

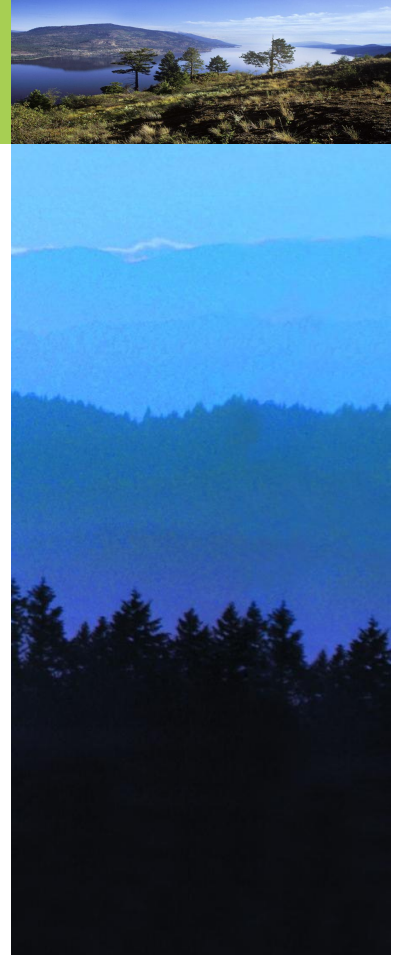
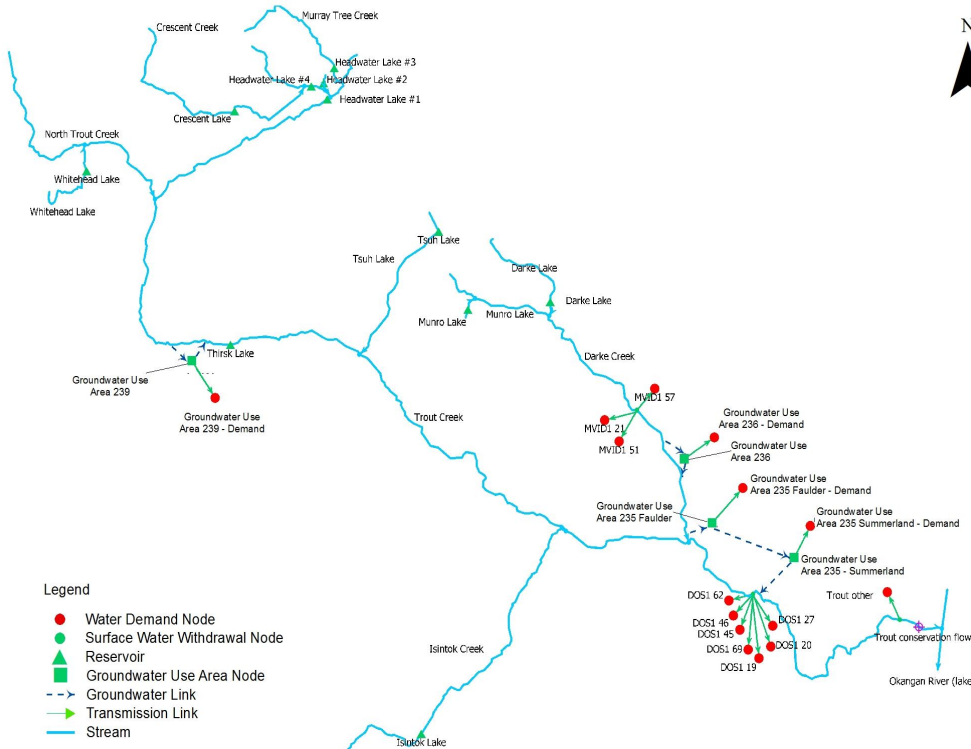
Final Report

Okanagan Basin Water Board

Okanagan Hydrologic Connectivity Model: Trout Creek Watershed Groundwater Integration

Project: 2010-8967.000.005

March 2013



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March 25, 2013

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**Re: OKANAGAN HYDROLOGIC CONNECTIVITY MODEL:
TROUT CREEK WATERSHED GROUNDWATER INTEGRATION - DRAFT REPORT**

Summit Environmental Consultants Inc. (Summit) is pleased to provide this draft report on the inclusion of groundwater within Trout Creek watershed within the Okanagan Hydrologic Connectivity Model (OHCM). The work was completed by a consulting team led by Summit that included Western Water Associates Ltd., Piteau Associates, Polar Geoscience Ltd., and Stockholm Environment Institute.

The draft report describes how groundwater within Trout Creek watershed has been added to the OHCM and identifies the limitations and potential uses of the groundwater application within the OHCM. It also includes recommendations to enhance groundwater representation within the OHCM and other models developed during Phase 2 of the Okanagan Water Supply and Demand Project.

If you have any questions, please contact myself or Brian. The report will be finalized upon receipt of your comments.

Yours truly,

Summit Environmental Consultants Inc.

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The primary investigator was Laurie Welch of Western Water Associates Ltd. Project management and other scientific and technical input was provided by Dan Austin, Drew Lejbak, and Brian Guy of Summit Environmental Consultants Inc.

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1 INTRODUCTION

1.1 PROJECT BACKGROUND

The Okanagan Water Supply and Demand Project (OWSDP) is a multi-phase work program focussed on improving the state of knowledge of the water resources of the Okanagan Basin (“the Basin”) through credible scientific and modelling studies aimed at establishing current water availability, water use, and future potential influences on supply and demand (Summit 2010). 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 2010).

To continue to build upon Phases 1 and 2 of the OWSDP, in March 2012, an Okanagan Hydrologic Connectivity Model (OHCM) was developed as a tool to illustrate how water management actions are interconnected within the Basin and to help the Okanagan Basin Water Board (OBWB) and major water purveyors investigate how water is stored, licensed and flows through the Basin. The OHCM was successfully developed and verified using the Water Evaluation and Planning (WEAP) modeling platform with data from the models developed during Phase 2. The OHCM represents both the natural and human influences on the Basin’s surface water resources including rivers and creeks, reservoirs, inter-basin transfers, water users, return flows, and instream flow needs (IFN) (Summit 2012).

The OHCM was developed as a surface water specific model, with groundwater only included implicitly through interflow and baseflow contributions to surface water flow. Groundwater pumping and its effects on aquifer storage and streamflow in nearby watercourses were not included. Accordingly, in September 2012, the OBWB requested the addition of groundwater pumping to the OHCM to develop a more robust water management tool. A pilot watershed was identified (Trout Creek) by the OBWB as a test watershed for the implementation of a groundwater module for the OHCM. A consulting team led by Summit Environmental Consultants Inc. was formed to develop and implement the groundwater module for Trout Creek watershed. Other key contributors on the team included Western Water Associates Ltd., Piteau Associates, Polar Geoscience Ltd., and Stockholm Environment Institute.

1.2 PROJECT OBJECTIVES

The objectives of the project were to:

1. Develop a methodology to include groundwater (i.e. a groundwater module) within the OHCM that considers groundwater movement and storage, pumping, and interaction between groundwater and surface water; and
2. Test the groundwater module to ensure functionality and reasonable representation of groundwater processes in a pilot watershed within the OHCM.

The OBWB selected Trout Creek for the pilot watershed. The scope of this work was outlined in a proposal submitted to the OBWB by Summit Environmental Consultants Inc. on September 5, 2012.

2 METHODOLOGY

The development of the groundwater module for the OHCM within the Trout Creek watershed is summarized in this section. The methodology for groundwater module development involved the following tasks:

- Review of available background information and data (Section 2.1)
- Delineation of groundwater use areas (Section 2.2)
- Incorporation of groundwater demand data at Nodes (Section 2.3)
- Characterization and consideration of surface water – groundwater linkages (Section 2.4)
- Characterization and consideration of aquifer - aquifer linkages (Section 2.5)
- Modification of the WEAP modeling platform for groundwater representation (Section 2.6)
- Model simulation and testing (Section 2.7)

2.1 REVIEW OF AVAILABLE BACKGROUND INFORMATION

Groundwater module development first involved the collection and review of relevant and available information and previous reports. The following information sources were reviewed (ordered by date).

- Groundwater Development in the Meadow Valley Aquifer, District of Summerland, British Columbia, Golder Associates Ltd., November 17, 2003.
- Preliminary Hydrogeological Assessment for the Development of an Aquifer Monitoring Program, Faulder, British Columbia, Golder Associates Ltd., October 4, 2005.
- Groundwater Provenance and Water Level Assessment, Faulder, British Columbia, Golder Associates Ltd., August 2008.
- Status Assessment and Rehabilitation of Faulder Community Well, Faulder, British Columbia, Golder Associates Ltd., August 2008.
- District of Summerland Water Master Plan 2008, Agua Consulting Inc., November 2008.
- Phase 2 Okanagan Water Supply and Demand Project, Groundwater Objectives 2 and 3 Basin Study, Prepared for Okanagan Basin Water Board by Golder Associates Ltd. and Summit Environmental Consultants Ltd., July 2009.
- Phase 2 Okanagan Water Supply and Demand Project, Surface Water Hydrology and Hydrologic Modelling Study “State of the Basin” Report, Prepared for Okanagan Basin Water Board by Summit Environmental Consultants Ltd., September 2009.
- Okanagan Basin Water Accounting Model (OWAM) Final Report, Prepared for Okanagan Basin Water Board by DHI Water and Environment, May 2010.
- BC Wells Database, BC Ministry of Environment,
 - <https://a100.gov.bc.ca/pub/wells/public/indexreports.jsp>
- BC Observation Well Network, BC Ministry of Environment,
 - http://www.env.gov.bc.ca/wsd/data_searches/obswell/
- WEAP User Guide, Stockholm Environment Institute,
 - http://www.weap21.org/downloads/WEAP_User_Guide.pdf

In addition to the above-noted information sources, discussions were held with the following people:

- Dr. Denise Neilsen, Agri-Foods and Agriculture Canada, regarding groundwater demand;
- Mr. Rob Palmer, Regional District of Okanagan-Similkameen, regarding Faulder community well operation;
- Mr. Skye Thomson, Ministry of Forests, Lands and Natural Resource Operations, regarding previous hydrogeological studies in the Trout Creek Watershed area; and
- Mr. Jack Sieber and Mr. Charles Young, Stockholm Environment Institute (USA), regarding WEAP model applications.

2.2 DELINEATION OF GROUNDWATER USE AREAS

Groundwater aquifers are represented in the WEAP modeling platform as nodes which can be assigned groundwater demand, and which can be linked to the surface water system at specified stream reaches. Groundwater aquifers (bedrock and alluvium) have been mapped across the entire Okanagan Basin (Golder Associates Ltd. and Summit Environmental Consultants Ltd. (Golder and Summit) 2009), however, only those OWSDP aquifers that were identified as having groundwater demand (see Section 2.3) were represented in the groundwater module (because the WEAP modeling platform is not a groundwater flow model, see upcoming Section 4). It is noted here that the aquifers mapped for the OWSDP by Golder and Summit (2009), which are referenced in this report (referred to hereafter as “mapped aquifers”), are different than aquifers mapped for British Columbia by the BC Ministry of Environment (e.g. BC Water Resources Atlas).

Because mapped groundwater aquifers may be large in relation to the aquifer area that is actually influenced by groundwater extraction, “groundwater use areas” were estimated within the mapped aquifers of Golder and Summit (2009), based on the review of 1996-2006 water demand data provided by Agriculture and Agri-Foods Canada from the OWDM (Section 2.3) and background information sources indicated in Section 2.1. Groundwater use areas were delineated using the following procedure:

- The relative “level” of groundwater use was identified as either rural/residential wells (i.e. individual wells with low pumping rates) or larger production community supply wells;
- For the community supplies, previous reports and available data were reviewed, where available, for previously determined estimates of the area of influence of pumping; and
- For the rural/residential groundwater use areas, the BC Wells database was consulted to identify areas of well clusters within a mapped aquifer as a preliminary approximation of the area of influence.

Representation of groundwater use areas or aquifers in the WEAP modeling platform requires data to characterize aquifer dimensions (area and thickness) and effective porosity to estimate aquifer storage (volume x effective porosity). Dimensions of groundwater use areas were determined based on analysis conducted by Golder and Summit (2009). Additional information regarding the groundwater use areas was obtained from previous reports for the Trout Creek area as cited in Section 2.1. Effective porosity was assumed to be 0.2 for all unconsolidated aquifer groundwater use areas that were represented in this

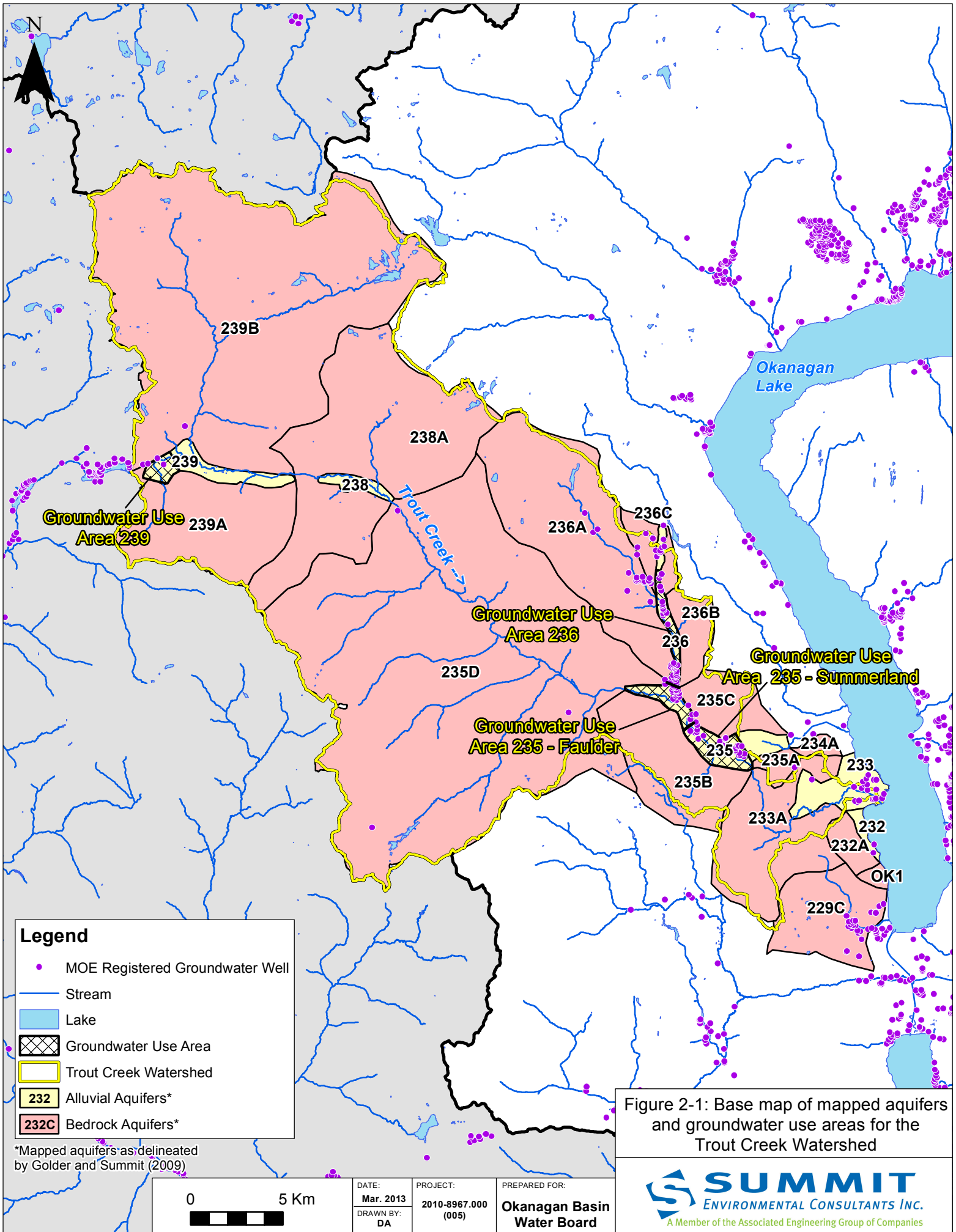
module. This assumption was made because aquifer porosity has not been characterized in the Okanagan, and this value represents a reasonable estimate for sand and gravel aquifers.

The groundwater use areas were compiled into a GIS polygon file with attributes for area, thickness, theoretical storage capacity, aquifer material (alluvium/bedrock), groundwater use type, and data references (Figure 2-1). Two rural/residential groundwater use areas are represented within the Trout Creek groundwater module (236 and 239, within mapped aquifers 236 and 239, respectively). Two community groundwater use areas were also represented (i.e. 235_Faulder and 235_Summerland): one is associated with the aquifer area supplying the Faulder Community Supply Well (currently operational and servicing the community of Faulder) and the other is associated with the aquifer area supplying the District of Summerland Alternative Supply Wells (currently not operational, but could potentially be used as an alternative or short term supply for Summerland). Both of these community groundwater use areas were located within OWSDP mapped aquifer 235. Information for the District of Summerland alternate supply wells from previous reports (e.g, Golder Associates Ltd. (Golder) 2003) indicated a maximum distance of influence of 3.8 km up-gradient. Therefore, the portion of aquifer 235 within the Trout Creek watershed was separated into two groundwater use areas based on the maximum distance of influence: one for the Faulder area (235_Faulder) and one for the District of Summerland Alternative Supply Wells (235_Summerland). It is noteworthy that mapped aquifer 235 extends outside the Trout Creek Watershed model area; this consideration is further discussed in Section 4 (limitations).

2.3 INCORPORATION OF GROUNDWATER DEMAND DATA AT NODES

Groundwater demand data associated with specific bedrock and alluvial aquifers from Golder and Summit (2009) were obtained from the OWDM (for mapped aquifers 235, 235C, 235D, 236, 236A, 236C, 239, and 239B). Because mapped bedrock aquifers are conceptualized to flow into associated unconsolidated aquifers (Golder and Summit (2009)), groundwater demand for bedrock aquifers was combined with the associated alluvial aquifer demand. This approximation is reasonable because demand in bedrock aquifers is relatively small and this representation alleviates the data requirements and gross approximations that would be necessary for detailed representation of groundwater flow between aquifers in the WEAP modeling platform (see also Section 2.5)

In addition to the water demand nodes from the OWDM, a groundwater demand node was linked to groundwater use area 235_Summerland representing the Summerland Alternative Supply Wells. While these wells are currently not operational, they have the potential to be used and, therefore a demand node was included to allow flexibility for scenario testing if these wells were to become operational.



2.4 CHARACTERIZING SURFACE WATER – GROUNDWATER LINKAGES

For the purpose of this study, it is necessary to characterize stream losses to aquifers at groundwater use areas. There is, however, significant uncertainty associated with stream loss locations due to a lack of data, both in the Trout Creek area and throughout the Okanagan Basin. Where available, aquifer information from previous hydrogeological reports was used to provide a basis to identify locations of stream losses to groundwater use areas. However, because of the lack of data, locations of aquifer – stream interactions were inferred for some aquifers based on the type of aquifer (confined versus unconfined) and the position of the aquifer within the watershed as summarized below.

- **Unconfined aquifers in stream valleys** (i.e. groundwater use areas 236 and 239 in Figure 2-1): These aquifers are inferred (in the absence of data) to be in direct hydraulic communication with a stream reach along their length. Replenishment due to stream losses is assumed to be along a stream reach that intersects the aquifer. Aquifer replenishment due to stream losses that is not accounted for by aquifer demand can be routed back to the stream or back to the stream via another groundwater use area (see aquifer-aquifer connections, Section 2.5, below).
- **Unconfined aquifers in alluvial fans** (there are no groundwater use areas of this type in this study): Stream losses to replenish this type of aquifer would be assumed along the associated intersecting stream reach. Aquifer replenishment due to stream losses not accounted for by aquifer demand would be routed back to the stream within the framework of the OHCM model which was calibrated to streamflow. A potentially more accurate representation of hydrogeological flow systems would report stream losses to the main stem lake system, but such routing could disturb the previously balanced OHCM model.
- **Confined aquifers in stream valleys**: These aquifers are assumed to be hydraulically disconnected from an overlying stream along most of their length, when the confining layer lies below the base of the stream bed. For these aquifers (i.e. groundwater use areas 235_Faulder and 235_Summerland in Figure 2-1), stream losses would be assigned to reaches in upslope areas where the stream crosses the top of the aquifer. Excess stream losses that are not needed to satisfy demand would be routed back to the stream (in some cases via another groundwater use area) for water accounting purposes.
- **Confined aquifers in alluvial fan areas** (i.e. none for the Trout Creek groundwater module application): These aquifers would be incorporated in a way similar to confined aquifers in stream valleys. An unconfined aquifer system exists above the groundwater use areas that have been designated as 235_Faulder and 235_Summerland. However, as noted in upcoming Section 2.5, the unconfined system is not specifically represented, as groundwater demand has not been quantified.
- **Isolated aquifers that are not in proximity to a stream**: This category includes groundwater use areas that have groundwater demand that are not mapped to directly coincide with a stream. For the Trout Creek application, these aquifers (which consisted of mapped bedrock aquifers 235A, 235D, 236A, 236C, and 239B) were not specifically represented as nodes due to their low demand, but were collectively represented by an associated stream valley aquifer based on Figure 9 within

Golder and Summit (2009). For example, mapped aquifers 236A, 236B, and 236C were conceptually represented by groundwater use area 236.

It is noted that site-specific conditions may contradict the inferred locations for anticipated stream losses described above where hydrogeological data and reports were not available; this conceptual understanding provided a basis for representing stream – aquifer linkage locations in the WEAP modeling platform.

Once surface water – groundwater linkage locations were conceptualized, stream losses were specified as a percentage of streamflow (an option in the WEAP modeling platform). A benefit of this approach is that stream losses (and therefore aquifer recharge) vary seasonally as a function of streamflow. Disadvantages include the fact that stream losses are unknown for the Trout Creek area (and elsewhere throughout the Okanagan Basin). Therefore, the stream loss variable (percentage of streamflow) was varied as a “calibration” parameter during model trial simulations to provide enough recharge to satisfy aquifer demand while maintaining streamflow in Trout Creek.

2.5 CHARACTERIZING AQUIFER-AQUIFER LINKAGES

For the Trout Creek Watershed, representation of “aquifer-aquifer” interactions was necessary for groundwater use areas 235_Faulder and 235_Summerland, where more detailed hydrogeological analysis has been previously carried out indicating these areas are hydraulically connected (Golder 2003). Therefore, stream losses providing replenishment to 235_Faulder that were not used to satisfy groundwater demand, were routed to 235_Summerland. From 235_Summerland, the remaining groundwater flow component after demand was routed back to Trout Creek for water accounting purposes. At this location, the conceptual model presented by Golder and Summit (2009) depicts groundwater flow out of the Trout Creek watershed toward an alluvial fan aquifer system which ultimately discharges to Okanagan Lake. Representing losses of water to the system in this way within the OHCM framework could interfere with water accounting and water balancing. Also, mapped aquifer 235 crosses the Trout Creek watershed boundary in the area of the Summerland balancing reservoir, and here aquifer-aquifer and aquifer-surface water interactions are highly complex. This portion of aquifer 235, however, is outside the area considered in the Trout Creek watershed, which is the subject of this project.

An upper (unconfined) aquifer within the delineated mapped aquifer 235 area has been identified based on the review of available information, and aquifer-aquifer linkages between this shallow unconfined aquifer and the deeper confined, or partially confined aquifer (235_Faulder and 235_Summerland) have been suggested through previous investigations referenced in Section 2.1. Such aquifer interactions were not represented in this groundwater module because: (1) demand data did not distinguish between the shallow and deeper aquifer systems, (2) most of the demand for the Faulder area is inferred to be associated with the community supply system which pumps from the deeper confined aquifer, and (3) the vertical flux rate between the two aquifers and flux locations are unknown.

2.6 MODIFICATION OF THE WEAP MODELING PLATFORM FOR GROUNDWATER REPRESENTATION

In order to represent aquifer interactions with streams or other aquifers as described in Sections 2.4 and 2.5, Stockholm Environment Institute was contacted to modify the WEAP modeling platform. The existing WEAP modeling platform was adjusted to allow for routing of groundwater flow through aquifers (either to a stream reach or to another aquifer). The resulting inclusion of the groundwater module within the OHCM was completed using the revised WEAP modeling platform, version 3.3005.

2.7 GROUNDWATER MODULE VERIFICATION AND TESTING

In order to verify the groundwater module, scenarios were conducted and the streamflow results at the mouth of Trout Creek were compared to the OHCM on a weekly time-step over the 1996-2006 baseline period. This baseline period is the same as the time period that was used for development and calibration of the OHCM.

Stream loss percentages were adjusted during scenarios to maintain Trout Creek streamflow. The results of the scenarios are presented in Section 3, groundwater module limitations are discussed in Section 4, and the potential usefulness of the model for assisting with water management decisions is discussed in Section 5.

3 TROUT CREEK WATERSHED GROUNDWATER MODULE

3.1 GROUNDWATER MODULE SCHEMATIC

Figure 3-1 presents a schematic representation of the groundwater module application within Trout Creek watershed. With respect to groundwater, the module includes four groundwater use area nodes, four groundwater demand nodes, and linkages between surface water bodies or other aquifers as annotated. The arrows in Figure 3-1 representing linkages were added for visual purposes – they are not included in schematic output produced by the WEAP modeling platform.

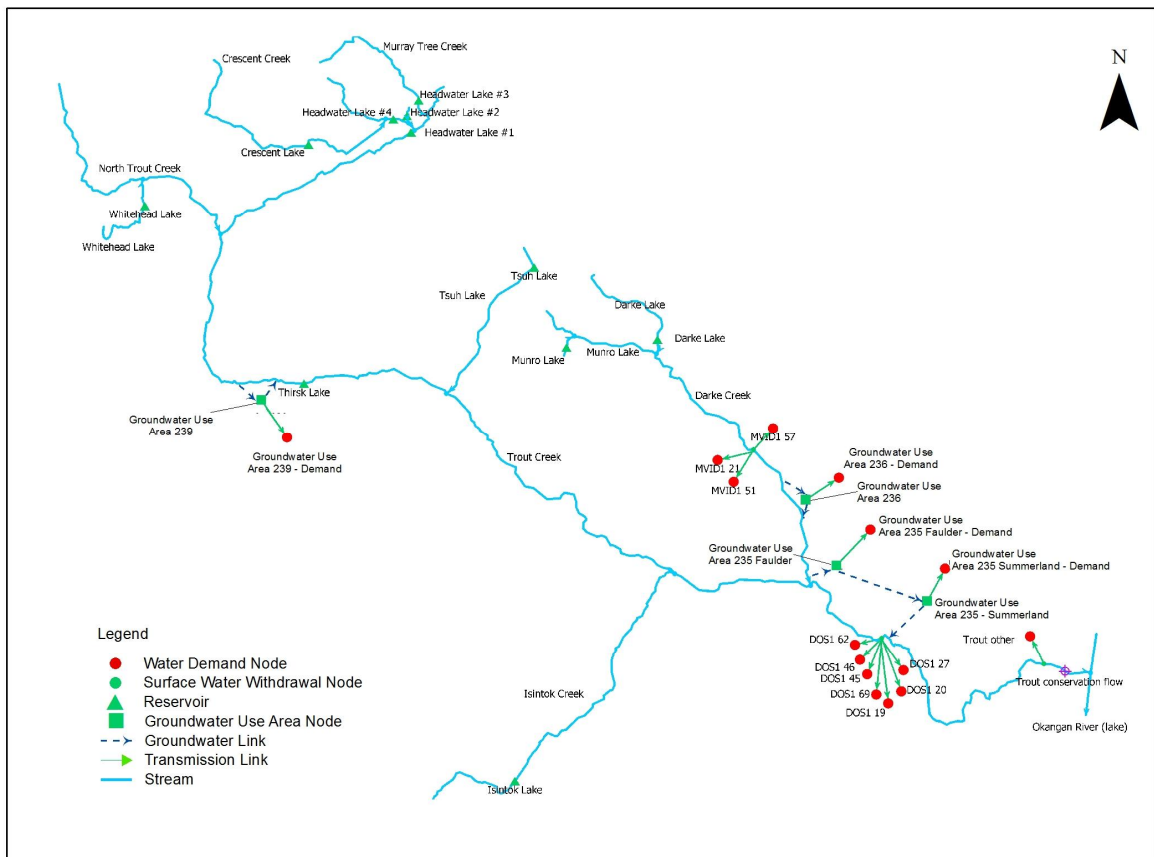


Figure 3-1 Schematic representation of the groundwater module for Trout Creek watershed.

3.2 VERIFICATION AND SCENARIO RESULTS

3.2.1 Baseline Period

The groundwater module was developed using values for stream losses as 0.1% of weekly streamflow. Using this stream loss rate, some of the groundwater demand at each demand node was satisfied by stream losses to the groundwater use area aquifer, and the remainder of the demand was satisfied by changes (decreases) in aquifer storage. Figures 3-2 and 3-3 present the weekly results over the baseline period for Trout Creek streamflow at the mouth and aquifer storage, respectively. Figure 3-2 provides a comparison of Trout Creek streamflow at the mouth for the original OHCM model and the (new) updated model that includes a representation of groundwater. The modelled groundwater demand did not significantly influence streamflow at the mouth of Trout Creek, and resulted in very small decreases in aquifer storage over the baseline period (Figure 3-3).

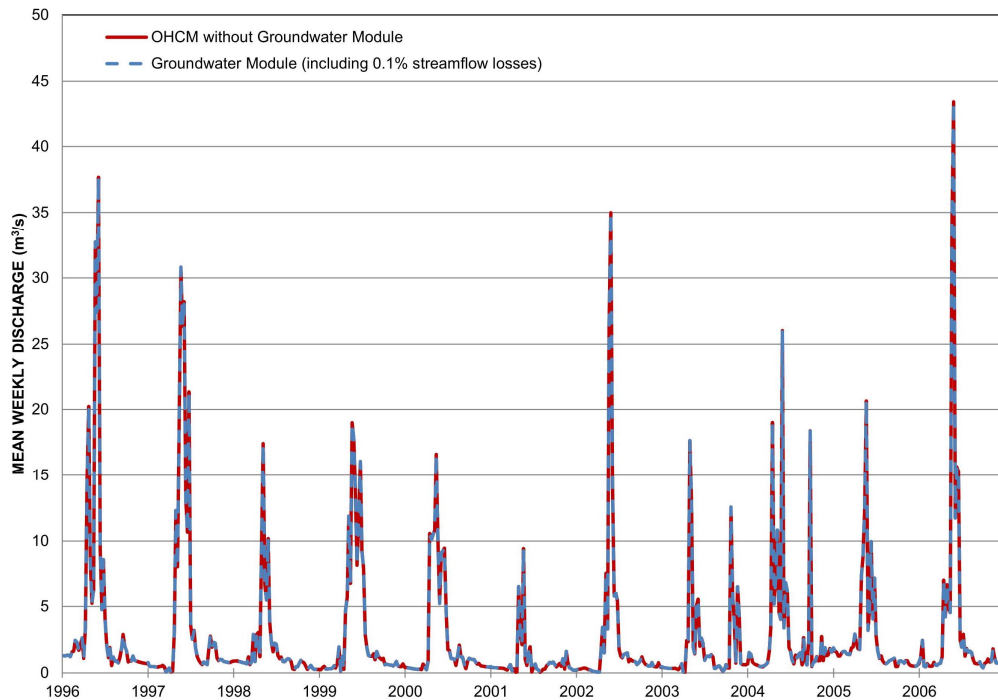


Figure 3-2 Mean weekly discharge of Trout Creek at the mouth over the baseline simulation period (1996-2006), including (1) the OHCM without the groundwater module and (2) the OHCM with the groundwater module and 0.1% streamflow losses.

3 - TROUT CREEK WATERSHED GROUNDWATER MODULE

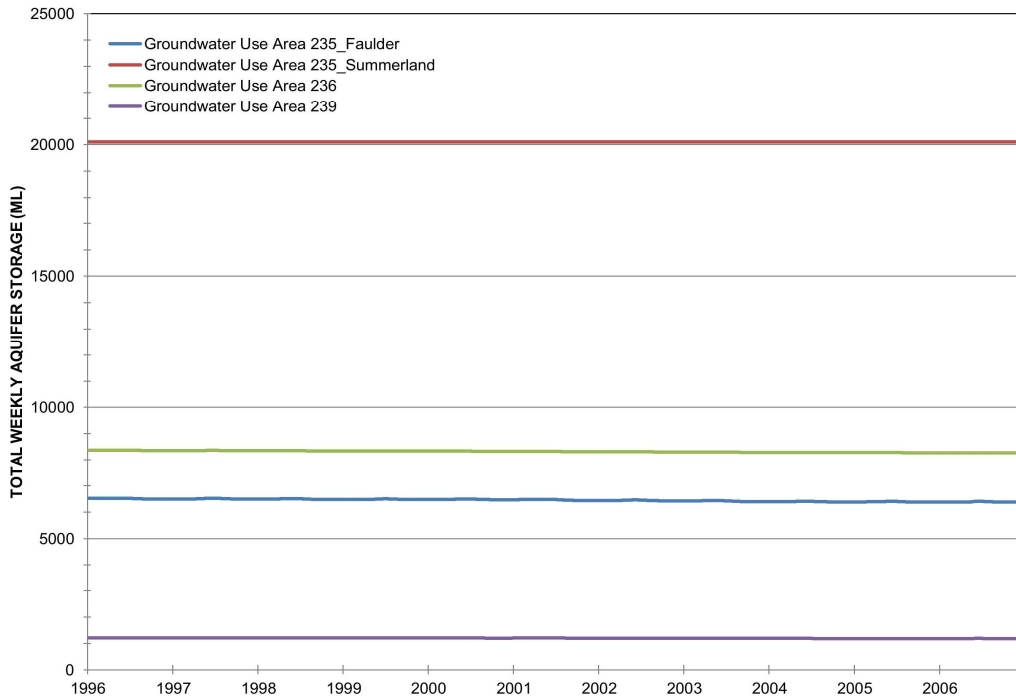


Figure 3-3 Total weekly aquifer storage for the Trout Creek watershed groundwater use areas using a 0.1% streamflow loss.

Under the baseline case, the results of the groundwater module application indicate that groundwater pumping at current demand rates does not significantly influence streamflow at the mouth of Trout Creek. In addition, aquifer storage associated with each groundwater use area was minimally influenced. Aquifer 235_Summerland does not change at all since there are no demands associated with it (the Alternative Supply Wells are not currently used). The results reflect the rates of groundwater demand within the Trout Creek watershed, which are low compared with streamflow rates (i.e. they are <1% of streamflow) and with total aquifer storage capacity.

Given the high uncertainty in stream loss rates and aquifer storage characteristics as discussed in this report, a simulation using a lower stream loss rate of 0.01% was also completed. The results indicated that the lower stream loss rate did not influence streamflow at the mouth of Trout Creek; however, as expected, aquifer storage declines over time were slightly greater (Figure 3-4).

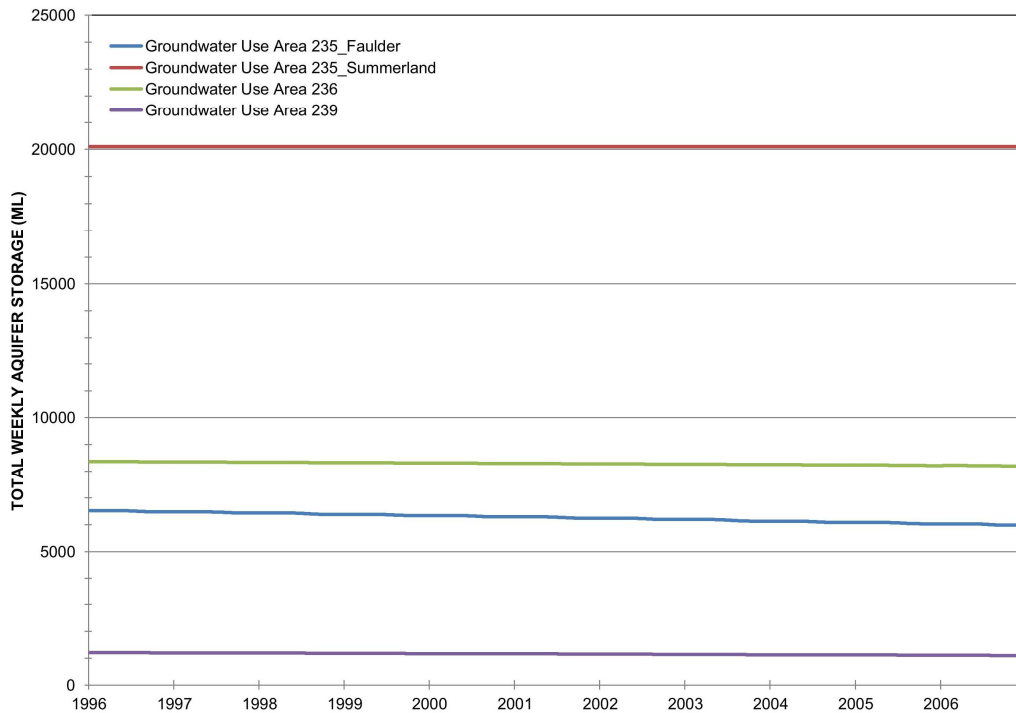


Figure 3-4 Total weekly aquifer storage for the Trout Creek watershed groundwater use areas using a 0.01% streamflow loss.

3.2.2 Scenarios Results

In an effort to evaluate and understand the influence of groundwater demands within the Trout Creek watershed, two separate scenarios were considered over the baseline period. The scenarios assumed a constant 0.1% streamflow loss to groundwater and groundwater demands of two- and five-times greater than the baseline case.

Under both scenarios, results indicated that groundwater pumping does not change streamflows at the mouth of Trout Creek. However, aquifer storage declined over time (Figures 3-5 and 3-6) in both cases. The results reflect the influence of the constant streamflow loss coefficient utilized within the groundwater module, as groundwater recharge is added at a low constant rate from streamflow loss only, and thereby minimally impacts streamflows within Trout Creek. Aquifers are generally recharged from aquifer-aquifer linkages and upgradient recharge; however, the input into the OHCM (from the OWAM) already includes interflow and baseflow contributions within the streamflows (and their associated aquifer-aquifer linkages) (see Section 4). Accordingly, this module provides a worst case scenario review of groundwater pumping, as it does not account for aquifer recharge other than through streamflow losses.

3 - TROUT CREEK WATERSHED GROUNDWATER MODULE

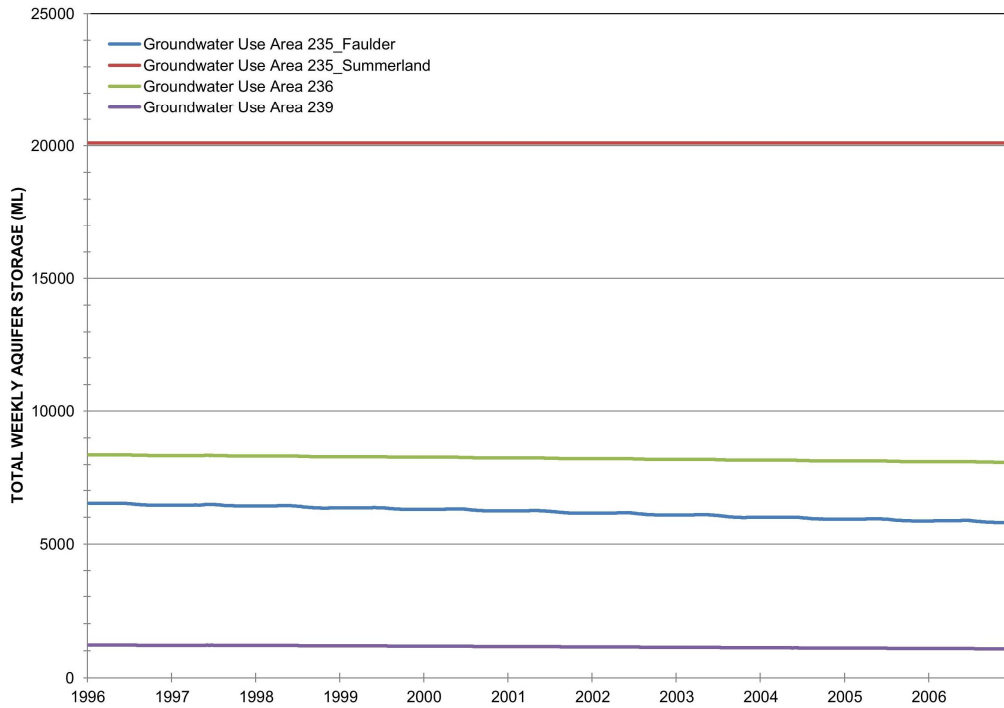


Figure 3-5 Total weekly aquifer storage for the Trout Creek watershed groundwater use areas assuming 0.1% streamflow loss and groundwater demands that are double the current demands.

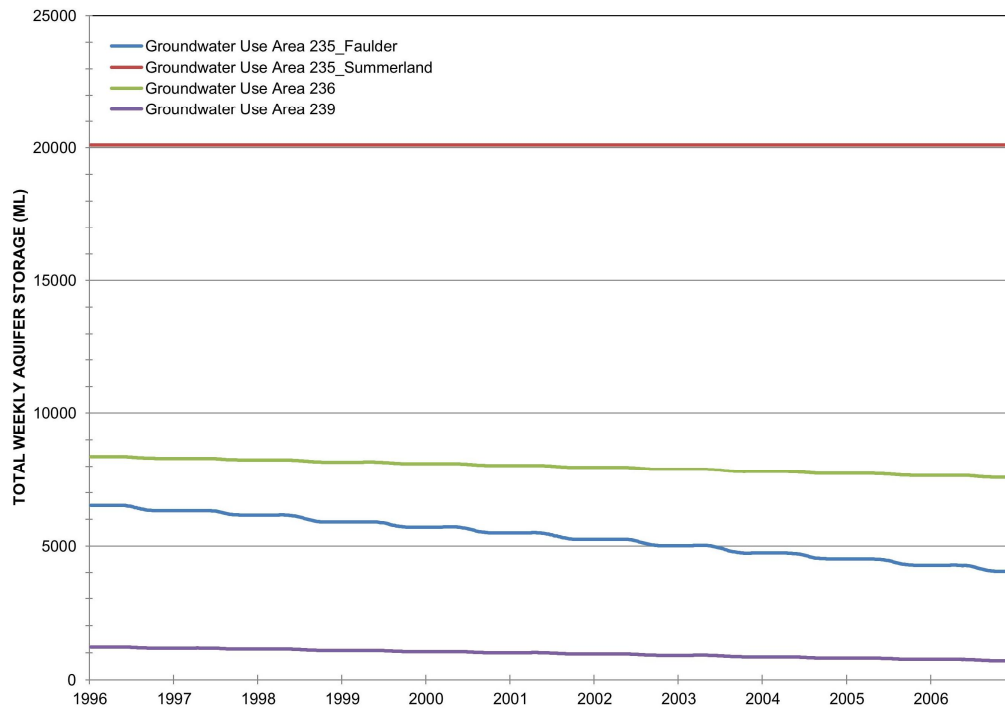


Figure 3-6 Total weekly aquifer storage for the Trout Creek watershed groundwater use areas assuming 0.1% streamflow loss and groundwater demands that are five-times greater than the current demands.

4 GROUNDWATER MODULE LIMITATIONS

The groundwater module development was influenced by several factors relating to:

- The WEAP modeling platform;
- The incorporation of OWAM groundwater data into the previously developed OHCM; and
- The data availability and uncertainty.

These factors are discussed below and are important considerations for evaluating the potential uses of the Trout Creek groundwater module in Section 5.

Groundwater aquifers are represented in the WEAP modeling platform as storage reservoirs for groundwater with inputs and outputs, and groundwater pumping (an output) is represented as a decrease in overall aquifer storage. Groundwater storage in turn is replenished by groundwater inputs such as stream losses. Therefore, the WEAP methodology provides a basis for a preliminary understanding of the effects of pumping when combined with site-specific information and an understanding of the groundwater system. However, because the model is simple and in general there isn't enough site-specific data on aquifer characteristics and stream losses, the results should not be relied on for quantitative hydrogeological analysis. For example, the results should not be used for quantitative hydrogeological assessment of aquifer sustainability, aquifer drawdown due to pumping, influence of groundwater pumping on streamflow, susceptibility of aquifers to climate change or drought, or understanding / verifying groundwater flow systems.

Another limitation with incorporating groundwater into the existing OHCM model relates to the use of the OWAM data for streamflow inputs, which was part of the original OHCM development. Streamflow assigned to different stream reaches in the OHCM includes inputs from the groundwater "reservoirs" in OWAM which have been "routed" back (via interflow and baseflow) to Trout Creek. Therefore, groundwater recharge in the Trout Creek groundwater module is only represented by the specification of stream losses. However, aquifers would actually be recharged by inputs from adjacent aquifers and surface recharge, but because these sources of recharge have already been routed to Trout Creek from the OWAM inputs, they are not specifically represented here to avoid "double-counting". The methodology employed in this application; however, is reasonable as an approximation because groundwater demand effectively influences streamflow (either by stream losses or by interception of groundwater that would otherwise discharge to a stream). We note here that the routing of groundwater inputs directly to Trout Creek in the existing OHCM also creates water accounting challenges for the representation of groundwater losses due to flow across bedrock or unconsolidated aquifers that cross beneath watershed boundaries.

Because of the limitations discussed above, the following qualifying comments are provided regarding the Trout Creek groundwater module development:

- The level of detail of the module reflects the level of detail of the existing OHCM, the level of detail included by Golder and Summit (2009), and the level of detail that can be reasonably incorporated

into the WEAP modeling platform for representation of groundwater. As stated in the proposal and discussed in this report, the WEAP modeling platform is not appropriate for considering influences of individual pumping wells, but rather the overall influence of groundwater extraction on aquifer storage and only where sufficient data are available to characterize aquifers.

- In terms of defining variables for representation in the OHCM, the greatest uncertainty of the groundwater module application relates to estimates of stream losses, which are highly uncertain due to a lack of data (e.g. Summit Environmental Consultants Ltd. (2009)). Some uncertainty is also associated with estimating aquifer storage, which was based on dimensional characterization and assumptions regarding aquifer effective porosity as discussed previously.
- Only the most heavily utilized aquifers in the Trout Creek area have been represented as groundwater use area nodes in the groundwater module. However, if the module was proposed to be used to investigate new areas for groundwater development (i.e. “groundwater use areas” that are not presently represented in the model), the module would require updating.

5

POTENTIAL USES AND APPLICATIONS FOR WATERSHED MANAGEMENT

The approach presented herein for integration of a groundwater module in the Trout Creek watershed is transferable to other watersheds represented in the OHCM. This transfer will be facilitated because there are similarities with respect to types and locations of aquifers within the mountain watersheds comprising the Okanagan Basin. In addition, the availability of data utilized for the Trout Creek groundwater module development (e.g. groundwater demand data, the BC wells database, the OWSDP Groundwater Study (Golder and Summit (2009)), and more detailed hydrogeological reports for higher capacity production wells) is also consistent across the Okanagan Basin. Therefore, the methodology presented here provides a framework for similar integration of groundwater for other watersheds.

As discussed previously, the representation of groundwater within the WEAP framework is necessarily a simplification of actual hydrogeological conditions and is based on limited data with variable accuracy. Despite its limitations, however, the groundwater module has the potential to provide the following useful applications if applied on an individual watershed basis.

Conceptualization

Well-developed conceptual models form the foundation of any water resources assessment. Accordingly, the WEAP modeling platform provides a framework to represent surface water and groundwater systems and their interactions conceptually, with consideration of site-specific conditions and within the context of a complete watershed system. Well-founded conceptual models lead to improved results for subsequent more detailed or quantitative assessments. Using the WEAP modeling platform to represent conceptualized water systems for watersheds in the Okanagan Basin has the potential to be useful for education, preliminary risk assessment, and guidance for further investigation as discussed below.

Education

The integration of groundwater into the OHCM provides a more complete representation of the components of the hydrologic cycle. Because the linkages and exchanges of groundwater and surface water can be conceptually represented in the WEAP modeling platform, the addition of the groundwater module to the OHCM may provide a useful tool for educating water managers and the public regarding the interconnectedness of water systems. The groundwater module, in this case, would best be utilized and simulated for hypothetical scenarios to provide a preliminary level of understanding of the concept that groundwater extractions can influence surface flows, or other concepts related to water management and water interconnectedness.

Screening Tool for Risk Assessment

The integration of groundwater into the OHCM may provide a useful screening tool to identify potential influences of future proposed water use (i.e. surface water or groundwater extractions). While quantitative

analysis of influences or risks would not be possible, the groundwater module may be useful to identify “locations” of risk related to the different water components represented. For example, if groundwater extraction was to increase in a particular aquifer area, which components of the groundwater module would be most likely to be influenced? The strength (accuracy) of the conceptual representation in the WEAP modeling platform is important to consider for risk assessment applications. The use of the groundwater module in this way will potentially require representation of new areas of groundwater demand for groundwater use areas that are not currently represented. Therefore, the groundwater module should be considered as a flexible tool, and simulations for screening or risk assessment may involve variations of the module to represent additional groundwater use areas and linkages (i.e. scenario testing using the module could include actual modification of the nodes and linkages rather than simply scenario testing for demand variability). Given the level of uncertainty of the groundwater module, the use of the module as a screening tool for risk assessment would be best conducted with input from a qualified hydrogeologist.

Guidance for Further Investigation

The current model can be used to provide guidance for further investigation. A more detailed representation of groundwater processes than employed in the present study has the potential to improve results of quantitative analysis at any level; from simple regional-scale water budget calculations to detailed numerical modeling studies.

6 SUMMARY AND RECOMMENDATIONS

6.1 SUMMARY

To continue to build upon Phases 1 and 2 of the OWSDP, the OHCM was developed as a tool to illustrate how water management actions are interconnected within the Basin and to help investigate how water is stored, licensed and flows through the Basin. The OHCM was developed as a surface water specific model, with groundwater only included implicitly through interflow and baseflow contributions to surface water flow. Groundwater pumping and water use were not included.

To develop the OHCM into a more robust water management tool, a methodology was developed to include groundwater (i.e. a groundwater module) within the OHCM that considers groundwater movement and storage, pumping, and interaction between groundwater and surface water. The methodology was built upon the mapped bedrock and alluvial aquifers and groundwater water use areas identified during Phase 2 of the OWSDP. A pilot watershed was selected (Trout Creek) as a test watershed for the implementation of a groundwater module for the OHCM.

For the groundwater module within the Trout Creek watershed, the module included four groundwater use area nodes, four groundwater demand nodes, and linkages between surface water bodies or other aquifers. The results of the groundwater module application for the 1996-2006 baseline case suggest that groundwater pumping at current demand rates does not significantly influence streamflow at the mouth of Trout Creek. In addition, aquifer storage associated with each groundwater use area was minimally influenced. However, scenario testing of the groundwater module indicated that under increased groundwater demands, aquifer storage declined significantly over time, while the streamflows within Trout Creek stayed generally the same.

The approach for integration of a groundwater module in the Trout Creek watershed is generally transferrable to other watersheds represented in the OHCM because there are some similarities with respect to types and locations of aquifers within the mountain watersheds comprising the Okanagan Basin. However, the representation of groundwater within the OHCM framework is an oversimplification of actual hydrogeological conditions and is based on limited data of variable certainty. Therefore, the application of the module to other Okanagan watersheds should be done with input from a qualified hydrogeologist.

6.2 RECOMMENDATIONS

The following recommendations should be considered if a groundwater module is to be included for other watersheds within the OHCM:

1. Neither the WEAP modeling platform nor the OWAM physically model groundwater flow. Both models include a simplistic representation of groundwater. If detailed groundwater investigations are required, consideration should be given to the development of a physically-based groundwater

- model (e.g. FEFLOW) coupled with the existing OWAM. With the inclusion of a physically-based groundwater model, combined with better site-specific data, quantitative hydrogeological assessments of aquifer sustainability, aquifer drawdown due to pumping, influences of groundwater pumping on streamflow, susceptibility of aquifers to climate change or drought, or understanding / verifying groundwater flow systems could be completed with a higher level of confidence than current model applications allow; and
2. The general lack of data for groundwater and aquifers is a major obstacle for the representation of groundwater systems within the WEAP modeling platform and the OWAM for the Okanagan. Additional data and physically-based investigations are required to improve our knowledge of groundwater within the Okanagan Basin.

References

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