Appendix B

SPATIAL LAYERS, WATER BALANCE TERMS, AND WATER BALANCE EQUATIONS

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Appendix B provides descriptions of the spatial layers developed for the Phase 2 project, and of the various water balance terms and equations used to define the Okanagan water balance.

1.0 OVERVIEW OF THE PHASE 2 SPATIAL LAYERS

Three ground-based layers were developed specifically for the Phase 2 Project:

- A surface water layer (surface water “nodes” – Attachment 1 to the main report);
- A groundwater layer (aquifers – Attachment 2 to the main report) ; and
- A water use area layer (water use areas – Attachment 3 to the main report).

In addition, a climate layer consisting of a 500 m by 500 m grid was developed by Environment Canada prior to the start of the Phase 2 project for use in water demand modelling and other applications. Through various scientific procedures, estimates of daily maximum and minimum temperature, as well as the daily precipitation, have been derived for the mid-point of each climate grid cell for the historic period back to 1961. In addition, 12 data sets consisting of daily temperature and precipitation estimates have been generated for each day to the year 2100. The 12 datasets were derived using 6 different General Circulation Models (GCMs) each running twice. The historic climate layer has been used in Phase 2 for both water demand modelling and water supply modelling. In addition, the Phase 2 project made use of two of the 12 future climate dataset in examining future scenarios. The development of the climate datasets is explained in Section 5.0 of the main report and are not considered further here.

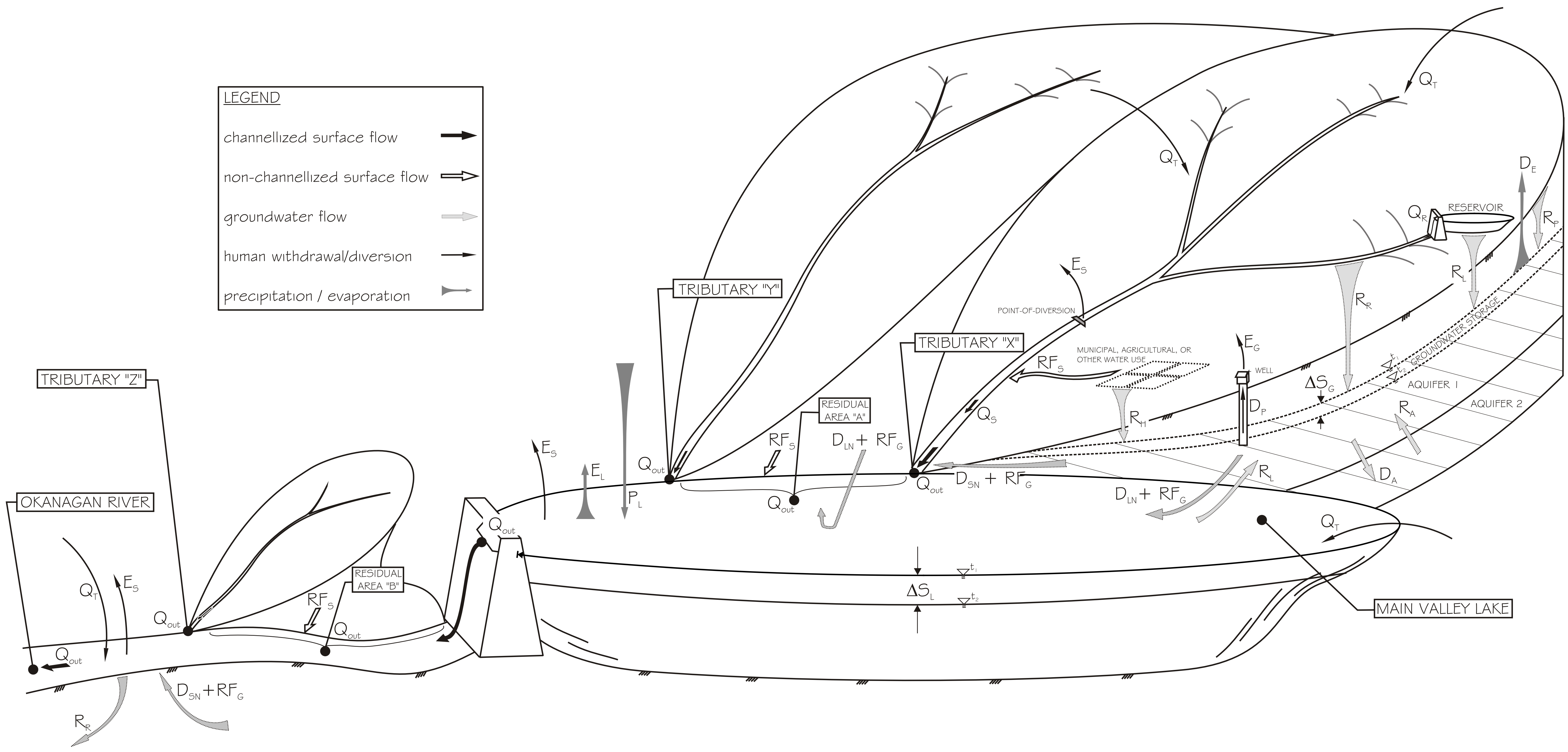
In addition to these layers, the Okanagan Water Demand Model has employed several other data layers covering the developed areas of the Basin, including soil, cadastral, irrigation systems, and crop types. These layers are described in Section 14.0 of the main report and are not considered further here.

The three data layers developed specifically for the Phase 2 project are described further in this Appendix.

2.0 WATER MOVEMENT SCHEMATIC

Figure 2.1 schematically illustrates the various ways in which water can move on the surface and within groundwater aquifers within the Basin. The symbols used on the figure are described in this Appendix. This figure and the associated water-related terms formed the foundation for a series of water balance equations describing water movements for surface nodes and groundwater aquifers. The figure includes both natural and human-influenced forms of water movement.

OKANAGAN BASIN WATER BALANCE SCHEMATIC



NOTES:	SCALE:	DATE:		PROJECT:
Refer to text for definitions of water balance terms	Not to scale	January 2008	SUMMIT ENVIRONMENTAL CONSULTANTS LTD.	OKANAGAN BASIN WATER SUPPLY & DEMAND STUDY PHASE 2
		DRAWN BY: L. Uunila, P.Geo.	#200 - 2800 29th Street Vernon, B.C., V1T 9P9 Ph: (250) 545-3672 Fax: (250) 545-3654 www.summit-environmental.com	PROJECT NO.: 7200-004.01
			PREPARED FOR: B.C. MINISTRY OF ENVIRONMENT & OKANAGAN BASIN WATER BOARD	DRAWING NO. 1 of 1
				FILE: OK_water_balance_v4.cdr
				OKANAGAN BASIN WATER BALANCE SCHEMATIC

3.0 SURFACE WATER

3.1 SURFACE WATER SPATIAL LAYER

The Okanagan Basin covers 8,024 km^2. The Phase 2 project team defined 81 surface-water sub-basins (nodes) for the Project (Table 3.1), which can be characterized as follows:

- tributaries;
- residual land areas;
- mainstem lakes (i.e. Kalamalka, Okanagan, Skaha, Vaseaux, and Osoyoos); and
- mainstem Okanagan River nodes.

Some nodes represent aggregations of two or more nodes (e.g. Okanagan Lake). The nodal linkages are shown on Attachment 1 to the main report.

Table 3.1 Okanagan Basin water balance nodes (organized from north to south)

No.	**POINTS-OF-INTEREST**	
	West side of Okanagan Basin	***East side of Okanagan Basin***
1		Vernon Creek at outlet of Kalamalka Lake
2		Kalamalka – Wood Lake
3	Deep Creek (mouth)	
4	Residual area W-1	
5	Irish Creek (mouth)	
6	Residual area W-2	
7		Residual area E-1
8	Equesis Creek (mouth)	
9	Residual area W-3	
10	Nashwhito Creek (mouth)	
11	Residual area W-4	
12		Vernon Creek (mouth); includes Zone A & B
13		Residual area E-2
14	Whiteman Creek (mouth)	
15	Residual area W-5	
16	Shorts Creek (mouth)	
17	Residual area W-6	
18	Lambly Creek (mouth)	
19	Residual area W-7	
20		Kelowna (Mill) Creek (mouth)
21		Residual area E-3
22		Mission Creek (mouth)
23		Residual area E-4
24		Bellevue Creek (mouth)
25		Residual area E-5
26	McDougall Creek (mouth)	
27	Residual area W-8	
28	Powers Creek (mouth)	
29	Residual area W-9	

30	Trepanier Creek (mouth)	
31	Residual area W-10	
32	Peachland Creek (mouth)	
33	Residual area W-11	
34		Chute Creek (mouth)
35		Residual area E-6
36	Eneas Creek (mouth)	
37	Residual area W-12	
38		Robinson Creek (mouth)
39		Residual area E-7
40		Naramata Creek (mouth)
41		Residual area E-8
42	Trout Creek (mouth)	
43	Residual area W-13	
44		Turnbull Creek
45		Residual area E-9
46		Penticton Creek (mouth)
47	Okanagan Lake	
48	Okanagan River at Penticton	
49	Residual area W-14	
50		Residual area E-10
51	Shingle Creek (mouth)	
52		Ellis Creek (mouth)
53	Residual area W-15	
54		Residual area E-11
55	Marron River	
56	Residual area W-16	
57	Residual area W-17	
58	Skaha Lake	
59	Okanagan River at Okanagan Falls	
60		Shuttleworth Creek (mouth)
61	Residual area W-18	
62	Residual area W-19	
63		Residual area E-12
64	Vaseux Lake	
65		Residual area E-13
66		Vaseux Creek (mouth)
67	Residual area W-20	
68		Residual Area E-14
69	Park Rill (mouth)	
70	Residual area W-21	
71		Wolfcub Creek (mouth)
72		Residual area E-15
73	Testalinden Creek (mouth)	
74	Residual area W-22	
75	Okanagan River near Oliver	
76		Residual area E-16
77	Residual area W-23	
78		Inkaneep Creek (mouth)
79		Residual area E-17
80	Osoyoos Lake	
81	Okanogan River at Oroville, WA.	

3.2 SURFACE WATER BALANCE EQUATION TERMS

In this section the surface water terms used in the water balance are defined. Tables 3.2 and 3.3 identify the relevant terms, and for all terms to be supplied to the water model, the source of the data. Terms are shown in schematic form on Figure 1.1. Units of volume used in the project are dam^3 (equivalent to ML), and units of flow (volume/time) are m^3/s.

Table 3.2 Definitions of natural surface water balance terms, and those indirectly related to human activity

Term	Units	Definition
$Q_{out\ i,t}$	Volume/time	Residual streamflow (after storage and withdrawal effects) from node i during time period t
$Q_{upstream\ i,t}$	Volume/time	incoming streamflow to node i from all sources (e.g. mainstem river, tributary and miscellaneous surface flow) during time t
$Q_{in\ i,t}$	Volume/time	Net inflow to mainstem lake (node i) during time t (incoming streamflow from all sources (mainstem river, tributary and miscellaneous surface flow) plus direct precipitation onto the lake, less evaporation from the lake, plus human additions and subtractions from the lake itself.
Δt	Time	The duration of the time interval t
$\Delta S_{L\ i,t}$	Volume	Change in lake storage (node i) during time t
$L_{e\ i,t}$	Length	Lake elevation in node i at start of time t
$Q_{S\ i,t}$	Volume/time	Natural rapid (overland) flow component of streamflow at node i during time t
$Q_{F\ i,t}$	Volume/time	Naturally-occurring stormflow component of streamflow in node i during time t
$(\sum D_{SN\ j})_{i,t}$	Volume/time	Naturally-occurring baseflow component of streamflow at node i during time t (the sum of natural groundwater discharge from one or more groundwater aquifers)
$Q_{S\ i,t}+Q_{F\ i,t}+(\sum D_{SN\ j})_{i,t}$	Volume/time	Natural streamflow at node i during time t
$P_{L\ i,t}$	Volume	Precipitation onto lake during time t (used for the 5 main lake nodes only)
$E_{L\ i,t}$	Volume	Evaporation from lake during time t (used for the 5 main lake nodes only)

Table 3.3 Surface water balance terms directly related to human activity

Term	Units	Definition
$Q_{Emax\ i,t}$	Volume/time	Maximum possible rate of extraction from node i during time t
$Q_{I\ i,t}$	Volume/time	For tributary, residual, and river nodes: streamflow necessary to meet all instream uses at node i (e.g. fish, recreation, submergence of irrigation intakes). This is part of the rule curve for a lake.
$Q_{R\ i,t}$	Volume/time	Upstream reservoir component of streamflow at node i during time t (positive during reservoir release, negative during reservoir filling)
$Q_{R\ i,t}\ \Delta t$	Volume	Volume represented by $Q_{R\ i,t}$ during time t
$RF_{S\ i,t}$	Volume	Surface component of return flow to node i during time t due to human activity (e.g. municipal wastewater discharges)
$RF_{G\ i,t}$	Volume	Return flow due to human activity to node i during time t via groundwater
$Q_{T\ i,t}$	Volume/time	Rate of water transfer into streams in node i from streams outside node i (e.g. interbasin transfers of streamflow) during time t. This does not include interbasin transfers via pipeline.
$Q_{T\ i,t}\ \Delta t$	Volume	Volume represented by $Q_{T\ i,t}$ during time t.
$E_{S\ i,t}$	Volume	Total volume extracted from surface sources within node i during time t .
$E_{G\ i,t}$	Volume	Volume extracted from groundwater sources <u>that would otherwise have discharged to the stream network</u> in node i during time t. This is a component of total groundwater pumping during time interval t from node i (i.e. $(\sum D_{Pj})_{i,t}\ \Delta t$)

3.3 SURFACE WATER BALANCE EQUATIONS

3.3.1 Tributary and Residual Nodes

In words, the water balance equation for a tributary or residual area can be expressed as:

"Total Flow from the node during time t equals natural streamflow volume (comprised of overland flow, stormflow, and groundwater components) plus human additions and subtractions (involving both surface flow and groundwater) during time t".

The natural streamflow volume during time t is the sum of overland flow, stormflow, and baseflow components of the natural stream hydrograph multiplied by the duration of the time interval, i.e.:

$$[Q_{S\ i,t} + Q_{F\ i,t} + (\sum D_{SN\ j})_{i,t}]\ \Delta t$$

The human influence on streamflow during time t is expressed as:

$$(Q_{R\ i,t} + Q_{T\ i,t})\Delta t + RF_{S\ i,t} + RF_{G\ i,t} - E_{S\ i,t} - E_{G\ i,t} - (\sum R_{RH\ j})_{i,t}\ \Delta t$$

The term $RF_{G\ i,t} = (\sum D_{SH\ j})_{i,t}\ \Delta t$ (Table 4.1). Groundwater inputs and outputs are kept separate to acknowledge that groundwater could be adding to a stream from one or more aquifers at the same time as it is being removed to other aquifers from the stream. Although it may be impossible during the Phase 2 project to accurately account for these groundwater inputs and outputs, and the specific influence of humans on groundwater, we have defined the terms for completeness. It is possible that these groundwater terms may be useful for some areas during the present phase of the project, and it is expected that they may become relevant and useful in other areas as information improves in future phases of the Project.

Combining these terms leads to:

$$Q_{out\ i,t}\ \Delta t = [Q_{S\ i,t} + Q_{F\ i,t} + (\sum D_{SN\ j})_{i,t}]\ \Delta t + (Q_{R\ i,t} + Q_{T\ i,t})\Delta t + RF_{S\ i,t} + RF_{G\ i,t} - E_{S\ i,t} - E_{G i,t} - (\sum R_{RH\ j})_{i,t}\ \Delta t$$

Furthermore:

$$Q_{out\ i,t}\ \Delta t = (Q_{Emax\ i,t} + Q_{I\ i,t})\Delta t$$

Note that (per the above-noted definitions) $Q_{I\ i,t}$ is the streamflow (volume per unit time) necessary to meet all instream uses, and $Q_{Emax\ i,t}$ is the maximum streamflow (volume per unit time) still available at the node for extraction from the stream within time t. The product $Q_{Emax\ i,t}\ \Delta t$ is the total volume still available at the node for extraction from the stream during time t. (Note that the basin-wide sum of these terms is the total basin-wide volume still available for extraction from surface sources during time t).

Finally, note that the term $Q_{I\ i,t}$ is intended to represent a generalized instream flow guideline. It is conceivable that more than one specific instream flow threshold could be appropriate, and future work may be necessary to develop appropriate flow thresholds for all relevant species, times, and locations.

3.3.2 Mainstem Lakes

There are five significant valley-bottom lakes in the Okanagan Basin, and each is represented as an individual node: Kalamalka, Okanagan, Skaha, Vaseaux, and Osoyoos Lakes. In words, the water balance equation for a mainstem lake is as follows: "outflow from the lake during time t equals net inflow during time t minus change in storage during time t". In equation form, it is expressed as: $Q_{out\ i,t}\ \Delta t = Q_{in\ i,t}\ \Delta t - \Delta S_{L\ i,t.}$

Inflow during time t consists of:

- incoming streamflow from all sources (e.g. mainstem river, tributary and miscellaneous surface flow) ($Q_{upstream\ i,t}\ \Delta t$)
- direct precipitation onto the lake ($P_{L\ i,t}$)
- groundwater inflow into the lake [$(\sum D_{LN\ j})_{i,t}\ \Delta t$ and $(\sum D_{LH\ j})_{i,t}\ \Delta t = RF_{G\ i,t}$] (natural and human influenced, respectively)
- human additions to the lake surface ($RF_{S\ i,t}$ and $Q_{Ti,,t}\ \Delta t$)

Less:

- evaporation from the lake ($E_{L\ i,t}$)
- groundwater losses from the lake [$(\sum R_{LN\ j})_{i,t}\ \Delta t$ and $(\sum R_{LH\ j})_{i,t}\ \Delta t$] (natural and human-influenced, respectively)
- surface withdrawals from the lake ($E_{S\ i,t}$)

In equation form, this is expressed as follows:

$$Q_{in\ i,t}\ \Delta t = Q_{upstream\ i,t}\ \Delta t + P_{L\ i,t} + (\sum D_{LN\ j})_{i,t}\ \Delta t + RF_{G\ i,t} + RF_{S\ i,t} + Q_{Ti,,t}\ \Delta t - E_{L\ i,t} - (\sum R_{LN\ j})_{i,t}\ \Delta t - (\sum R_{LH\ j})_{i,t}\ \Delta t - E_{S\ i,t}$$

Combining all terms, the water balance equation for a mainstem lake is:

$$Q_{out\ i,t}\ \Delta t = Q_{upstream\ i,t}\ \Delta t + P_{L\ i,t} + (\sum D_{LN\ j})_{i,t}\ \Delta t + RF_{G\ i,t} + RF_{S\ i,t} + Q_{Ti,,t}\ \Delta t - E_{Li,t} - (\sum R_{LN\ j})_{i,t}\ \Delta t - (\sum R_{LH\ j})_{i,t}\ \Delta t - E_{S\ i,t} - \Delta S_{L\ i,t}$$

Note that:

$$\Delta S_{L\ i,t} = L_{e\ i,t+1} - L_{e\ i,t}$$

Furthermore:

$$Q_{out\ i,t}\ \Delta t + \Delta S_{L\ i,t} = (Q_{Emax\ i,t} + Q_{I\ i,t})\ \Delta t$$

In this case, $Q_{I\ i,t}\ \Delta t$ accounts for all in-lake uses (to meet water level targets for fish, recreation, protection of property, etc.) and $Q_{Emax\ i,t}\ \Delta t$ is the maximum volume of water still available for extraction from the lake during time t.

3.3.3 Mainstem River Nodes

Several nodes have been defined along the mainstem of the Okanagan River downstream of Penticton. The water balance equation for each of these nodes can be expressed in words as "flow from the node during time t equals flow from the closest upstream node (which is either a lake node or a river node) plus tributary inputs (natural inputs plus or minus the human influence) plus groundwater inputs (natural and human-influenced) minus groundwater losses from the river (natural and human-influenced), plus direct human additions to minus direct human losses from the river itself between the closest upstream node and the node itself (all during time t)".

The sum of flow from the closest upstream node (lake or river) and tributary inputs (natural inputs plus or minus the human influence) during time t is given by: $Q_{upstream\ i,t}\ \Delta t$.

Groundwater input to the river (which can be from more than one aquifer) during time interval t is given by:

$(\sum D_{SN\ j})_{i,t}\ \Delta t + (\sum D_{SH\ j})_{i,t}\ \Delta t$ (natural and anthropogenic, respectively);

where $(\sum D_{SH\ j})_{i,t}\ \Delta t = RF_{G\ i,t}$

Groundwater loss from the river to adjacent aquifers during time interval t is given by: $(\sum R_{Rj})_{i,t}\ \Delta t = [(\sum R_{RN\ j})_{i,t} + (\sum R_{RH\ j})_{i,t}]\ \Delta t$ (natural and human-influenced, respectively).

The direct human influence on the river between the lake and the river node is given by: $RF_{S\ i,t} + Q_{T\ i,t}\ \Delta t - E_{S\ i,t}$, where these terms represent removals from or additions to the river itself.

Combining these terms leads to:

$$Q_{out\ i,t}\ \Delta t = Q_{upstream\ i,t}\ \Delta t + (\sum D_{SN\ j})_{i,t}\ \Delta t + RF_{G\ i,t} - (\sum R_{Rj})_{i,t}\ \Delta t + RF_{S\ i,t} + Q_{T\ i,t}\ \Delta t - E_{S\ i,t}$$

Furthermore:

$$Q_{out\ i,t}\ \Delta t = (Q_{Emax\ i,t} + Q_{I\ i,t})\ \Delta t$$

Where $Q_{I\ i,t}$ is the streamflow (volume per unit time) necessary to meet all instream uses (e.g. fish flow requirements, meeting river water level targets for irrigation intakes), and $Q_{Emax\ i,t}$ is the maximum streamflow (volume per unit time) still available at the node for extraction from the river during time t. The product $Q_{Emax\ i,t}\ \Delta t$ is the total volume still available at the node for extraction from the stream.

4.0 GROUNDWATER BUDGET COMPONENTS AND EQUATIONS

The groundwater resources in the Okanagan Basin are generally found in the main valley bottom, and are in hydraulic continuity with the major valley-side tributary creeks which deposited them. In the north and central parts of the basin, the surficial aquifers form primarily in alluvial fans and fan complexes. Examples include Shorts Creek Fan on the Westside of Okanagan Lake at Fintry, and the large alluvial fan complex of Mission and Kelowna Creeks in the greater Kelowna area. This system includes both confined and unconfined aquifers. In the South Okanagan, there is a large aquifer occupying the valley bottom on both sides of the Okanagan River. This long narrow aquifer system extends from near Okanagan Falls to the U.S. Border. Alluvial fans along the valley walls interfinger with this productive and heavily used (for irrigation and domestic) valley bottom aquifer system. In addition, bedrock aquifers may contain groundwater, although the magnitude of groundwater recharge to bedrock aquifers is uncertain. Groundwater recharge to bedrock aquifers in upland areas can contribute to overall groundwater storage. This groundwater discharges to the valley bottom aquifers and to the lake as mountain block recharge.

Table 4.1 lists groundwater terms identified as relevant in the Okanagan Basin. Table 4.1 separates some of the recharge and discharge terms into natural and human-affected sub-components. It is understood that in the Phase 2 project it will not be possible to separate the natural and anthropogenic influences on groundwater, except in obvious circumstances such as direct removals through pumping. Nevertheless, to ensure consistency with the surface water balance terms, some terms are sub-divided into natural and human-influenced sub-components. The terms which link surface water and groundwater are listed in Table 4.2.

The general groundwater budget equation for aquifer j in time period t can be expressed as:

$$\Sigma \{\text{Inflows}\}_{j,t} - \Sigma \{\text{Outflows}\}_{j,t} = \Delta S_{G\ j,t}$$

With reference to Table 4.1, this equation becomes:

$$[R_{R\ j,t} + R_{L\ j,t} + R_{P\ j,t} + R_{H\ j,t} + R_{A\ j,t}]\ \Delta t - [D_{S\ j,t} + D_{L\ j,t} + D_{P\ j,t} + D_{A\ j,t} + D_{E\ j,t}]\ \Delta t = \Delta S_{G\ j,t}$$

Fully expanded into the natural and human-influenced sub-components identified in Table 4.1, the groundwater balance equation is written as:

$$[(R_{RN\ j,t} + R_{RH\ j,t}) + (R_{LN\ j,t} + R_{LH\ j,t}) + R_{P\ j,t} + R_{H\ j,t} + (R_{AN\ j,t} + R_{AH\ j,t})]\ \Delta t -$$
$$[(D_{SN\ j,t} + D_{SH\ j,t}) + (D_{LN\ j,t} + D_{LH\ j,t}) + D_{P\ j,t} + (D_{AN\ j,t} + D_{AH\ j,t}) + D_{E\ j,t}]\ \Delta t = \Delta S_{G\ j,t}$$

In these equations, <u>j and t refer to aquifer and time period, respectively</u>. Note that the equations are written for an <u>aquifer</u>, <u>not for a surface node</u>. The Okanagan Basin Water Accounting Model links aquifers to surface water nodes, and these linkages were specified by the groundwater study completed during the Phase 2 project.

Time series of values for each term in Table 4.1 were supplied to the Okanagan Basin Hydrology Model from the OkWater Database, for the purpose of calibrating the groundwater component of the model.

Table 4.1 Definitions of groundwater balance terms

INFLOWS TO AQUIFER (Recharge terms):

Term	Definition	Units
$R_{R\ j,t} = R_{RN\ j,t} + R_{RH\ j,t}$	Rate of loss from rivers (and tributary streams) to aquifer j during time t. This term can be considered to be comprised of a natural component (R_{RN}) and a human-affected component (R_{RH}).	Volume/time
$R_{L\ j,t} = R_{LN\ j,t} + R_{LH\ j,t}$	Rate of lake, pond & wetland seepage loss to aquifer j during time t. This term can be considered to be comprised of a natural component (R_{LN}) and a human-affected component (R_{LH}).	Volume/time
$R_{P\ j,t}$	Rate of net recharge to aquifer j during time t from precipitation (net natural areal recharge from precipitation, i.e. total precipitation minus evapotranspiration minus surface runoff minus soil water storage)	Volume/time
$R_{H\ j,t}$	Rate of recharge to aquifer j during time t due to human activity. Examples include septic system leakage and over-irrigation.	Volume/time
$R_{A\ j,t} = R_{AN\ j,t} + R_{AH\ j,t}$	Rate of recharge from an adjacent, or overlying or underlying aquifer (equal to negative $D_{A\ j,t}$ in an aquifer pair). This term can be considered to be comprised of a natural component (R_{AN}) and a human-affected component (R_{AH}).	Volume/time
$\Delta S_{G\ j,t}$	Change in groundwater storage within aquifer j during time t. Positive means an increase in storage, negative means a decrease in groundwater storage.	Volume

OUTFLOWS FROM AQUIFER (Discharge terms):

Term	Definition	Units
$D_{S\ j,t} = D_{SN\ j,t} + D_{SH\ j,t}$	Discharge to surface streams (rivers and tributaries) from aquifer j during time t. This term can be considered to be comprised of a natural component (D_{SN}) and a human-affected component (D_{SH}). It contributes to the baseflow component of streamflow.	Volume/time
$D_{L\ j,t} = D_{LN\ j,t} + D_{LH\ j,t}$	Discharge as underflow to lakes from aquifer j during time t. This term can be considered to be comprised of a natural component (D_{LN}) and a human-affected component (D_{LH}). It appears in the lake water balance equation.	Volume/time
$D_{P\ j,t}$	Rate of groundwater pumping from aquifer j during time t (several end uses). There are three possible D_P sources: intercepted groundwater flow, groundwater storage, and (in GUDI wells) streamflow.	Volume/time
$D_{A\ j,t} = D_{AN\ j,t} + D_{AH\ j,t}$	Discharge to an adjacent, or overlying or underlying aquifer. This term can be considered to be comprised of a natural component (D_{AN}) and a human-affected component (D_{AH}).	Volume/time
$D_{E\ j,t}$	Evapotranspiration loss from the water table.	Volume/time

Note that "change in storage" is neither an inflow nor an outflow. It is listed under inflows for convenience only.

Table 4.2 Groundwater components of the surface water balance

Term	Definition	Units
$(\sum D_{SN\ j})_{i,t}\ \Delta t$	Sum of naturally-occurring aquifer discharges to streams in node i during time t (i.e. baseflow component of natural streamflow at node i during time t)	Volume
$(\sum D_{SH\ j})_{i,t}\ \Delta t = RF_{G\ I,t}$	For river and tributary nodes, the sum of human components of aquifer discharges to streams in node i during time t (i.e. the "return flow" part of the baseflow of the human-altered streamflow at node i during time t)	Volume
$(\sum D_{LN\ j})_{i,t}\ \Delta t$	For mainstem lake nodes, the sum of naturally-occurring aquifer discharges to the lake during time t (i.e. the natural part of the groundwater discharge to the lake during time t)	Volume
$(\sum D_{LH\ j})_{i,t}\ \Delta t = RF_{G\ I,t}$	For mainstem lake nodes, the sum of human component of aquifer discharges to the lake during time t (i.e. the "return flow" part of the groundwater discharge to the lake during time t)	Volume
$(\sum R_{RN\ j})_{i,t}\ \Delta t$	For river and tributary nodes, the sum of naturally-occurring aquifer recharge from node i during time t	Volume
$(\sum R_{RH\ j})_{i,t}\ \Delta t$	For river and tributary nodes, the sum of human-influenced aquifer recharge from node i during time t	Volume
$(\sum R_{LN\ j})_{i,t}\ \Delta t$	For mainstem lake nodes, the sum of naturally-occurring aquifer recharge from node i during time t	Volume
$(\sum R_{LH\ j})_{i,t}\ \Delta t$	For mainstem lake nodes, the sum of human-influenced aquifer recharge from node i during time t	Volume
$E_{G\ i,t}$	Volume extracted from groundwater sources that would otherwise have discharged to the stream network in node i during time t. This is a component of total groundwater pumping $(\sum D_{Pj})_{i,t}\ \Delta t$ from within node i during the time interval.	Volume

5.0 WATER USES AND WATER USE AREAS

Water extracted from surface sources and groundwater wells is distributed and used on the land base for several purposes, as listed in Table 5.1. The land base has been divided into “water use areas” (Attachment 3 of the main report). The Okanagan Water Demand Model is able to compute (for historic and future conditions) water demand for all indoor and outdoor water uses (Table 5.1), and integrate the uses – both temporally (to a weekly time base) and spatially (to water use areas). A table within the model links each water use area with one or more sources of water (surface sources and/or groundwater sources). By computing the water used within each water use area, then linking the water use areas to water sources, the model calculates the impacts of land-based water use on each of the surface nodes (Attachment 1) and aquifers (Attachment 2) identified for the Project. Specifically, the model computes a time series of weekly withdrawals from each surface node (variable $E_{S\ i,t}$) and aquifer (variable $D_{P\ j,t}$), which are then uploaded to the OkWater Database. The Okanagan Basin Water Accounting Model then accesses this information from the database to combine it with the water supply calculations performed in the Okanagan Basin Hydrology Model.

Table 5.1 Land-based uses of water

Land-based uses of water	Term (Units = volume)	Definition
Agriculture	$U\ ag_{k,t}$	Volume of water used in water use area k during time t used for irrigation of agricultural land.
Golf courses	$U\ golf_{k,t}$	Volume of water used in water use area k during time t used for irrigation of golf courses.
Parks/open space	$U\ park_{k,t}$	Volume of water used in water use area k during time t used for irrigation of parks and open spaces.
Domestic indoor	$U\ domin_{k,t}$	Volume of water used in water use area k during time t used for domestic indoor use.
Domestic outdoor	$U\ domout_{k,t}$	Volume of water used in water use area k during time t used for domestic outdoor use.
Institutional	$U\ inst_{k,t}$	Volume of water used in water use area k during time t used for institutional use.
Commercial	$U\ comm_{k,t}$	Volume of water used in water use area k during time t used for commercial use.
Industrial	$U\ ind_{k,t}$	Volume of water used in water use area k during time t used for industrial use.
Losses	$U\ loss_{k,t}$	Volume of water used in water use area k during time t that is lost or unaccounted for.
Total	$U\ total_{k,t}$	Total volume of water used in water use area k during time t.