PART FIVE – KEY FINDINGS AND RECOMMENDATIONS

Part Five of this Summary Report summarizes the key findings and recommendations that were made during the Phase 2 studies.

19.0 KEY FINDINGS

Key findings of the technical studies, database development work, model development, and scenario modelling completed during Phase 2 are outlined here.

Water Management and Use

Annual Water Balances

The average annual water balances for the Okanagan Basin and for Okanagan Lake are shown in Figures 6.1 and 6.2, respectively.

Water Suppliers

- 101 known water suppliers in the Basin supply approximately 82% of the total water used in the Basin.

Water licences

- There are currently over 4,000 active water licences to store or use surface water in the Basin. In total, 443,000 megalitres (ML[10]) of surface water is allocated annually for offstream use and 350,642 ML is allocated for in-stream (conservation) use and other non-consumptive uses, for a total allocation of 793,642 ML. This compares with an estimated natural streamflow of 884,000 ML (1996-2006 average). Approximately 163,000 ML of licensed storage supports some of the water uses. About 95% of the total volume of water licensed for offstream use is held by 57 of the main water suppliers in the Basin. These same suppliers hold 88% of the licensed storage in the Basin.

Water Storage

- There are 36 large upland reservoirs in the Basin with a total developed storage capacity of 133,000 ML (82% of the total licensed storage).

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[10] A megalitre (ML) is a million litres. A ML is the same as a cubic decameter (dam^3). An Olympic-sized swimming pool contains 2.5 ML.

Water Imports

- Eight (8) water suppliers import water from outside the Basin or divert water between sub-basins to supplement existing water supplies. The 1996-2006 average annual volume of water imported from outside the Okanagan Basin is 17,000 ML. This represents about 8% of the total water used in the Basin. Most of this water is routed directly to water supplier distribution systems or reservoirs.

Water Use

- The 1996-2006 average annual volume of water used in the Basin is 219,000 ML, of which 147,000 ML is taken from surface sources (this is about 33% of the licensed allocation from surface sources).

Sources of Water

- Water used in the Basin is derived from several sources, in the following proportions (Figure 6.4):
  - Surface water: 67%
  - Groundwater: 22%
  - Imported water: 8%
  - Recycled wastewater: 3%
- Amongst the surface water sources, the three most heavily utilized are:
  - Okanagan Lake
  - Mission Creek
  - Kalamalka–Wood Lake
- Groundwater is an increasingly utilized source of water. There are currently 23 main water suppliers and numerous private users that pump groundwater in the Basin.

End Uses of Water

- Of the total water used in the Basin, the proportions used by each end-use category are as follows (Figure 6.5):

Outdoor:	Agriculture: 55%
	Domestic outdoor: 24%
	Golf courses: 5%
	Parks and open spaces: 2%
	TOTAL: 86%
Indoor:	Domestic indoor: 7%
	Institutional: 1%
	Commercial: 4%
	Industrial: 2%
	TOTAL: 14%

- Outdoor irrigation areas and requirements (including losses to the subsurface) are as follows:
    - Agriculture: 18,300 ha require an average of 120,000 ML (660 mm),
    - Golf courses: 1,060 ha require an average of 10,000 ML (960 mm),
    - Parks and open spaces: 590 ha require an average of 5,000 ML (920 mm)
    - Domestic outdoor: 5,935 ha require an average of 53,000 ML (890 mm)
- Total annual irrigation requirements for 1996-2006 average 188,000 ML or 86% of the total water use in the Basin.
- Basin-wide total domestic water use averages 675 L/person/day year-round, of which 150 L/person/day is for indoor use and 525 L/person/day is for outdoor use. This means that during the landscaping irrigation season, actual outdoor use likely exceeds 1,000 L/person/day in the Basin.
- Between all end-uses, approximately 51,000 ML or 23% of all water extracted, imported or recycled in the Basin is lost or unaccounted for. The largest component of this [25,000 ML (11% of the total water use)] is associated with over-irrigation resulting in deep percolation of water below the root zone. An additional 10,000 ML may also be recharging aquifers through septic systems.

Groundwater Resources

- Because of minimal regulation of groundwater use, and the limited records of groundwater use, there is relatively little information on groundwater resources in the Okanagan Basin.
- A conceptual model was developed to describe the movement of groundwater beneath the land surface in the Okanagan from the uplands down to the valley bottom – a shallow flow system accounting for 85% of groundwater flow and a deep bedrock system accounting for 15% of groundwater flow.
- 79 distinct unconsolidated aquifers were identified – located primarily in the lower elevation valley bottom. Three areas of the Basin contain connected aquifer systems of regional importance: (1) North Okanagan – Coldstream/Vernon and Spallumcheen unconsolidated aquifers; (2) Central Okanagan - Greater Kelowna aquifers; and (3) South Okanagan - Vaseux Lake to Osoyoos Lake aquifers.
- Based on the assumptions and methods used in the groundwater study, the estimated mean annual groundwater discharge to the valley-bottom rivers/lakes in all 79 unconsolidated aquifers is 943,000 ML/yr. This value significantly exceeds the value estimated independently in the surface water study and by the OBHM – approximately 290,000 ML.
- The mean annual groundwater discharge into Okanagan Lake is estimated to range from 41,300 ML (surface water study) to 296,000 ML (groundwater study). The

large range in estimates is a reflection of two independent methods of analysis, and a reliance on estimated (vs. measured) groundwater properties.

Lake Evaporation

- There are at least 19 potentially-relevant methods for computing evaporation from the main valley-bottom lakes, all of which suffer from a lack of data for making the calculations.
- The Penman-Monteith method was chosen for computing lake evaporation because it is widely accepted globally due to its theoretical justification, and is the method used in both the Okanagan Water Demand Model and the Okanagan Basin Hydrology Model for computing evapotranspiration from the land surface.
- Evaporation from the main valley lakes averages 972 mm annually, based on the Penman-Monteith method.
- The evaporated volume is a significant component of the water balance of Kalamalka and Okanagan Lakes, accounting for 90% and 50%, respectively of the net inflow to these lakes.

Surface Water Hydrology

The surface water study that provided the data for calibrating the OBHM indicated the following:

- The pattern of natural runoff in the Basin varies considerably by elevation, and varies spatially in response to precipitation type and amount, evapotranspiration, and other factors. For the 1996-2006 period, total natural streamflow from all tributaries and residual areas in the Okanagan Basin averaged 884,000 ML per year. When converted to a depth, this volume would cover the watershed surface (excluding the main valley lakes) to a depth of 117 mm. Streamflow is comprised of direct surface runoff and baseflow contributed by groundwater. Approximately 83% of the annual total flows into Okanagan Lake, while 17% of the total flows into Okanagan River and the mainstem lakes downstream of Okanagan Lake.
- Upstream of Penticton, the runoff averages 130 mm, while downstream of Penticton, runoff averages only 78 mm. Furthermore, runoff on the east side of the Basin tends to be higher than on the west side. Annual flow from all tributaries and residual areas on the west side of the Okanagan Valley averaged approximately 99 mm over the 1996-2006 period, while those on the east side totalled approximately 134 mm.
- Mission Creek has the largest streamflow, delivering 28% of the total flow in the Basin. Trout and Vernon Creeks are the second and third largest contributors, each producing about 7% of the total.
- Streamflow during the 7 months of August to February accounts for only 14% of the annual total, while the 5-month period March to July accounts for 86%. The August

to February total streamflow averages about 18,200 ML per month, which is mostly contributed by groundwater (baseflow).

Instream Flow Assessment

- Prior to the beginnings of human management of water in the Okanagan, most Okanagan streams had insufficient flow during parts of the year for optimal fish production.
- Minimum instream flows for sustaining aquatic populations in 36 Okanagan tributaries were calculated using the B.C. instream flow needs (IFN) methodology, which is a desk-top analytical method. The outcomes provide a guide for selecting a minimum instream flow regime for Okanagan tributaries.
- A comparative analysis of regulated flows and naturalized flows showed that at some locations the BCIFN minimum risk flows were achieved more frequently in the late summer dry period with regulated flows than with naturalized flows. However, the opposite was true at other critical time periods (e.g. mid-winter). This indicates the importance of upland reservoirs as a potential source of instream flow in support of aquatic habitat.

OBHM and OBWAM Model Results

Based on the 11-year calibration period 1996-2006, the overall water balance for the Basin, as determined by the OBHM in conjunction with other Phase 2 studies, is shown in Figure 6.1. The values indicated on the figure are annual totals, but they are spatially and temporally averaged: i.e. they are averaged over the entire Basin surface, and they are averaged over the period 1996-2006. The figure does not indicate the variability which characterizes both water supply and demand. Decision-making must consider the seasonal variability in both supply and demand, the differences from place to place within the Basin, and the annual variability of both supply and demand.

Scenario Modelling Results

To demonstrate the power and utility of the three models developed during the study, 15 possible future scenarios were examined using the three study models. The outputs are not intended to provide the best estimate of the future. They provide one possible future outcome, based on a reasonable set of assumptions. Using the Canadian Global Circulation Model with the expected rate of global CO_2 production, the models suggest the following:

- Total annual precipitation and evapotranspiration do not exhibit any obvious trends in the future, but the average temperature is expected to increase and the number of days with temperatures below freezing is expected to decrease significantly.
- As a result of climate change, the maximum amount of water stored in the snowpack is likely to decline by almost 30% by the mid-point of this century, and the date that the peak snowpack occurs will likely become earlier by almost 3 weeks. As a result,

snowmelt runoff will likely peak 2-4 weeks earlier in the year, and spring snowmelt will provide a smaller amount of runoff.

- Although there is likely to be little change in the annual total tributary runoff, inflow to Okanagan Lake, and Okanagan River flows, the scenarios suggest a clear shift in the timing and magnitude of streamflow over time. Warmer winter temperatures will likely result in more winter precipitation in the form of rain, resulting in increased flows during winter. In the spring, peak flows will likely occur earlier and the magnitude of the peak flow will be reduced, as a result of less snow accumulation during winter. Furthermore, the summer low flow period will likely become extended over the long term.
- Over the long term, levels of Okanagan Lake are likely to remain within the "normal" range of lake levels during normal or wet years, but could be near or below the "normal" range during drought years.
- The effect of climate change on upland reservoirs will likely include earlier filling, as a result of an earlier onset of spring temperatures; lower peak volumes stored, in response to lower snow accumulation; earlier drawdown of storage, due to small spring snowmelt runoff volumes; and an average of 10% less stored water available in the late summer due to a longer summer season.
- If we assume that only climate changes and everything else (population, land use, amount and type of irrigated area, and water use efficiency) remains as it is currently, total annual water use is expected to increase by 10% for the 2011-2040 period, and 17% for the 2041-2070 period, relative to the present.
- If we assume that the population grows as expected, and assume that water use efficiencies continue to improve at present rates, the average annual water use over the 2011 – 2040 period will be 4% smaller than it is today. But if the population grows faster than the estimated rate, with present rates of improvements in water use efficiency, total water use will be roughly the same as it is currently.
- If all reasonably possible agricultural land becomes irrigated over the 2011-2041 period, annual water use will be 13% higher than it is currently.
- Assuming accelerated implementation of water efficiency measures with 33% efficiency achieved by 2020, water use is expected to decrease by 6-7%.
- In a future 3-year drought, climate change alone is expected to increase annual water demands by 16% relative to the present.
- If the irrigated agricultural land base expands to its potential size, annual water use during a 3-year drought is expected to be 25% greater than annual water use in an average year today.

20.0 RECOMMENDATIONS

The Phase 2 studies have outlined a number of recommendations for further work to improve our understanding of the water resources of the Okanagan Basin. These recommendations are summarized below.

Water Management and Surface Water

Because information on actual water use in the Basin is limited, this Project has had limited success in conclusively determining actual water use in the Okanagan Basin. The estimates of water use reported herein are based on estimates generated by the Okanagan Water Demand Model (OWDM), supported by limited data from water purveyors. Similarly, a thorough calibration of the OWDM against measured data has not been possible. It is recommended that:

- Water purveyors should measure their water withdrawals (from both surface and groundwater sources), and the amount of water they distribute to customers.
- Large water purveyors should report their water use to the Province on a regular basis. An appropriate definition of "large" could be derived from the studies reported herein. This information will improve our understanding of actual water use and will be useful in improving the natural streamflow estimates generated by the surface water hydrology study.
- Scenario results demonstrate that continuing to achieve greater efficiency in water use is very important to ensuring the long-term sustainability of the water supply. Because most of the water used is for irrigation, it is recommended that effort continue to be placed on achieving efficiencies in both agricultural and non-agricultural irrigation practices, using proven conservation measures.

Deficiencies in the hydrometric network make it difficult for water suppliers to manage their water supplies. These limitations affected the calibration of the OBHM. Recommendations include:

- Monitoring of the water supply should be improved through an extension of the hydrometric network. Monitoring stations should be placed downstream of the major storage reservoirs in the Basin. In particular, to improve the OBHM, additional monitoring should be focussed in the southeast portion of the Basin, where the network is particularly weak. Other recommendations of Dobson and Letvak (2008) should be considered.
- A field-based program to assess streamflow-groundwater interactions where streams flow across alluvial fans should be completed – this will lead to improvements in the OBHM.

- Streamflow estimates for small streams during summer low flow (or no flow) periods should be improved.
- Scenario results showed that in future, upland snowpacks will likely become smaller and melt earlier in the spring. In addition, the summer irrigation season may become longer. This will have implications for water suppliers reliant on storing spring runoff in upland reservoirs. It is recommended that water suppliers maintain their options for increasing storage in upland reservoirs in order to continue to provide reliable water supplies. Increased storage in these reservoirs could also be used to provide increased instream flows for aquatic species.

Implementing these recommendations will improve our understanding of water demand and supply in the Basin, our confidence in the OWDM and the OBHM, and our ability to make informed water management decisions. A continued focus on water use efficiency will mitigate the effects of changes in climate, population, and other drivers of water use.

Groundwater

Both groundwater resource availability and groundwater use are poorly understood in the Okanagan Basin. The following recommendations are made:

- Groundwater use should be regulated using the same system used to regulate surface water.
- Water use from groundwater should be reported to the Province.
- The network of Provincial groundwater observations wells should be extended to aquifers that are not currently monitored.
- Interactions between surface water and groundwater on the major alluvial fans in the Basin should be evaluated. This will improve the calibration of the OBHM during the low flow season from September through March, will improve our understanding of the role of groundwater, and will assist in identifying appropriate instream flow needs for key aquatic species.
- Studies to confirm the conceptual model of bedrock flow systems should be undertaken.
- Measurement and modelling of actual evapotranspiration should be conducted within the Basin – this will improve our understanding of recharge to groundwater aquifers in the Basin, and of the role of groundwater in the overall Basin water balance.

Lake Evaporation

Lake evaporation is a significant component of the water balance of some of the major valley-bottom lakes in the Okanagan Basin, yet our ability to determine reliable estimates of lake evaporation remains weak. Modelled results provide a range of estimates that result in large uncertainty. It is recommended that:

- Direct measurements of lake evaporation should be made in the main valley-bottom lakes in the Okanagan Basin. This will provide a better understanding of actual evaporation losses, and permit identification of a reliable method of estimating lake evaporation in the Basin.

Instream Flow Needs

Despite a comprehensive evaluation of relevant methods of estimating the instream flows required to sustain populations of aquatic biota and their ecosystems in the Okanagan, it is apparent that there are no desk-top methods available for reliably estimating the required instream flows. The following recommendations are made for future studies to refine the approach to specifying instream flow-needs to maintain aquatic biota and their ecosystems in the Basin:

- Conduct additional studies to assess the consequences of failure to meet particular low flow thresholds – e.g. production losses or extirpation of specified aquatic biota (fish and SARA-listed species).
- Initiate tests of the key assumption that habitat requirements of a broad range of sensitive aquatic biota will be met if the requirements of sentinel species such as salmonid fishes are satisfied.
- Assess the importance of combinations of surface and groundwater flows and withdrawals in various streams of the Okanagan to the maintenance of suitable, seasonal, thermal conditions required to sustain healthy populations of salmonids and other sensitive species of aquatic biota.
- Initiate work to identify how to expand effective application of the BCIFN methodology to sets of streams by determining the consequences of annual to seasonal temperature and flow variations on migration, dispersal, recolonization and production of sentinel species of aquatic biota among streams that taken together comprise the ecosystem(s) of such species.

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

- Agreement on an acceptable minimum instream flow regime for a set of streams will likely require that the agencies with a responsibility for aquatic species agree in advance on an acceptable level of risk to these species.
- A preliminary evaluation of the instream flows required to sustain aquatic biota should be made using the BC Instream Flow Methodology, with consideration of the 25^{th} flow percentile documented herein.

- These office-based studies should be supplemented by site-specific field evidence for the stream (or representative member of a characteristic set of streams).

Okanagan Water Demand Model, Okanagan Basin Hydrology Model and Okanagan Basin Water Accounting Model

Although these models make very good use of the available data and information, there are some areas where the models could be improved. The following recommendations are made:

- The techniques used to estimate outdoor water use in the OWDM should continue to be improved.
- The information used to estimate indoor water use in the OWDM has several limitations. This information should be improved as better information is made available in the future through improved reporting of water use.
- Site-specific research studies may be needed to better calibrate the computed water demand for all crops, including non-agricultural crops.
- Air temperature is a very important driver for several key hydrologic processes simulated by the OBHM. It is recommended to expand the network of stations measuring climate information in the Basin, particularly at middle and high elevations. This will make it possible for future improvements to be made in the downscaled gridded climate data used to drive the OBHM.
- The gridded temperature data should be re-examined to see if there is an apparent tendency to under-represent temperature gradients between high and low elevations, or over-predict temperatures at higher elevations, particularly during fall and winter when temperature inversions can occur.
- The manner in which the operational rules for the dams along the mainstem lakes are represented in the model should continue to be improved, to reduce the short term oscillations currently in the modelled outflow from the main lakes.
- The calibration period for the OBHM and the OBWAM could be extended to 2010, to evaluate and continue to improve the model.
- Groundwater will likely continue to be developed as a water supply source, with potential impacts to existing groundwater users and surface water bodies receiving groundwater discharge. Further hydrogeological characterization and quantification of groundwater flow and groundwater-surface water interactions are recommended. Numerical models could be used to evaluate the impacts of future groundwater development and changes to future hydrological inputs.
- Since the upland reservoirs play a key role in managing the supply of water to the downstream lakes and water licence holders, methods to improve the way the upland reservoirs operations are implemented in the model should be investigated.

- Scenario runs indicate that management of upland reservoirs will continue to be a very important aspect of future water supply for the Basin.
- In order to properly bracket the potential impacts of climate change, several additional climate models should be applied and evaluated before any final conclusions regarding climate change can be made.

Water Licences

- The OBWAM makes it possible to evaluate the impact of a water licence decision on other licensees. It is recommended that future licensing decisions consider the possible impacts of water withdrawals on other licensees within the Basin, both upstream and downstream of the proposed point of diversion.
- The OBWAM also makes it possible to evaluate the impact of a water licence decision on compliance with fisheries components of the Canada - B.C. Okanagan Basin Agreement (OBA). It is recommended that future licensing decisions consider the possible impacts of water withdrawals on compliance with the OBA.
- It is recommended that water licence decisions are made with an understanding of the wide year-to-year variability in climate that characterizes the Okanagan Basin.
- Scenario runs showed that it is possible that the irrigation season could begin earlier in spring, and extend later in the fall than at present. It is recommended that the Ministry of Environment consider extending the length of the irrigation season for these licences, subject to maintaining compliance with the Canada–B.C. Okanagan Basin Agreement.

Other recommendations

Other recommendations of Phase 2 include:

- A communication plan should be developed to communicate the results to stakeholders and the public. The web-based reporting tool currently under development should be a key part of this communication plan.
- The three Project models are capable of providing scientifically-based information to support water management decisions. The OBWB and other agencies should develop key questions that can be addressed by the models, and run these additional scenarios.
- The Project models make good use of available information. However, the models should all be improved following a period of additional data collection.

Phase 3 Work Program

The Working Group has developed a Phase 3 work plan that reflects these recommendations. The proposed Phase 3 work program can be subdivided into four components:

- Communication with stakeholders;

- Using and maintaining the databases and models;
- Turning results into policy; and
- Updating and improving the data and models;

Communication with Stakeholders

Development of the web-based reporting tool is continuing. The Project pages on the OBWB website will be enhanced for easier dissemination of Project reports. Videos on the three Project models are being developed – these videos will be available on the OBWB website. There are plans to develop visualization tools to help communicate Project results. Meetings to obtain input from stakeholders on key questions that could be addressed by the models are planned. Finally, a community consultation program is planned to communicate the Phase 2 results, and to identify ways to use the results in community planning.

Using and maintaining the databases and models

To make full use of the science developed in Phase 2 for policy development, the databases and models must be hosted and supported. This will permit and facilitate access to Project information from a broad audience – from academic personnel to the general public. It is anticipated that the OBWB will host the hardware and software for the data and models.

The OBWB plans to assist in the training of university researchers and local consultants to ensure a competent local knowledge base and to promote the use of the models. New scenarios will be examined to provide a better understanding of the possible range of water futures. Results of future scenario runs will be stored in the OkWater database so they can be viewed through the web-based reporting tool. The OkWater database will be expanded and made more accessible to the public and expert users. The OBWB will make sure that the reports used in the Project are available to the public through the OBWB website.

Turning Results into Policy

Phase 2 was primarily a technical study – it did not make policy recommendations. The work of extending the Phase 2 science and modelling to inform decision-making and policy will occur in Phase 3. In particular, three initiatives are planned:

- An analysis of the current water policies in the Okanagan, and how they are suited to respond to water shortages, with recommendations for changes as needed;
- The community consultation program identified above will inform a process to link water management and community planning; and
- Development of a strategy to facilitate equitable water distribution during shortages, such as a Basin-wide drought plan, water use plan, or water management plan.

Updating and Improving the Data and Models

Scientific work during Phase 2 was restricted to working with available data. In all cases, data gaps and data sparseness have constrained the results. This is particularly notable for the streamflow, water use, groundwater, lake evaporation, and climate data. Phase 3 will include improving the data inventories that provide the knowledge base for understanding natural processes and human management impacts in the Basin. In particular, a streamlined water use reporting tool will be developed for use by water purveyors to report their water use to the Province on a regular basis. A project to measure lake evaporation has been initiated. Funding and partnerships will be sought to improve the hydrometric network in the Basin, and the network of groundwater observation wells.

In addition, all three models developed during Phase 2 will be re-evaluated as the new data becomes available. New data will improve the performance of the models, and increase the level of confidence in their predictions. Improvements to the Okanagan Water Demand Model have already been initiated, driven by the needs of in-kind partners, including consideration of the effects of livestock water use, and refinements to the outdoor and indoor water use components of the model.