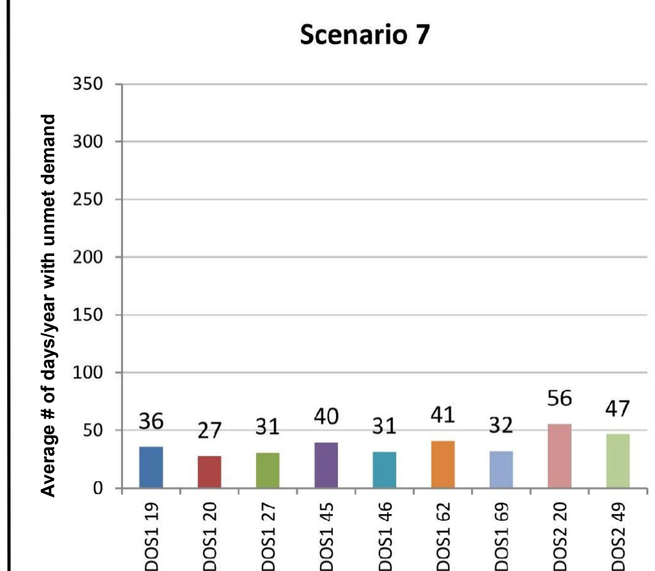


Figure G: The average number of days per year the demand is not satisifed for DOS - Scenario 7

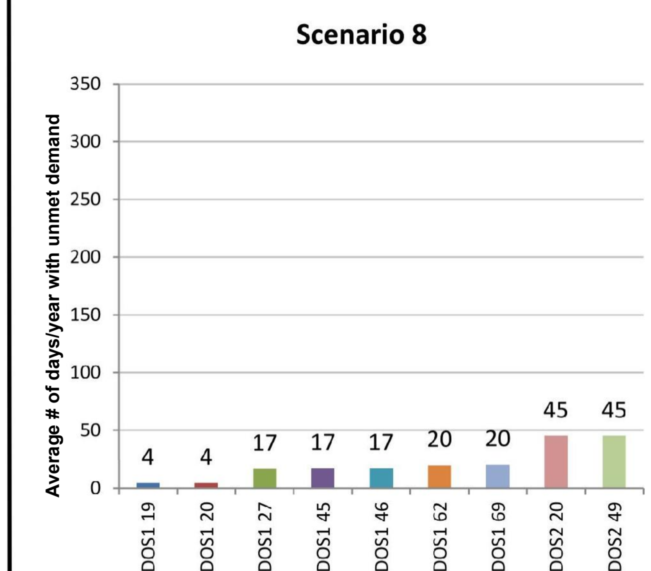


Figure H: The average number of days per year the demand is not satisifed for DOS - Scenario 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO: 2010-8005.000
FILE: DOS UN_Reliability.mxd

Figure C-11: DOS Demand Site Unreliability Results for OHCM Scenarios 1-8

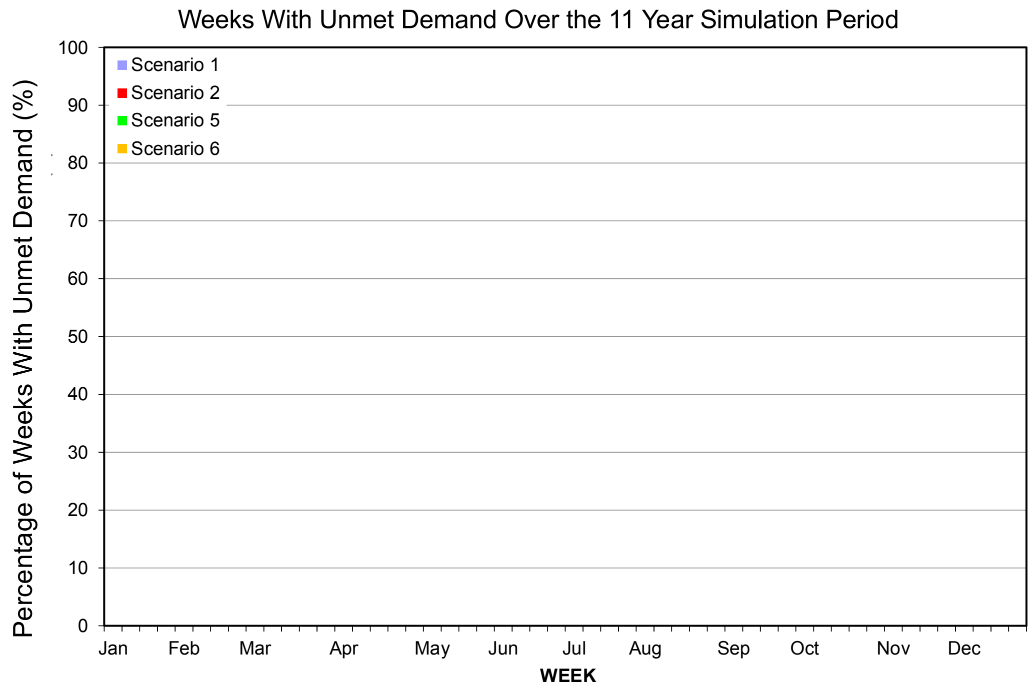


Figure A: Unmet Demand for COK for Scenarios 1, 2, 5, and 6

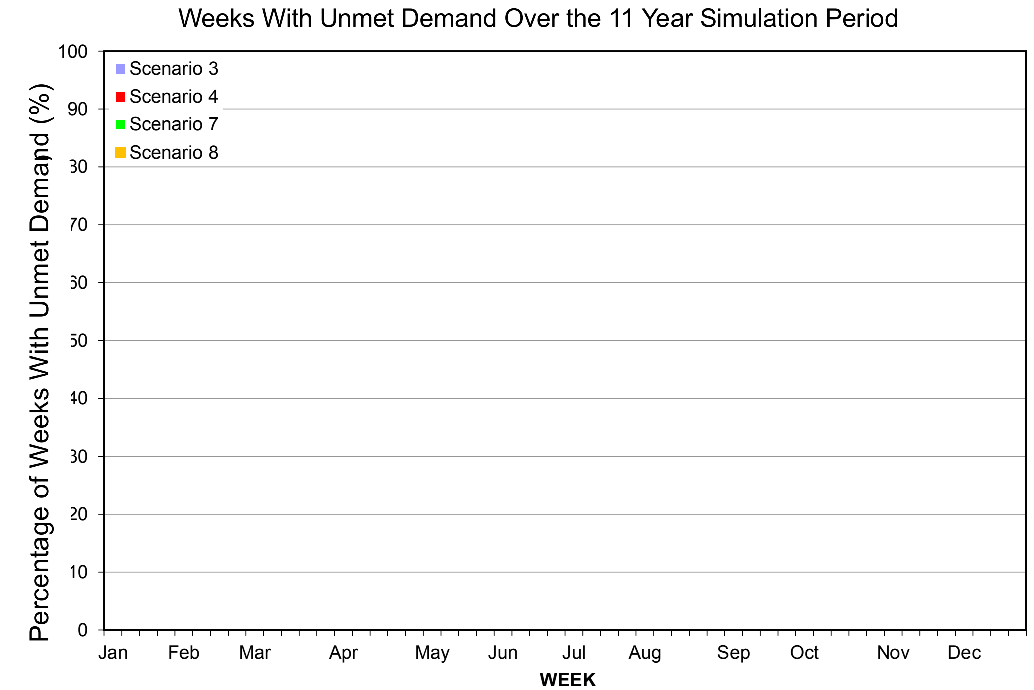


Figure B: Unmet Demand for COK for Scenarios 3, 4, 7, and 8

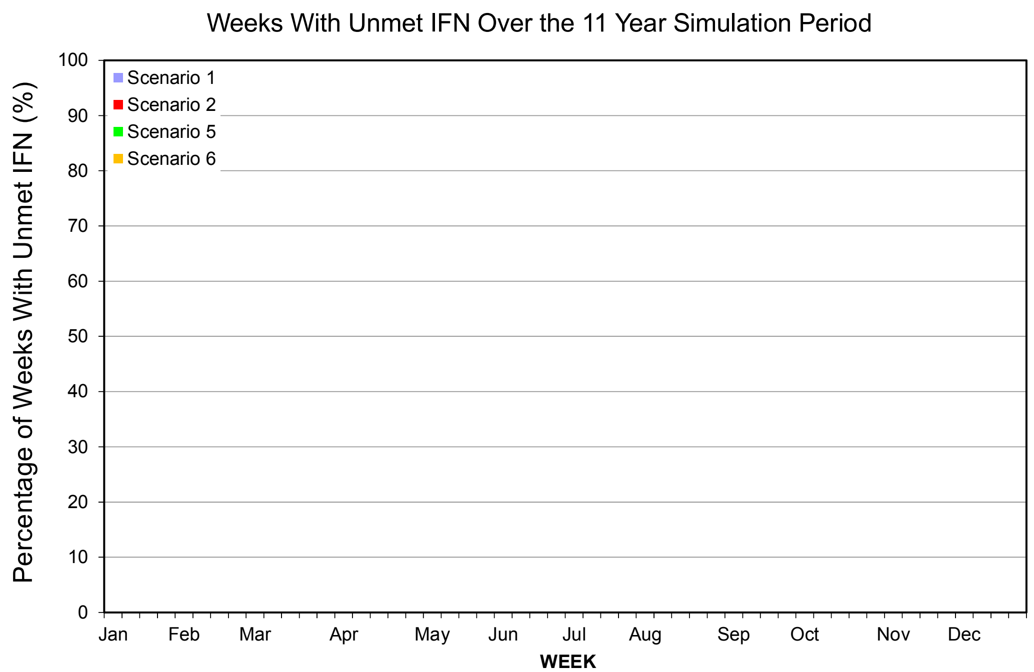


Figure C: Unmet IFN for Okanagan Lake for Scenarios 1, 2, 5, and 6

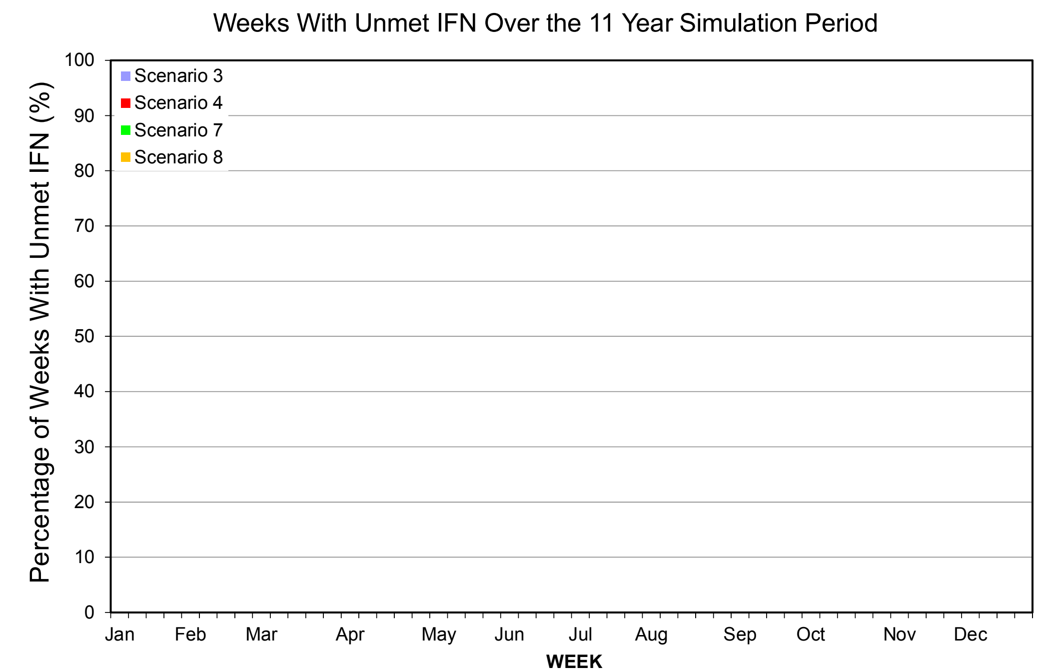


Figure D: Unmet IFN for Okanagan Lake for Scenarios 3, 4, 7, and 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO: 2010-8005.000

FILE: COK Unmet.mxd

Figure C-12: COK Unmet Demand and Okanagan Lake Unmet IFN for OHCM Scenarios 1-8

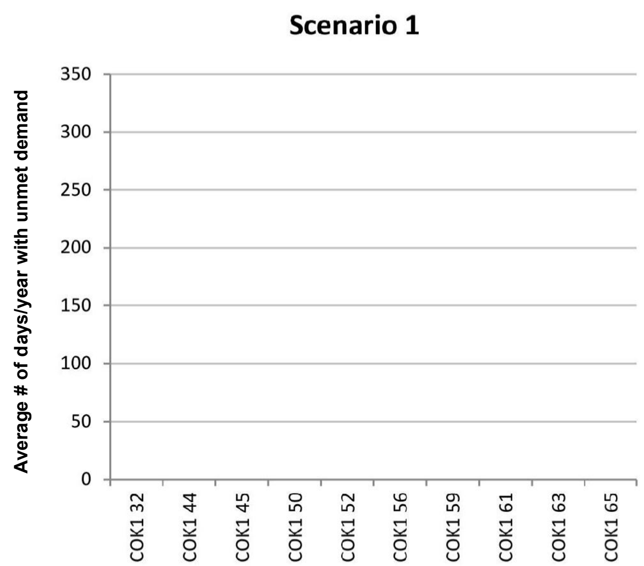


Figure A: The average number of days per year the demand is not satisifed for COK - Scenario 1

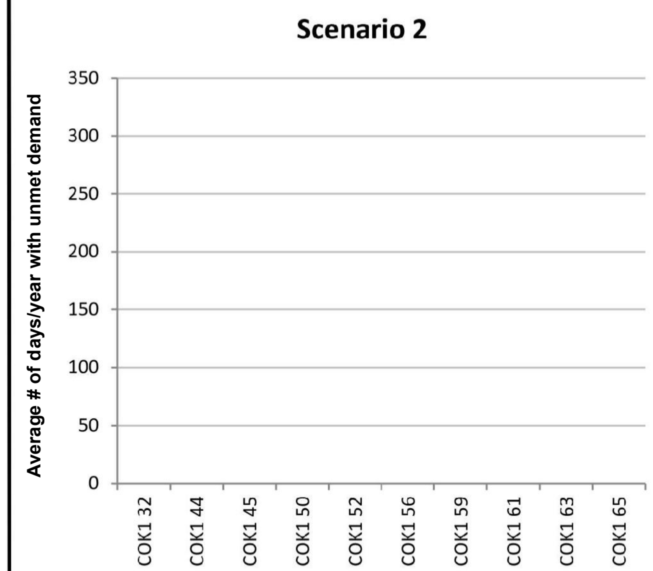


Figure B: The average number of days per year the demand is not satisifed for COK - Scenario 2

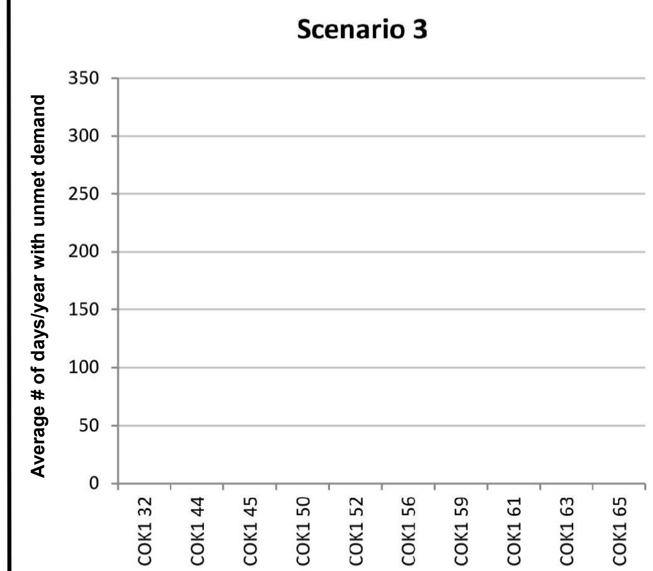


Figure C: The average number of days per year the demand is not satisifed for COK - Scenario 3

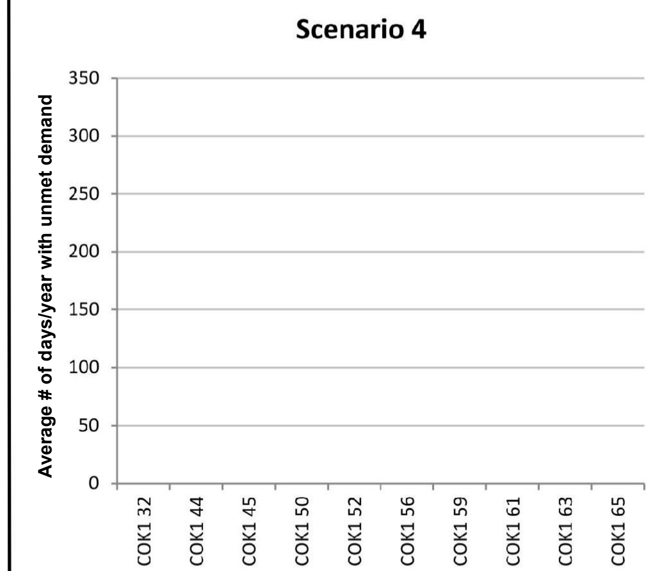


Figure D: The average number of days per year the demand is not satisifed for COK - Scenario 4

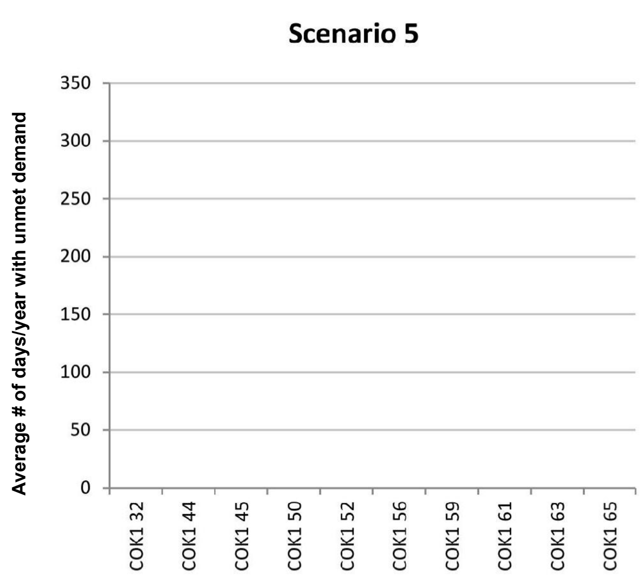


Figure E: The average number of days per year the demand is not satisifed for COK - Scenario 5

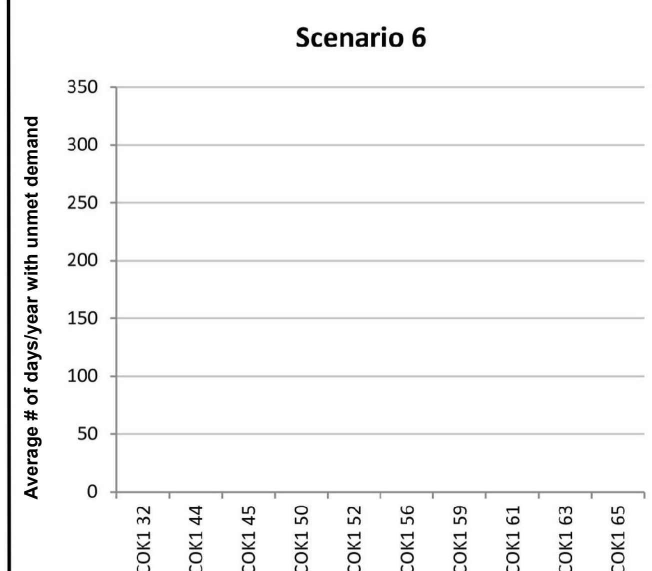


Figure F: The average number of days per year the demand is not satisifed for COK - Scenario 6

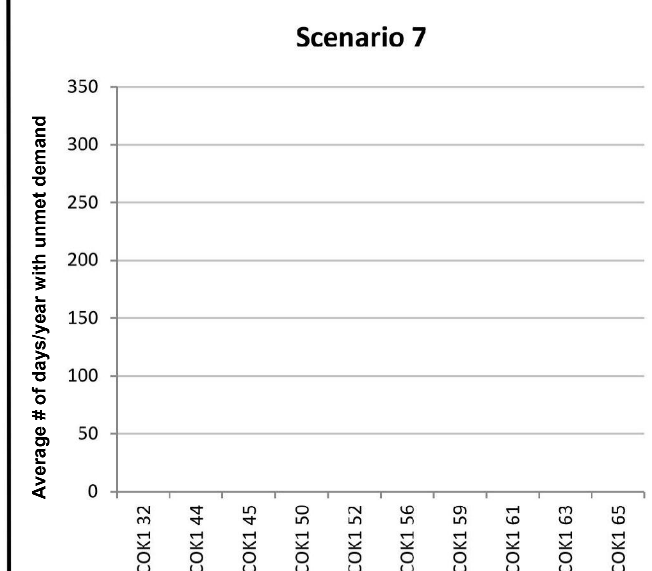


Figure G: The average number of days per year the demand is not satisifed for BMID - Scenario 7

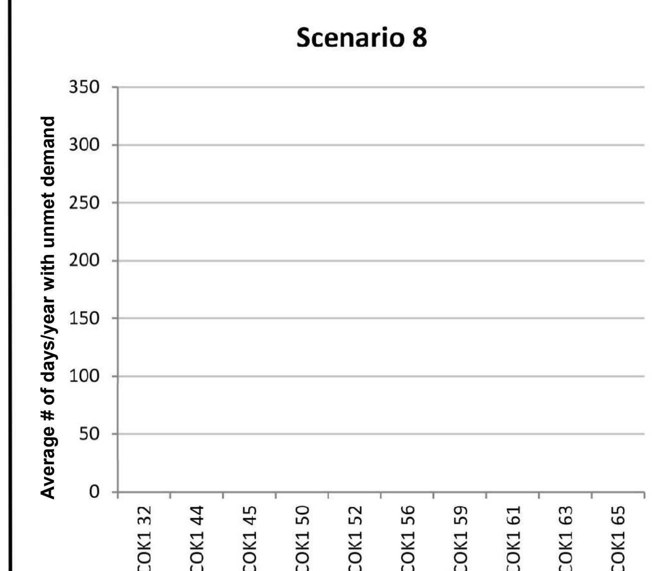


Figure H: The average number of days per year the demand is not satisifed for COK - Scenario 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC.
A Member of the Associated Engineering Group of Companies

PROJECT: OKANAGAN HYDROLOGIC CONNECTIVITY MODEL
PROJECT NO: 2010-8005.000
FILE: COK UN_Reliability.mxd

Figure C-13: COK Demand Site Unreliability Results for OHCM Scenarios 1-8

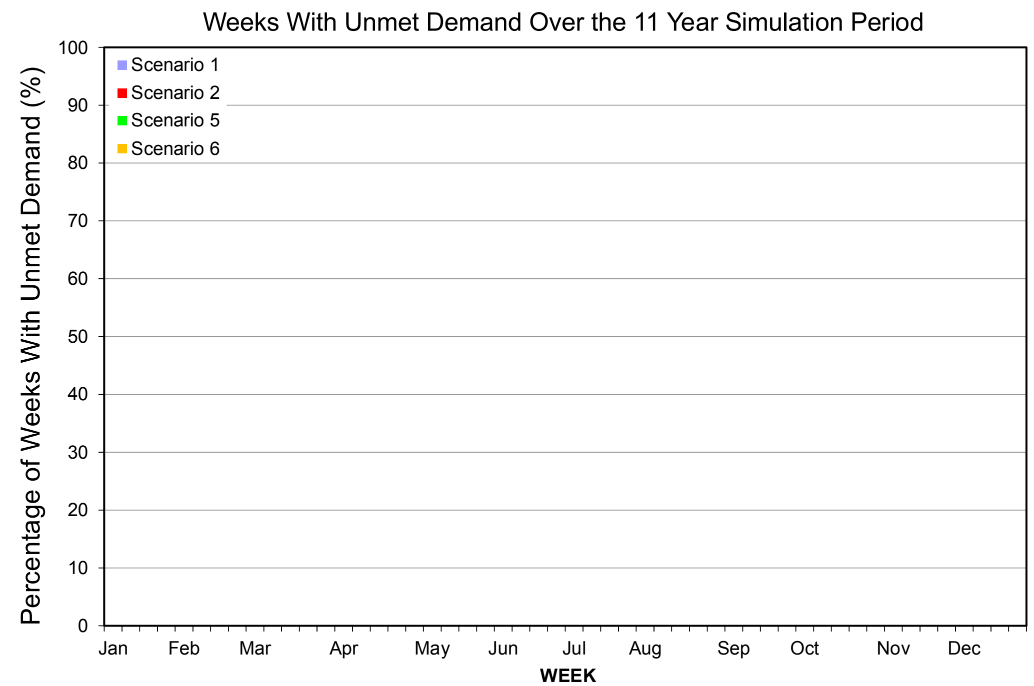


Figure A: Unmet Demand for OLIV for Scenarios 1, 2, 5, and 6

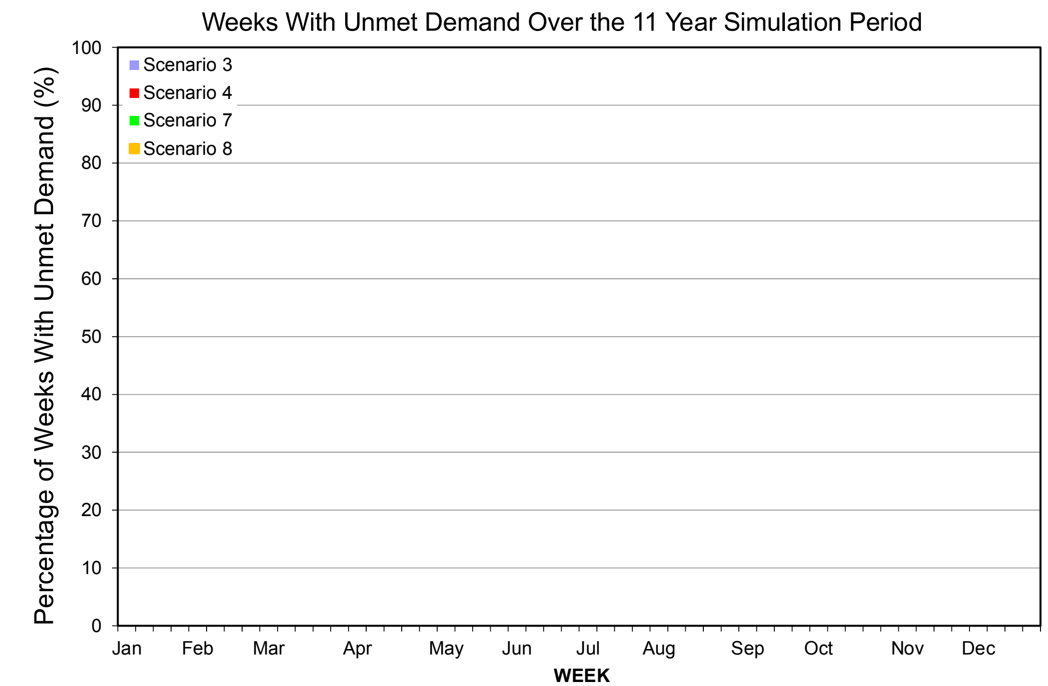


Figure B: Unmet Demand for OLIV for Scenarios 3, 4, 7, and 8

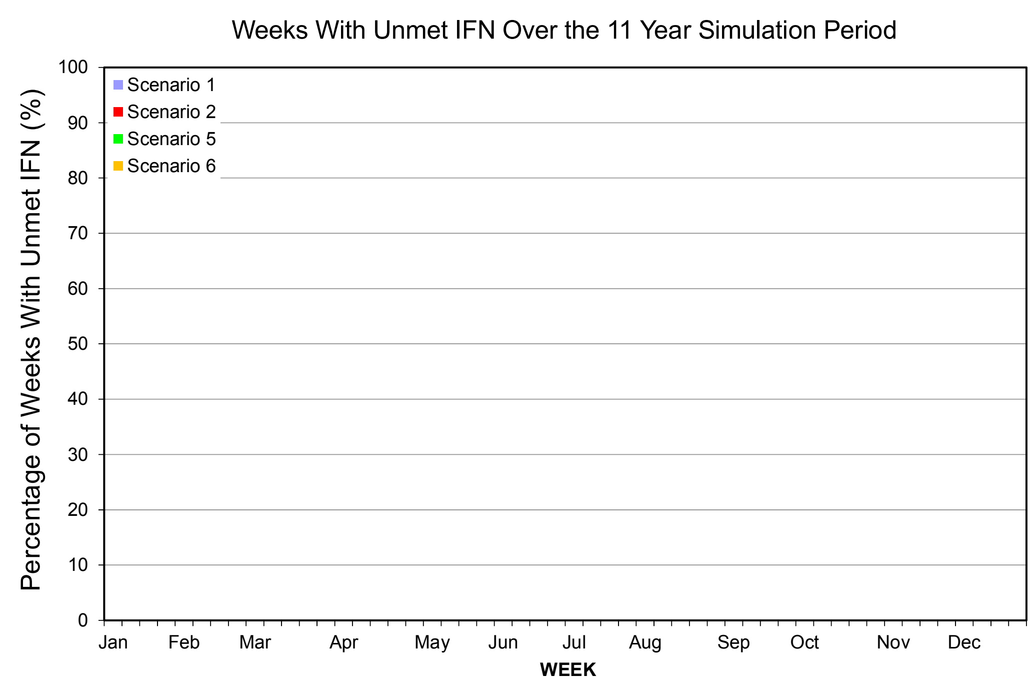


Figure C: Unmet IFN in the Okanagan River for Scenarios 1, 2, 5, and 6

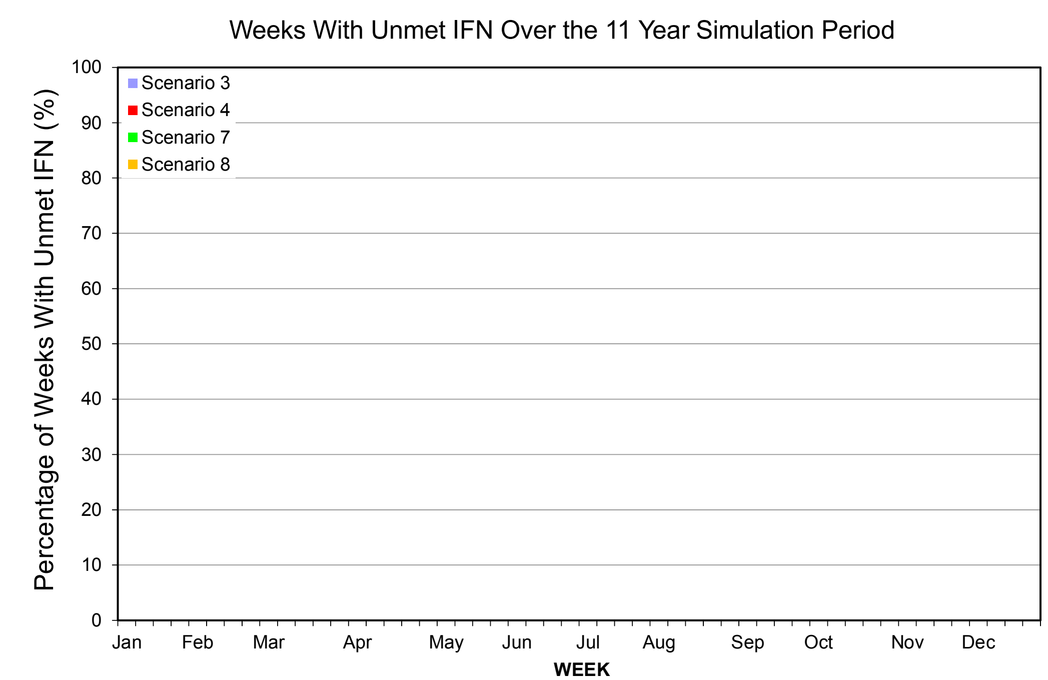


Figure D: Unmet IFN in the Okanagan River for Scenarios 3, 4, 7, and 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL**

PROJECT NO: 2010-8005.000
FILE: OLIV Unmet.mxd

Figure C-14: OLIV Unmet Demand and Okanagan River Unmet IFN for OHCM Scenarios 1-8

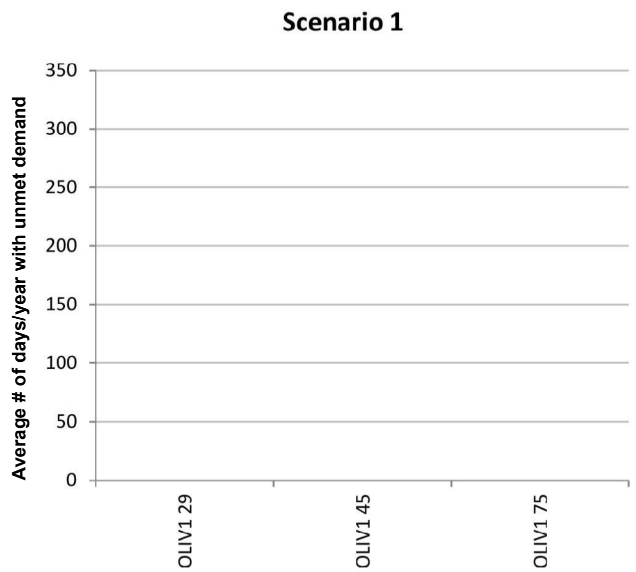


Figure A: The average number of days per year the demand is not satisifed for OLIV - Scenario 1

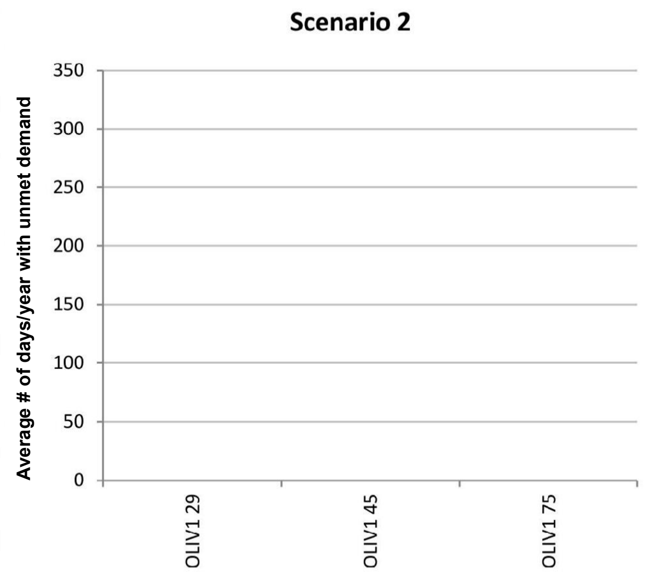


Figure B: The average number of days per year the demand is not satisifed for OLIV - Scenario 2

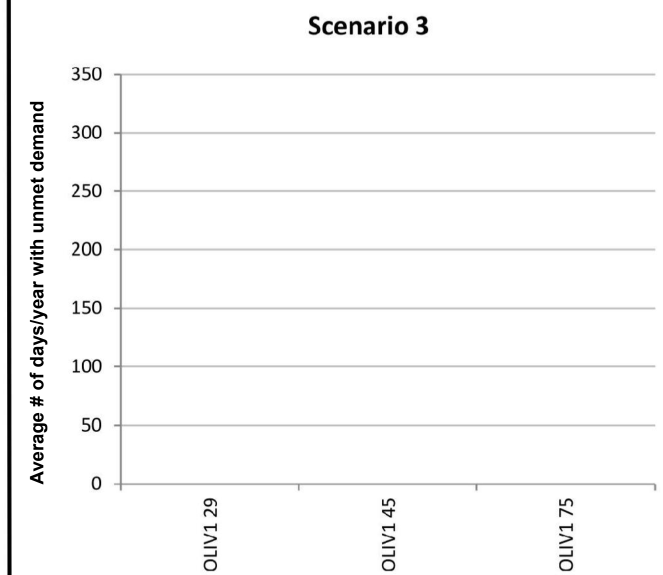


Figure C: The average number of days per year the demand is not satisifed for OLIV - Scenario 3

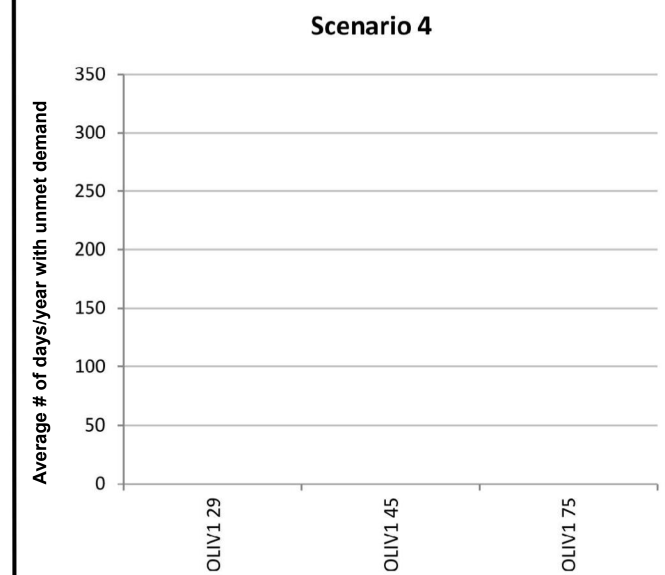


Figure D: The average number of days per year the demand is not satisifed for OLIV - Scenario 4

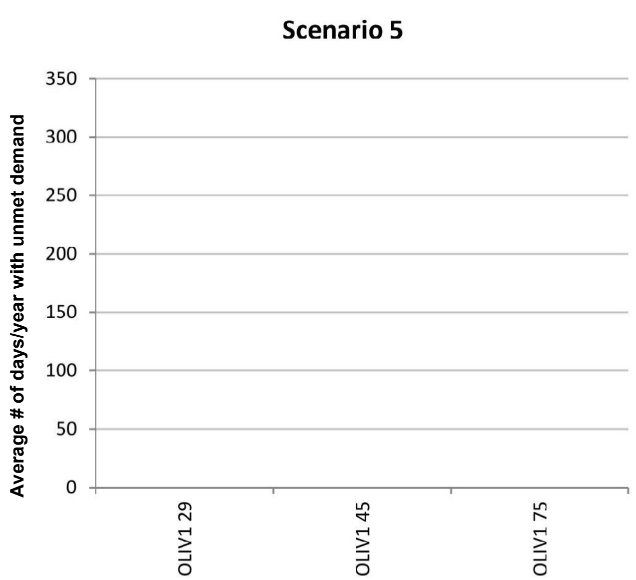


Figure E: The average number of days per year the demand is not satisifed for OLIV - Scenario 5

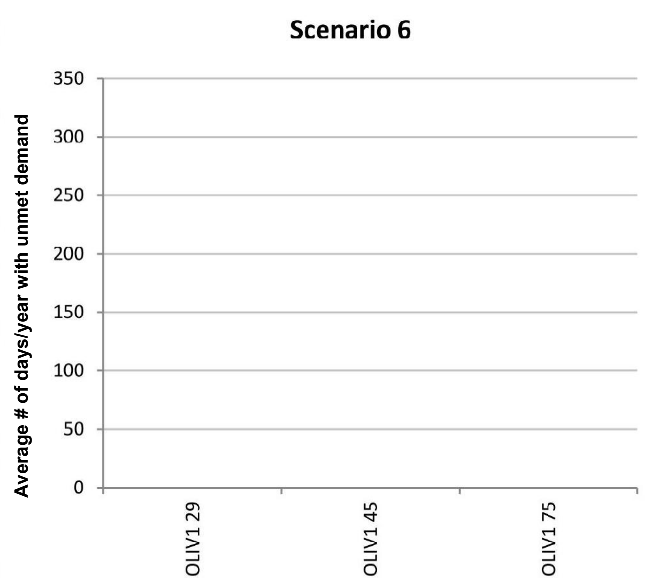


Figure F: The average number of days per year the demand is not satisifed for OLIV - Scenario 6

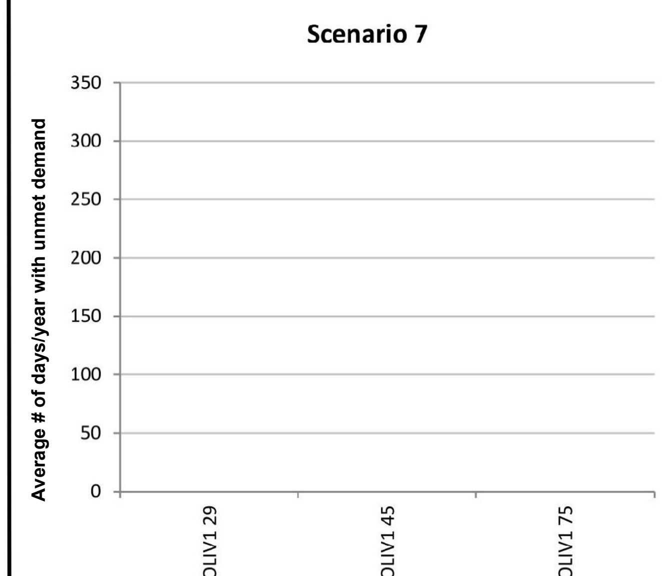


Figure G: The average number of days per year the demand is not satisifed for OLIV - Scenario 7

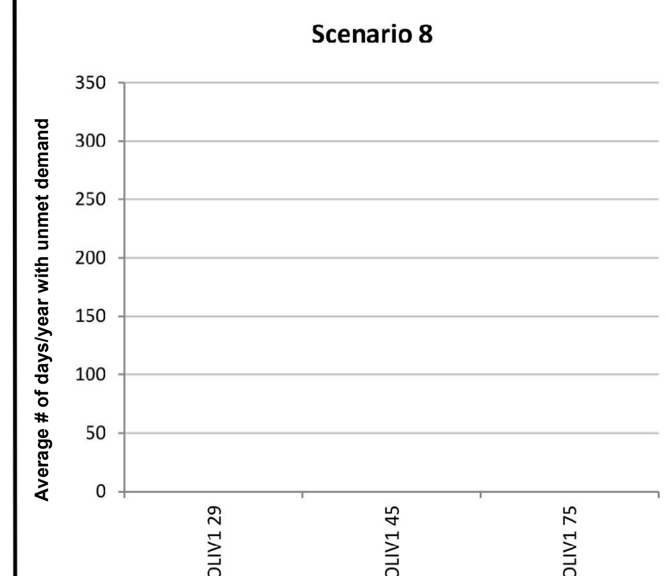


Figure H: The average number of days per year the demand is not satisifed for OLIV - Scenario 8

Scenario Description:
1) Actual demand, existing storage, highest IFN priority
2) Actual demand, existing storage, lowest IFN priority
3) Actual demand, potential storage, highest IFN priority
4) Actual demand, potential storage, lowest IFN priority
5) Max demand, existing storage, highest IFN priority
6) Max demand, existing storage, lowest IFN priority
7) Max demand, potential storage, highest IFN priority
8) Max demand, potential storage, lowest IFN priority

DATE: May 2013
DRAWN BY: DA/TN/DL
DATA SOURCE(S): OHCM

PREPARED FOR: OKANAGAN BASIN WATER BOARD

PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

PROJECT: OKANAGAN HYDROLOGIC CONNECTIVITY MODEL

PROJECT NO: 2010-8005.000

FILE: OLIV UN_Reliability.mxd

Figure C-15: OLIV Demand Site Unreliability Results for OHCM Scenarios 1-8

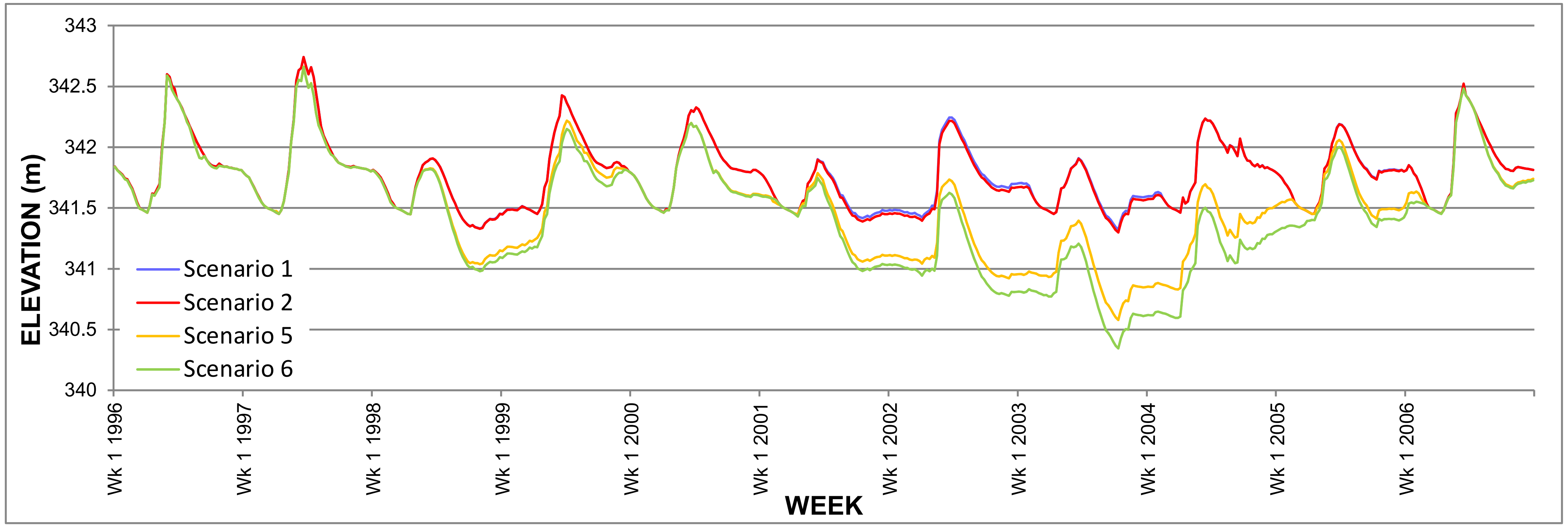


Figure A: Okanagan Lake Level Elevations (1996-2006) for Scenarios 1, 2, 5, and 6

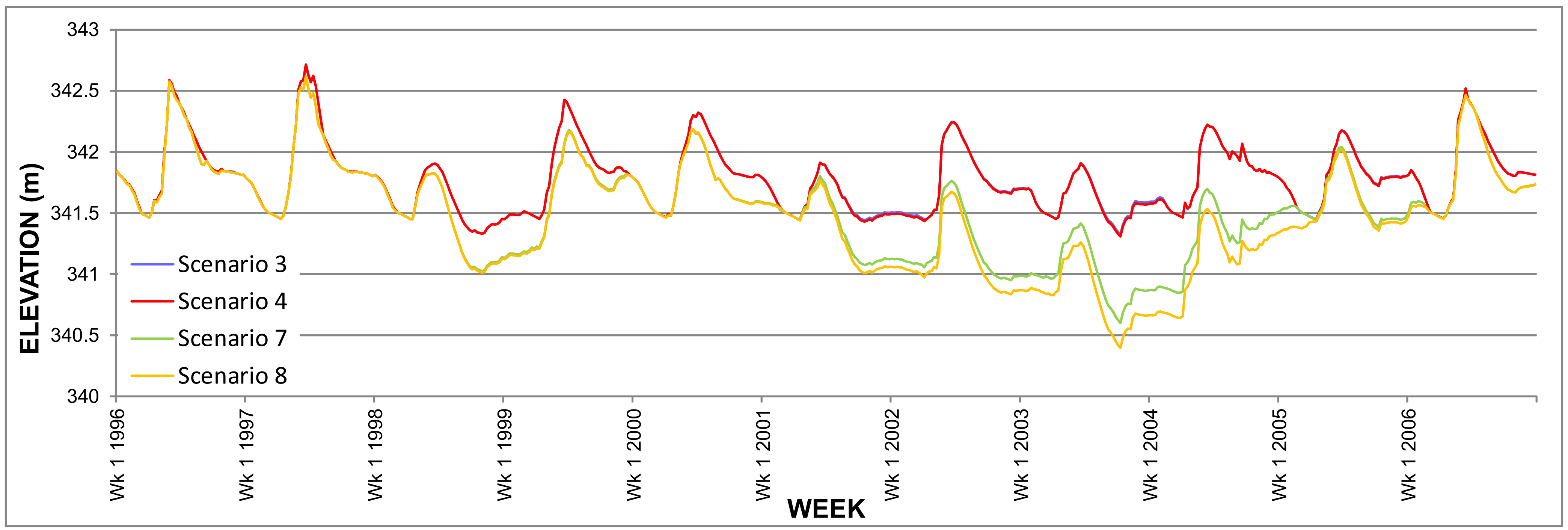


Figure B: Okanagan Lake Level Elevations (1996-2006) for Scenarios 3, 4, 7, and 8

Scenario Description: 1) Actual demand, existing storage, highest IFN priority 2) Actual demand, existing storage, lowest IFN priority 3) Actual demand, potential storage, highest IFN priority 4) Actual demand, potential storage, lowest IFN priority 5) Max demand, existing storage, highest IFN priority 6) Max demand, existing storage, lowest IFN priority 7) Max demand, potential storage, highest IFN priority 8) Max demand, potential storage, lowest IFN priority	DATE: May 2013 DRAWN BY: DA/TN/DL DATA SOURCE(S): OHCM	PREPARED FOR: OKANAGAN BASIN WATER BOARD PREPARED BY: SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies	PROJECT: **OKANAGAN HYDROLOGIC CONNECTIVITY MODEL** PROJECT NO: 2010-8005.000 FILE: OK Lake Levels.mxd Figure C-16: Okanagan Lake Elevations for OHCM Scenarios 1-8

D Appendix D - OHCM GUI: Results Viewer

SUMMIT ENVIRONMENTAL CONSULTANTS INC.
A Member of the Associated Engineering Group of Companies

Date:	May 26, 2013
File:	2010-8005.000
To:	Okanagan Basin Water Board
From:	Brian Guy (Summit Environmental Consultants Inc.)
Project:	Okanagan Hydrologic Connectivity Model
Subject:	**Appendix D:** OHCM Graphical User Interface - Results Viewer

MEMO

This memorandum is Appendix D of the final report "*Okanagan Hydrologic Connectivity Model: Summary Report*". This document supports the electronic files attached in this Appendix, which are required to be uploaded to the OBWB's website.

1 INTRODUCTION

The OHCM Graphical User Interface (GUI) – Results Viewer was completed as the final deliverable to the OHCM project. It is based on the conceptual OHCM schematic and the results from the eight OHCM scenarios outlined in the Final Report. The OHCM GUI – Results Viewer is a web-based results viewer that requires uploading and hosting within the OBWB's website (or other hosting location). The installation and management of the GUI will be the responsibility of the OBWB, though Summit will lend technical assistance when required.

2 GUI PURPOSE

The purpose of the GUI is to allow users to interact, investigate, compare, and understand the huge amount of results and information generated from the eight OHCM scenarios. These results include inflows and water elevations for the upland reservoirs and mainstem lakes, demand and unmet demand for each demand site, required and unmet in-stream flow requirements, and net streamflow at the mouths of the major stream catchments included in the OHCM.

Due to the complex nature and large volume of the results, this viewer is intended to give the user an understanding of how results change between scenarios, so that the implications of the scenarios on water use and supply in the Okanagan Basin can be understood without actually using the complex WEAP model interface.

3 GUI COMPONENTS AND USE

The viewer is divided into three components: (1) the base map; (2) the schematic area and scenario selection; and (3) the results views.

3.1 BASE MAP

The base map, located on the left of the page, is a representation of the entire Okanagan Basin. Within it, the specific stream catchments modeled in the OHCM are highlighted. Those highlighted stream catchments can be used to navigate directly to a stream catchment of interest in the schematic area.

3.2 SCHEMATIC AREA

The Schematic Area of the GUI is where the interaction with the modeled results occurs. Checkboxes listing the eight OHCM scenarios are arrayed along the top of the Schematic Area. These checkboxes allow a user to select scenarios to be viewed in the results view.

Within the Schematic Area, there are 'hot spots' at all demand sites, upland reservoirs, mainsteam lakes, and in-stream flow locations. Clicking on a 'hot spot' in this view zooms the user into that location and by clicking away from a 'hot spot', the view zooms back out allowing the user to navigate more clearly. Scroll bars on the bottom and right sides also allow for navigation within the Schematic Area. Additionally, vertical navigation can be achieved using the mouse wheel.

There are also two navigation arrows in the top left and right corners in the Schematic Area. These arrows navigate the user to the next 'hot spot' within the system downstream from the current location. For locations at the outlet of a stream catchment, the next location is at the top of the next stream catchment.

3.3 RESULTS VIEW

By clicking a 'hot spot' location, the map zooms automatically into that location. At this point, the results available via a "Launch" button opens a graphical representation of the results for that location. From here, it is possible to choose from the results tabs available, as well as the scenarios of interest. The list within the results tabs vary with the type of location (e.g. demand site or in-stream flow needs location) and for the different sites of interest at that location (e.g. upland reservoirs or individual demand sites). For example, if multiple reservoirs or multiple demand sites are listed at a 'hot spot', there is a choice of which site to display results for.

E Appendix E - OHCM Communication Poster

Okanagan Hydrologic Connectivity Model

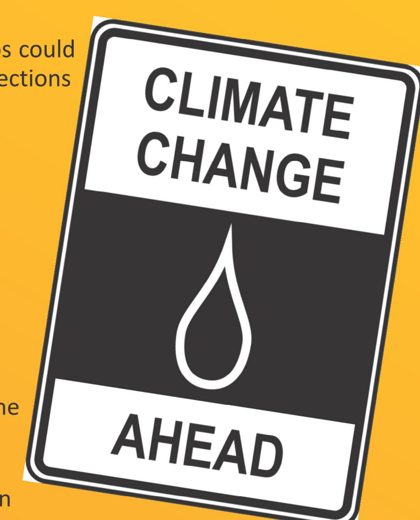
"...understanding how water users in theOkanagan Basin are connected...."

Study Goals

The Okanagan Hydrologic Connectivity Model (OHCM) builds upon a considerable volume of information collected during the Okanagan Basin Water Supply and Demand Project to demonstrate how surface water is stored, licensed, and extracted by the major water utilities in the Okanagan Basin. The OHCM is a key step in developing a better understanding of how water users in the Okanagan Basin are connected.

Specific study tasks included the following:

1. Exploring how the actions of water suppliers in the Okanagan may influence one another.
2. Examining the effects of invoking the B.C. Water Act principle of first in time, first in right (FITFIR).
3. Developing a user-friendly model (the Okanagan Hydrologic Connectivity Model) that demonstrates the connections between water users in the Okanagan that exist as a result of both the natural patterns of water flow and the legal system governing water extractions.
4. Using the model to examine how future water management scenarios could affect water users, by focusing on the hydrologic and legal connections between several large water utilities.



What We Did

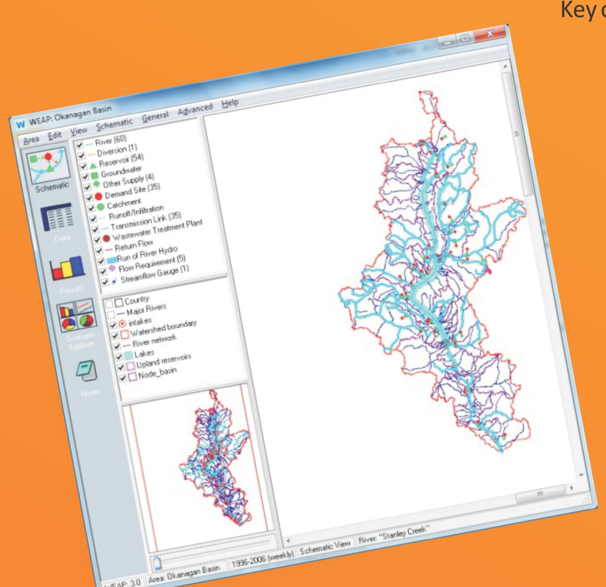
A team of water resource experts was responsible for conducting the study on behalf of the Okanagan Basin Water Board. The study was comprised of several steps:

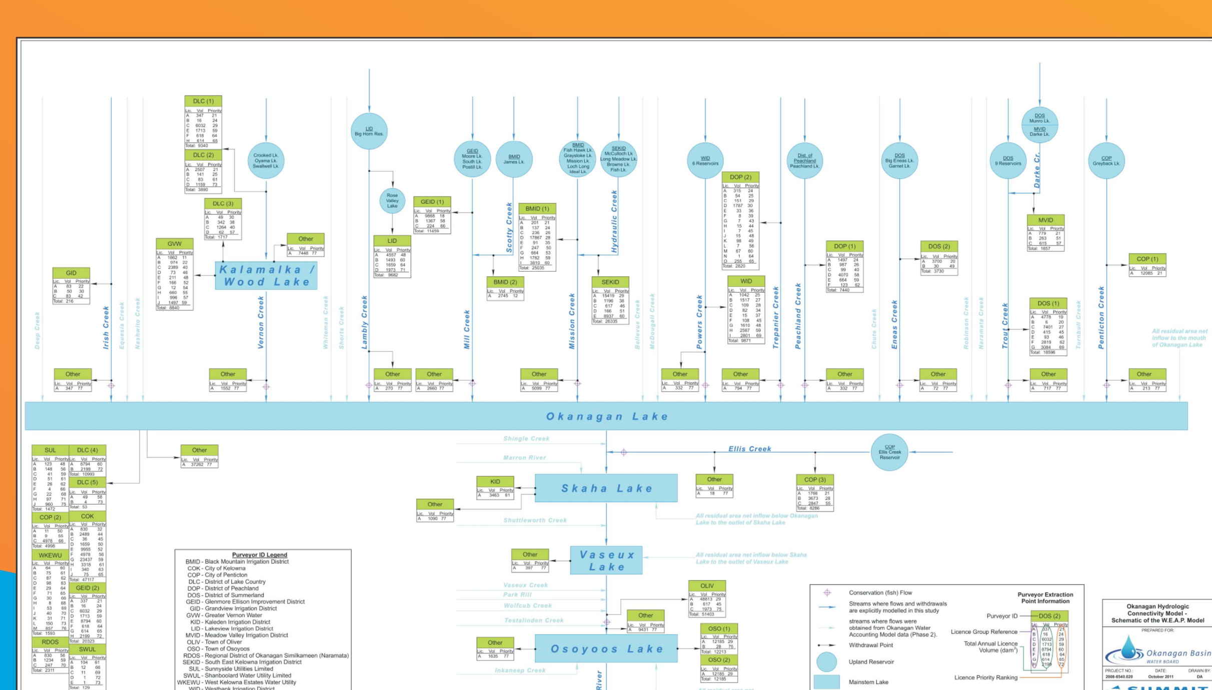
1. Selection of the Water Evaluation and Planning System (WEAP) model. This model is a comprehensive basin management and water allocation tool used throughout the world in many arid regions similar to the Okanagan.
2. Compilation of water supply and demand data from multiple sources, including the Okanagan Water Database, which houses the results from Phase 2 of the Okanagan Basin Water Supply and Demand Project.
3. Development and verification of the Okanagan Hydrologic Connectivity Model (OHCM) using the WEAP platform. This included identification of the main system components (e.g. storage reservoir location and volumes, intake locations and weekly demands, water licences, wastewater return flow) for 21 of the Okanagan's major water suppliers. For verification purposes, the 1996-2006 baseline period was used as there are reasonably good estimates of water supply and demand in the Okanagan over this period (see Phase 2 of the Okanagan Basin Water Supply and Demand Project).
4. To demonstrate the utility of the OHCM, the model was run for eight (8) possible scenarios that evaluate surface water supplies assuming increasing human water demands, assuming in-stream flow needs (IFN) take precedence, and assuming potential upland storage is maximized.
5. Analysis of model results and reporting.

Outcomes

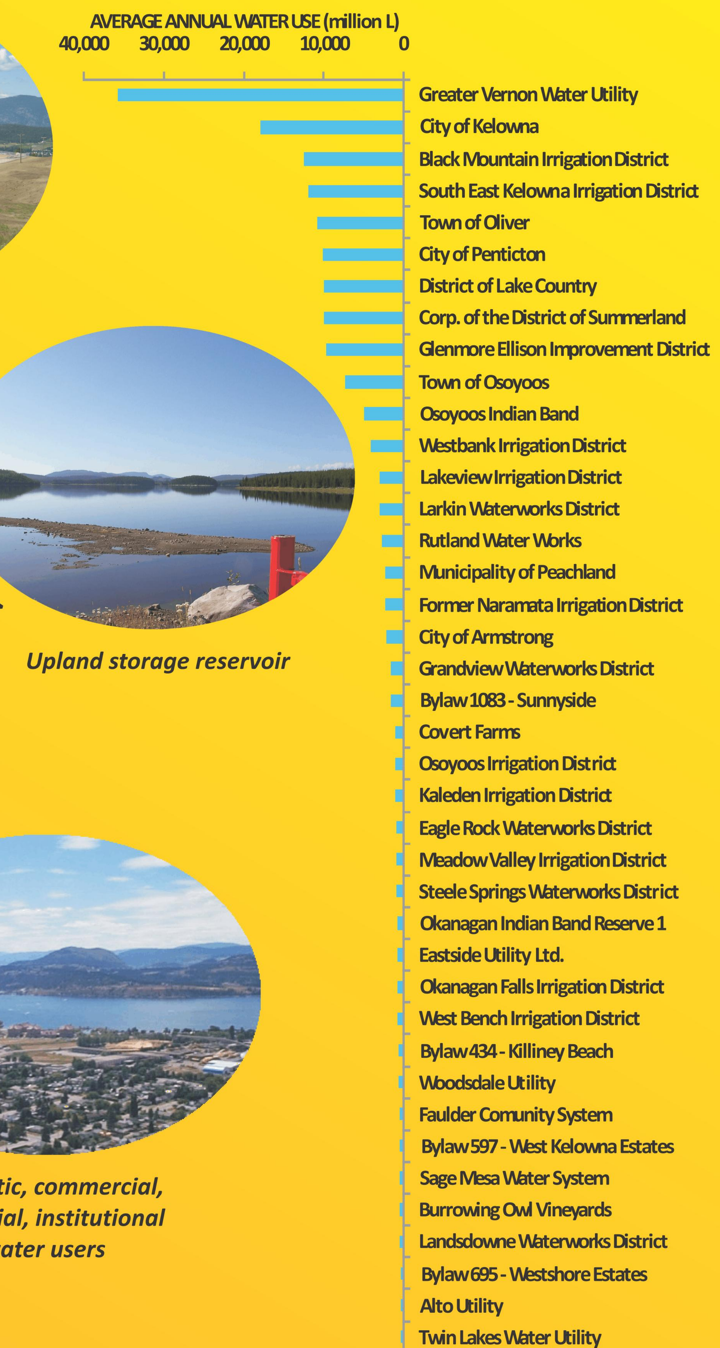
Key outcomes of the study include the following:

1. Under present-day water demands, giving IFN a higher priority would not likely significantly affect the ability of water suppliers to continue to provide water to their customers.
2. However under a high demand situation, either IFN are frequently not met; or water suppliers frequently run short of water (depending on the priorityattached to meeting in-stream flow needs).
3. Increasing upland storage reduces the frequency with which water suppliers and streams run short of water.
4. The priority attached to meeting the operating ranges of Okanagan Lake determines whether the model chooses to "mine the lake" in a high demand scenario, or meet IFN and other demands downstream.
5. The WEAP platform is well-suited to the OHCM application and to future studies intended to extend the Phase 2 Okanagan Water Supply and Demand Project (OWSDP) results.





Water Use by Supplier



(minor utilities not shown)

Study Team:

SUMMIT Environmental Consultants Inc. — A Member of the Associated Engineering Group of Companies

Agua Consulting Inc. "Engineered Water Solutions"

POLAR GEOSCIENCE LTD.

DHI Water & Environment

For more information on water supply in the Okanagan Basin, go to www.obwb.ca/wsd

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