REPORT

Regional District of Okanagan Similkameen

Similkameen Watershed Plan - Phase 3:
Agriculture Technical Report

July 2017

DELIVERED BY

Investment Agriculture Foundation of British Columbia

FUNDING PROVIDED BY

British Columbia

Canada

ISO 9001 and 14001 Certified | An Associated Engineering Company

This Similkameen Watershed Plan was funded in part by Agriculture and Agri-Food Canada and the Government of British Columbia through programs delivered by the Investment Agriculture Foundation of B.C.

Agriculture and Agri-Food Canada, the Government of British Columbia and the Investment Agriculture Foundation of BC, are pleased to participate in the Similkameen Watershed Plan. We are committed to working with our industry partners to address issues of importance to the agriculture and agri-food industry in British Columbia. Opinions expressed in this plan are those of Associate Environmental Consultants Inc. and not necessarily those of the Investment Agriculture Foundation, the Government of British Columbia or Agriculture and Agri-Food Canada.

DELIVERED BY

FUNDING PROVIDED BY

CONFIDENTIALITY AND © COPYRIGHT

This document is for the sole use of the addressee and Associated Environmental Consultants Inc. The document contains proprietary and confidential information that shall not be reproduced in any manner or disclosed to or discussed with any other parties without the express written permission of Associated Environmental Consultants Inc. Information in this document is to be considered the intellectual property of Associated Environmental Consultants Inc. in accordance with Canadian copyright law.

This report was prepared by Associated Environmental Consultants Inc. for the account of Regional District of Okanagan Similkameen. The material in it reflects Associated Environmental Consultants Inc.'s best judgement, in the light of the information available to it, at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Associated Environmental Consultants Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Associated Environmental

Associated Environmental Consultants Inc.
Suite 200, 2800 29 Street
Vernon, B.C., Canada V1T 9P9

TEL: 250.545.3672
FAX: 250.545.3654
www.ae.ca | ISO 9001 & 14001 Certified

July 14, 2017
File: 2016-8063.000

Justine Dougall
Public Works Manager
Regional District of Okanagan-Similkameen
101 Martin Street,
Penticton, BC
V2A 5J9

Re: PHASE 3 AGRICULTURE TECHNICAL REPORT - SIMILKAMEEN WATERSHED PLAN

Dear Ms. Dougall:

Associated Environmental Consultants Inc. is pleased to provide this Phase 3 Agriculture Technical Report. The Technical Report forms part of the overall Similkameen Watershed Plan.

The report includes an assessment of groundwater use by agriculture, estimates of future agriculture water demand considering climate change and water conservation measures, and recommendations for groundwater management. An initial assessment of groundwater quality in the lower elevation areas of the Similkameen Valley is also provided.

We trust this completes the Phase 3 technical assessment to your satisfaction. Please contact Melanie Piorecky or Hugh Hamilton if you have any questions.

Yours truly,

Hugh Hamilton, Ph.D., P.Ag.
Senior Environmental Scientist/Project Manager

British Columbia Institute of Agrologists
B.C.I.A.
Hugh Hamilton, P. Ag.
311

HH

Executive Summary

1 INTRODUCTION

The Similkameen Valley Planning Society (SVPS) and the Regional District of Okanagan-Similkameen (RDOS) are developing a watershed management plan for the Similkameen Valley. The Similkameen Watershed Plan (SWP) will address issues related to water supply, quality, and users, and develop strategies for water management for current and future use. This report is Part A of the two-part SWP Phase 3. It is the technical agricultural component that addresses current and future agricultural water demand from groundwater and surface water sources. The main components of Part A are:

1. Characterization of the future of agriculture in the Similkameen Valley over the period 2020-2050 to estimate future water demand and determine if water supply could constrain future agriculture opportunities.
2. An inventory of current groundwater use by agriculture, building on work done in Phases 1 and 2.
3. Estimating future agricultural water demand using modelling completed by Agriculture and Agri-Food Canada (AAFC) and new modelling to test the effectiveness of crop selection and water conservation on reducing agricultural water demand.
4. Characterizing irrigation groundwater quality based on a review of existing information and sampling of water from 10 wells on eight properties in the valley.
5. Outlining an implementation strategy for groundwater management by agriculture based on the results. The groundwater strategy is included in the draft SWP document prepared as the second part of Phase 3.

2 FUTURE OF AGRICULTURE IN THE SIMILKAMEEN VALLEY

By gathering an understanding of how agriculture might change in the valley, development of estimates of water demand under a number of future scenarios is possible. The estimates of future agricultural water use are needed to determine if water availability could constrain future agriculture opportunities. To gain estimates that are sufficiently realistic to inform watershed planning, the evaluation included engagement with local producers, farm organizations, and government agricultural staff to better understand current practices and concerns around water use. As well, available information was reviewed specific to agricultural commodities currently grown in the valley including but not limited to beef, chicken, pork, tree fruit, wine grapes, and vegetables. This included a review of the Statistics Canada Census of Agriculture (2012) and the Agricultural Land Use Inventory (ALUI) for the watershed. We also researched the scientific and agri-business literature for projected effects on the agricultural sector from climate change.

There is currently a well-established agricultural sector in the Similkameen Valley that is dominated by cattle ranching, followed by tree fruit and grape production. The spatial extent of agricultural production will likely increase slightly in the next 10 to 50 years, but is limited by the arable land available and the proximity of this land to water supply. Currently, water use challenges exist in the valley, and local producers anticipate these issues will continue to exist as they do now or with more frequency because of water demand and supply, which will be exacerbated due to climate change. Based on research and input from local producers, reduced pressure on water supply is possible through more efficient water use by agricultural operations. This could be implemented by adopting new technologies in irrigation management (e.g., changing sprinkler types, monitoring soil moisture to determine irrigation needs for specific crop types, and/or using automated systems), implementing soil conservation measures to improve soil moisture holding capacity, and changing crops (e.g., changing from tree fruit to grape production). Grape production requires about half of the volume of water that tree fruit production and cattle ranching (forage and alfalfa) require.

3 GROUNDWATER USE BY AGRICULTURE

The Phase 1 and 2 studies showed that there are good estimates of the volume of water used by water suppliers within the Similkameen watershed. However, there are agricultural areas throughout the watershed that are not serviced by a water utility and instead rely on individual groundwater wells. There are over 1,800 registered wells within the Similkameen watershed, and over 900 of those are found within the mapped boundary of the Similkameen Valley aquifer (Aquifer 259). The number of unregistered wells is unknown.

To address information gaps regarding water demand and use, and to assess private agricultural groundwater use by ranches and farms, we 1) confirmed the areas of the watershed not surveyed; 2) searched government databases to identify and tabulate all registered wells in non-serviced areas; 3) conducted in-person or over the phone interviews with growers to assess if there is a trend of moving from surface water to groundwater; and 4) confirmed with the Ministry of Agriculture that the 2008 ALUI included in the Agriculture Water Demand Model (AWDM) is the most current dataset.

Generally, the results of the interviews and screening exercise suggest that previous estimates of groundwater use by agriculture may be low, and that surface water use may be over-estimated. However, because groundwater and surface water in Aquifer 259 are hydraulically connected, whether the irrigation source is groundwater or surface water may not have a large impact on the overall water budget or on flows in the Similkameen River. As groundwater licensing moves forward under the *Water Sustainability Act* and groundwater use estimates are better defined, the total amount of extracted water could be over-estimated if land owners continue to keep their surface water licences. Therefore, periodic updates of actual water use (as opposed to licensed water use) will be needed to support water management in the valley for the foreseeable future.

4 ESTIMATES OF FUTURE AGRICULTURAL WATER DEMAND

Agriculture and Agri-Food Canada (AAFC) recently completed detailed modelling of future irrigation and livestock water demand in 17 regions of BC including the Similkameen Valley using the AWDM. Between 2000 and 2100, the irrigation water demand is expected to increase by 33% in the Similkameen Valley under the first greenhouse gas release scenario (representative concentration pathways; RCP4.5) and by 48% under the second (RCP8.5). The projected percent increases in water demand are somewhat less than neighbouring watersheds, reflecting differences in soils, crops, and irrigation practices. At present, not all the land that could reasonably be used for agriculture is being used in the Similkameen Valley. If irrigated agriculture were to expand into those areas with suitable soils and proximity to water sources, the effect would be an increase in irrigation water demand of 31–32% under both RCP emission scenarios.

Building upon AAFC's work, the consulting team completed new modelling scenarios to evaluate the effectiveness of crop selection and water conservation techniques to adapt to climate change by reducing water demand. Modelling of the effects of four conservation methods (i.e., change in crops, improved irrigation system efficiency, overall better irrigation management, and improved soil management practices) shows that individually these methods would result in only a modest reduction in irrigation demand. The volume of water that could be saved would help offset the increased demand from climate change up until about the 2030s, but would not offset the increased demand beyond that. However, if all four conservation methods were adopted according to the scenario that was assessed, the reduction in overall water demand would be significant at about 17-18%.

5 GROUNDWATER QUALITY

Based on the results of SWP Phase 2, little was known before 2016 about groundwater quality in aquifers in the Similkameen watershed. To address this data gap, Associated completed a review of the provincial water quality database to obtain existing data and identify areas without groundwater quality data, and completed a groundwater sampling program.

The results of the groundwater quality assessment indicate that the water quality in the unconsolidated aquifers is good. There were very few exceedances of applicable water quality guidelines, and those that were found to exceed (e.g., manganese, sulphate, TDS, and conductivity) are likely naturally occurring. Concentrations of key parameters that are associated with agricultural activities (e.g., nitrate, chloride, phosphorus) were relatively low, despite the prevalence of agriculture throughout the watershed. This may be because of the short residence time of the groundwater in the aquifer, which is believed to be freshly recharged and hydraulically connected to the Similkameen River.

Water quality was also relatively consistent spatially, with similarities in groundwater type noted even between wells located near the U.S. border and wells in the Princeton area. Most of the wells are located in the unconsolidated, freshly recharged valley-bottom aquifer. Small localized variations are likely due to either nearby human-caused sources or influences from neighbouring bedrock aquifers.

6 RECOMMENDED GROUNDWATER MANAGEMENT STRATEGY

The results of this technical assessment and preceding studies (Summit 2015, Associated 2016) show that groundwater is now the main source of water supply for agriculture as both water purveyors and individual farms have moved away from surface water over the past 5-15 years, but most have not given up their surface water licenses. Other key findings include that the quality of groundwater poses few constraints on agriculture, and that there are gaps in our understanding of how the valley aquifers are recharged and how groundwater and surface water interacts, although it is has been demonstrated that valley-bottom Aquifer 259 is connected to the Similkameen River and to the lower reaches of tributary streams. Based on these findings, groundwater management should be a priority for the SWP.

Understanding the regulatory framework for groundwater management is a key part of developing a strategy. Regulations or government guidelines that are applicable to groundwater management include the *Water Sustainability Act,* Groundwater Protection Regulation, the BC *Drinking Water Protection Act*, RDOS Subdivision Servicing Bylaw No. 2000, 2002, and a Groundwater Protection Plan being developed by the Village of Keremeos and the Keremeos Irrigation District. Also, understanding groundwater management issues is intrinsic to plan development. Issues in the Similkameen Valley watershed are related to water supply, groundwater quality, and environment and ecosystem functions.

The Similkameen Valley Watershed Plan will require strategic components specific to groundwater, which include:

- Groundwater and surface water should be valued and managed as a single source of water in the Similkameen watershed, especially in the valley bottom where there is agricultural land use and where most people reside;
- Recognizing their connected nature, the SWP should direct that all proposals for new development that would increase water use be supported by a hydrological assessment;
- In addition to strengthening groundwater protection, the implementation of the *Water Sustainability Act* provides opportunities to improve the database on groundwater. SVPS and RDOS should work with the provincial, First Nation, and federal governments to harmonize information collection, management, and communication to support decision-making;
- The recommended partnerships should be facilitated through a “Similkameen Groundwater Working Group” that meets regularly to share information and coordinate groundwater-related work[1];
- Although groundwater supply is adequate through much of the watershed, consider limiting additional groundwater use in the Keremeos Creek sub-basin and in the main Similkameen watershed downstream of Hedley until there is better information on how groundwater withdrawals are affecting streamflow;
- The watershed plan should provide direction on an overall water conservation strategy, of which agriculture is a component. It is important that there be a single water conservation strategy to reinforce the need to manage water as one resource;
- Look for opportunities to conserve water by implementing improvements to irrigation systems through a mixture of technology and best management practices;
- Communication and education initiatives within the SWP should include a groundwater component. Practical matters, such as WSA requirements, should also be communicated out on a regular basis; and
- Options for storage or water supply redundancy should be evaluated to prepare for drier than average years when groundwater extraction could be constrained. Climate change projections indicate that shortfalls will be more common from July through September, and not just limited to drought years.

Additional recommendations for scientific investigation to support groundwater management are provided in the main report.

---

[1] The SWP draft document (in development) will include recommendations for several such working groups (WG) to guide plan implementation (e.g., Riparian Areas WG, Groundwater WG), depending on the governance model selected.

Table of Contents

SECTION PAGE NO.

DELIVERED BY

FUNDING PROVIDED BY

Investment Agriculture Foundation of British Columbia

British Columbia

Canada

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Meaning
AAFC	Agriculture and Agri-Food Canada
ALR	Agricultural Land Reserve
ALUI	Agricultural Land Use Inventory
AWDM	Agricultural Water Demand Model
AWSC	Available water storage capacity
CBCCSP	Columbia Basin Climate Change Scenarios Project
CECA	Cumulative equivalent clear-cut area
COABC	Certified Organic Associations of British Columbia
CV	Coefficient of variation
EMS	Environmental Monitoring System
ESM	Earth System Model
GCM	Global Circulation Model
GWPR	Groundwater Protection Regulation
IWD	Irrigation water demand
LSIB	Lower Similkameen Indian Band
MFLNRO	Ministry of Forests, Lands and Natural Resource Operations
MOE	Ministry of Environment
MPB	Mountain pine beetle
OM	Organic matter
RCPs	Representative Concentration Pathways

Abbreviation	Meaning
RDOS	Regional District of Okanagan Similkameen
SAR	Sodium Adsorption Ratio
SRH	Similkameen River near Hedley
SRP	Similkameen River at Princeton
SVPS	Similkameen Valley Planning Society
SWE	Snow water equivalent
SWP	Similkameen Watershed Plan
TDS	Total dissolved solids
UBCO	University of British Columbia - Okanagan
U.S.	United States of America
USIB	Upper Similkameen Indian Band
WSA	*Water Sustainability Act*

1 Introduction

1.1 BACKGROUND – AGRICULTURE AND WATER MANAGEMENT IN THE SIMILKAMEEN VALLEY

The Similkameen Valley Planning Society (SVPS) with the Regional District of Okanagan-Similkameen (RDOS) is working to develop the Similkameen Watershed Plan (SWP, or “the watershed plan”). The watershed plan will eventually guide water-related decision making in the valley, and be integrated into other local plans, policies, bylaws, and best management practices. Figure 1-1 shows the boundaries of the Similkameen watershed, which totals 9,270 square kilometres (km^2) in area including 7,566 km^2 in British Columbia (BC) and 1,704 km^2 in Washington State.

In April 2016, RDOS retained Associated Environmental Consultants Inc. (Associated) to complete Phase 3 of the watershed plan. Phase 3 has two major parts:

A. technical agricultural component that addresses current and future agricultural water demand from groundwater; and
B. preparation of the draft watershed plan document that builds on the technical studies from Phases 1, 2, and 3.

This report is Part A, the Phase 3 agricultural technical study.

The agricultural sector is the largest user of water in the Similkameen watershed, with water licences in place for irrigation and stock-watering. Historically, most of the water supply for agriculture came from surface water sources including the Similkameen River and its tributaries. The hydrologic regime in the watershed is driven primarily by snowmelt processes at high elevations, resulting in peaks flows occurring in late spring and early summer, and the lowest average monthly flows in winter. As summer progresses, streamflows decline fairly quickly, with average flows in August and September being approximately 8-10 percent of those in June in the Similkameen River at the U.S. border (Water Survey of Canada 2016). This coincides with a period when irrigation demand remains high, creating potential challenges in years that are warmer and/or drier than average. For this and other reasons, a significant number of agricultural water users have moved to groundwater for all or part of their supply.

Until early 2016, it was not necessary to obtain a water licence to extract groundwater in BC[2], and therefore less was known about groundwater use than surface water use. The SWP Phase 2 report included an analysis of water supply and demand, determining that the proportion of irrigated land that was supplied by groundwater was increasing from what had been estimated for 2003 in the Similkameen Agriculture Water Demand Model (approximately 45%, van der Gulik at al. 2013), but that the precise breakdown was unknown (Summit 2015). In addition, there were a number of key information gaps remaining that constrain water management decisions, especially with respect to groundwater-surface water interaction and groundwater quality. With the prospect of climate change, it is important to expand the understanding of agricultural water use, now and in the future, in the Similkameen Valley.

---

[2] The *Water Sustainability Regulation* of the *Water Sustainability Act* came into effect on February 29, 2016.

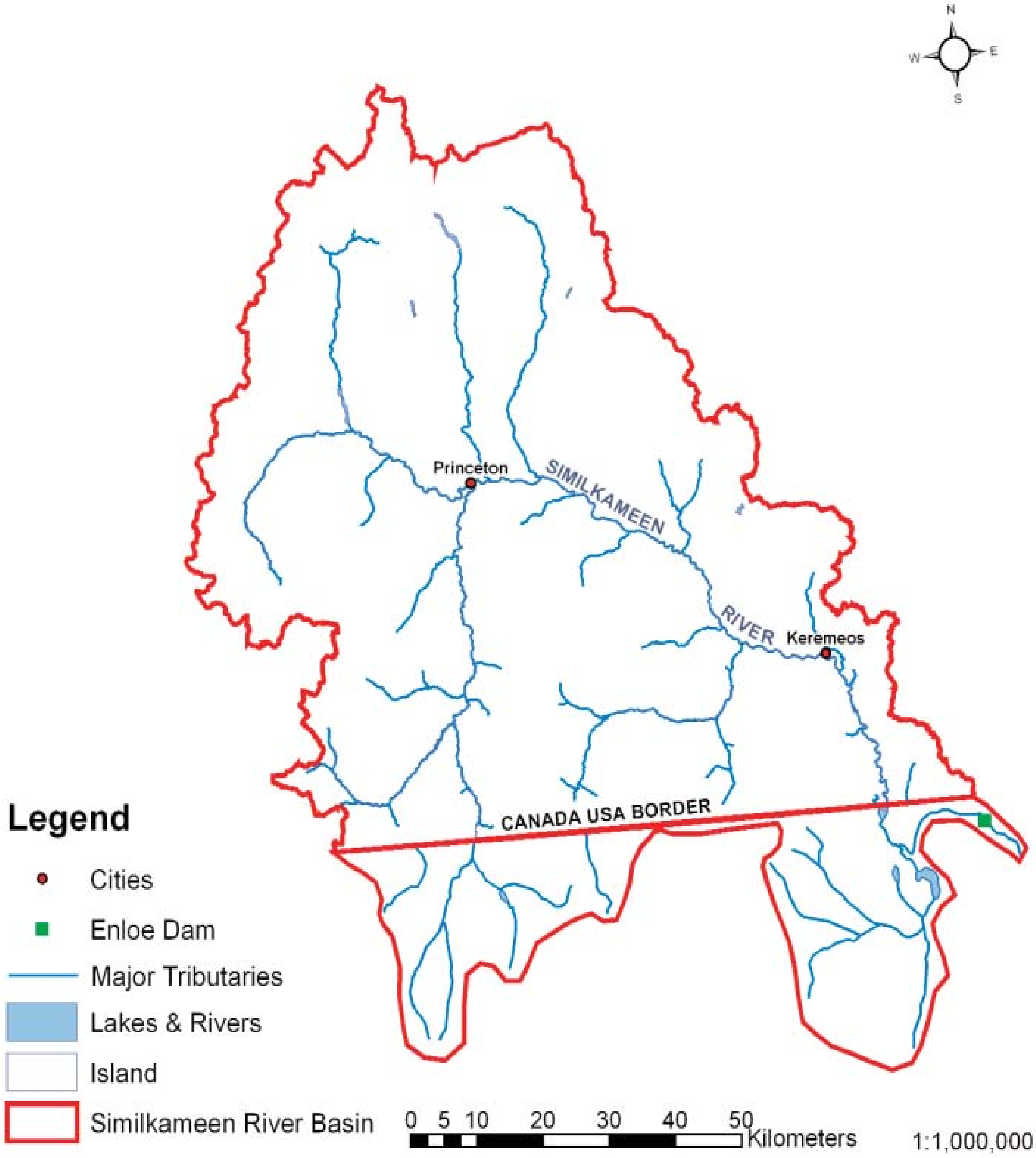

Figure 1-1
Similkameen watershed

1.2 PROJECT OBJECTIVES

The major objectives of the Agriculture Component (Part A) of Phase 3 are to:

1. Characterize the future of agriculture in the Similkameen Valley ("the valley") over the period 2020–2050 in order to develop realistic estimates of future water demand in the valley and to determine if water availability could constrain future agriculture opportunities.
2. Inventory and describe current groundwater use by agriculture, building on work done in Phases 1 and 2.
3. Estimate future agricultural water demand using the Similkameen Agriculture Water Demand Model (AWDM) (van der Gulik et al. 2013) for a range of scenarios, with the combinations of future agricultural use, climate change, conservation methods, and time frames determined in consultation with the agricultural sector (producers, BC Ministry of Agriculture, and Agriculture and Agri-Food Canada) as part of the "future of agriculture" task.
4. Characterize irrigation groundwater quality based on a review of existing information and on sampling of existing water wells in the valley.
5. Develop a draft implementation strategy for groundwater management by agriculture based on the results of the technical tasks for the four previous objectives, and incorporating recommendations for leadership, governance, and measurable indicators of success, resources, and schedule.
6. Prepare a report that presents the results of the Phase 3 Agriculture Component (i.e., this report).

In addition, this report provides a brief summary of a recent study by University of British Columbia Okanagan (UBCO) researchers on the effects of forest disturbance (forest harvest, Mountain pine beetle, and fire) in combination with climate change on the hydrology of the Similkameen watershed (Section 5).

2 The Future of Agriculture

2.1 WHY DO WE NEED TO KNOW HOW AGRICULTURE MIGHT CHANGE?

By gathering an understanding of how agriculture might change in the valley, it is possible to develop estimates of water demand under a number of future scenarios. The estimates of future agricultural water use are needed to determine if water availability could constrain future agriculture opportunities. Although predicting the future is challenging, the estimates need to be sufficiently realistic to provide input to watershed planning. For this reason, the evaluation of the future of agriculture benefits from engagement with local producers, farm organizations, and government agricultural staff to better understand current practices and concerns around water use.

2.2 METHODS

Our initial step to characterizing the future of agriculture in the valley was to review background information, including the work done in Phases 1 and 2, as well as research reports on the agricultural commodities currently grown in the valley and nearby areas including but not limited to beef, chicken, pork, tree fruit, wine grapes, and vegetables. This included a review of the Statistics Canada Census of Agriculture results (2012) and the AWDM for the Similkameen watershed (van der Gulik et al. 2013). We also researched the scientific and agri-business literature for projected effects on the Canadian and international agricultural sectors from climate change. The background and scientific review provided insight into possible changes in agricultural practices based on climate change (Section 2.4).

After completing the initial literature review, we inquired with the following organizations and people to gather insight into the future of agriculture in the Similkameen, and to get insight into which growers to contact that could provide input into the future of agriculture:

- Carl Withler – Industry Specialist Tree Fruit and Grapes, BC Ministry of Agriculture
- Susan L. Smith – Industry Specialist Organics and Vegetables, BC Ministry of Agriculture
- Clayton Botkin – Poultry Specialist, BC Ministry of Agriculture
- Geneve Jasper – Livestock Team Lead, Sector Development, BC Ministry of Agriculture
- Anne Skinner – Regional Agrologist for Okanagan South, BC Ministry of Agriculture
- Dr. Denise Neilsen – Research Scientist, Agriculture and Agri-Food Canada (AAFC)
- Hedy Dyck – Chief Operating Officer, BC Landscape and Nursery Association
- Jen Gamble – Executive Director, Certified Organic Associations of British Columbia (COABC)
- Kevin Boon – General Manager, BC Cattlemen's Association
- Christine Koch – General Manager, BC Poultry Association
- Louise Corbeil – Registrar, BC Grape Growers Association
- Kate Durisek – Executive Director, BC Wine Grape Council
- Scott Hennenfent – General Manager, BC Wine Authority
- Glen Lucas – General Manager, BC Fruit Growers Association
- Woody Siemens – Market Supply and Development Manager, BC Milk Marketing Board

From consultations with the above organizations and people, we created a list of 34 growers in the valley that included contact names, farm name(s), crop type(s), contact information, and addresses. Each grower on the list was contacted via phone to ask if they would be willing to answer questions related to water use. Most were asked the questions at the time of the call, and others were sent the list of questions as a questionnaire via email. The questionnaire is provided in Appendix A. The answers provided insight into the existing agricultural sector (Section 2.3) and the possible trends in agricultural production due to climate change from a local producer and local research perspective (Section 2.5).

The scenarios outlining the future of agriculture and directing the water demand modelling are based on this information.

2.3 EXISTING AGRICULTURAL SECTOR IN SIMILKAMEEN WATERSHED

Agriculture is a mainstay of the economy in the Similkameen Valley. Cattle ranching is the largest agricultural activity based on the area of crop land, with about 86% of the land in Areas B, G, and H of the RDOS in alfalfa, alfalfa mixtures, hay, or as natural land for pasture (Statistics Canada 2012). Fruit growing, including apples, cherries, grapes, and peaches, is the next most significant activity. In 2011, there were approximately 341 farms in Areas B, G, and H (Table 2-1), with an increase in average farm size moving from east to west. The average was 82 hectares (ha) in Area B, 143 ha in Area G, and 276 ha in Area H. In BC, there were approximately 19,759 farms in 2011, with an average farm size of 132 ha (Statistics Canada 2012).

According to the Statistics Canada Census of Agriculture, the dominant irrigation requirements in Areas B, G, and H are for hay, alfalfa, and pasture (Table 2-2). However, in Areas B and G, there is a greater percentage of irrigated tree fruit relative to percentages for the rest of the province (Table 2-1) (Statistics Canada 2012).

The Agricultural Land Use Inventory (ALUI) was completed in 2008 as part of development of the AWDM for the Similkameen watershed, to understand current and future water demands (van der Gulik et al. 2013). It calculates water use on a property-by-property basis, looking at crop, irrigation, soil texture, and climate data, and although it has comparable outcomes, it is more precise than the Statistics Canada Census of Agriculture. The survey area included all properties in the Agricultural Land Reserve (ALR) and all areas zoned for agriculture by local governments, which total 62,649 ha (van der Gulik et al. 2013). Based on the ALUI, the primary agricultural activities total 5,966 ha that are farmed, which is dominated by forage and pasture (4,637 ha), followed by tree fruit (673 ha), “other” (324 ha), and vine and berry production (231 ha). The total area irrigated in the Similkameen is 4,533 ha, summarized by crop in Table 2-3.

Note that the AWDM output and Statistics Canada produce slightly different estimates of the area utilized by agriculture and irrigation area, because of differences in the timing, methods, and purpose of the surveys.

Table 2-1
Detailed farming statistics for Regional District of Okanagan Similkameen Areas B, G, and H

North American Industry Classification System	**Area**		
Okanagan-Similkameen 2011 (Statistics Canada 2012)	**Area B**	**Area G**	**Area H**
Total number of farms	120	156	65
Cattle ranching and farming, including feedlots	11	9	20
Dairy cattle and milk production	2	-	-
Poultry and egg production	2	1	4
Sheep and goat farming	2	1	-
Other animal production	11	27	19
Hog and pig farming	-	1	1
Horse and other equine production	8	21	13
Animal combination farming	2	2	6
Apiculture	1	2	-
Vegetable and melon farming	33	17	6
Potato farming	1	1	2
Fruit and tree-nut farming (including grapes)	62	92	1
Greenhouse, nursery, and floriculture production	3	2	1
Other food crops grown under cover	2	1	-
Nursery and tree production	1	1	-
Other crop farming	13	16	17
Hay farming	9	10	17
Fruit and vegetable combination farming	4	2	-
Oilseed and grain farming	-	2	-

Table 2-2
Irrigation use in Okanagan-Similkameen and BC

Area	All Irrigation Use	Hay, Alfalfa, and Pasture (% of total)	Fruit (% of total)
Okanagan-Similkameen Area B	752 ha	374 ha (50%)	315 ha (42%)
Okanagan-Similkameen Area G	1,567 ha	979 ha (62%)	550 ha (35%)
Okanagan-Similkameen Area H	987 ha	987 ha (97%)	-
Subtotal	**3,306 ha**	**2,340 ha**	**865 ha**
BC	111,139 ha	73,128 ha (65%)	19,456 ha (18%)

Source: Statistics Canada 2012

Methods of irrigation captured in the Census of Agriculture are either sprinkler, micro, or surface irrigation. Statistics Canada data indicate an increase in the number of farms using micro-irrigation systems, or more efficient systems, by 12% in the Okanagan-Similkameen and by 26% in BC from 2010 to 2014. In that same period, sprinkler irrigation, which is generally a less efficient irrigation method, decreased by 24% in the Okanagan-Similkameen and by 36% in BC (Statistics Canada 2012). This indicates a shift to more water-conscious farm management in general. Data for surface irrigation in the Okanagan-Similkameen are “too unreliable to publish” (Statistics Canada 2012). Supporting the Statistics Canada data, the results of the agricultural land use inventory indicate that the most prominent irrigation system for fruit production in the Similkameen is micro-sprinkler, followed by micro-spray and solid set undertree. Micro-spray is the most efficient system, followed closely by micro-sprinkler then solid set undertree (van der Gulik et al. 2013).

Table 2-3
Irrigated area by crop in 2003

Crop	Total Irrigated Area (ha)	Total Irrigated (%)	Average Annual Water Requirement (mm)
Alfalfa	2,172.8	47.9	891
Forage	871.0	19.2	940
Apple	619.7	13.7	820
Grape	265.1	5.8	407
Recreational turf and golf	231.9	5.1	978 and 861
Fruit, other	153.7	3.4	884
Cherry	103.4	2.3	892
Vegetable	81.3	1.8	729
Corn	20.6	0.5	819
Greenhouse/nursery	7.7	0.2	1,059
Berry	6.1	0.1	834
Total	**4,533.3**	**100**	

Source: van der Gulik et al. 2013 (2003 data, average management)

Based on input from local producers, approximately 30% had issues with water supply, mostly due to gravity feed issues but occasionally due to reduced supply. Just over half of the producers with issues are ranchers. However, none of the local producers we spoke to have considered changing crop types or area due to challenges with water supply. All crops in the region, except alfalfa and forage, require irrigation to survive. All tree fruit, vegetable, grape, berry, and melon producers irrigate every cropped hectare of their land. Of the 16 tree fruit and grape producers we spoke to, 11 use drip irrigation (some with a combination of sprinkler and drip). Drip and micro-jet sprinklers are used, which facilitate irrigation with lower volumes of water than conventional systems. Conversely, ranchers do not irrigate all their land, but generally more than half of grass-legume forage and/or alfalfa is irrigated. Irrigation systems for forage and alfalfa production are either pivot, wheel, travelling guns, or hand-line sprinklers.

2.4 POSSIBLE CHANGES DUE TO CLIMATE AND FUTURE AGRI-BUSINESS TRENDS

2.4.1 Climate Change Adaptation by Agriculture

Due to climate change, the BC interior (such as the Similkameen Valley) is expected to be warmer with longer frost-free seasons and increased evaporation and plant transpiration from the surface into the atmosphere (Agriculture and Agri-Food Canada 2015). This may provide opportunities for agriculture in certain regions with an expansion of the growing season, and could increase productivity as well with the use of new and potentially more profitable crops. For livestock, warmer temperatures could result in lower feeding requirements (i.e., more grazing), higher survival rates of young, and lower energy costs.

The challenges in agriculture that may result from climate change in the BC interior could be due to increased intensity and frequency of droughts and violent storms, resulting in a decrease in crop yields. There have already been changes in drought frequency and severity, shifts in the timing of precipitation, and changes in storm intensity, which present risks to production. Hot weather could cause an increase in heat-wave related livestock deaths and reduced immunity, especially in poultry operations. The increase in extreme heat events will create a greater demand on water, which could coincide with water restrictions (Crawford and McNair 2012a). Other effects could be increased weed growth due to higher levels of atmospheric CO_2, and increased prevalence of pests and pathogens that historically would have been reduced during cold winters and/or had not been introduced to the Similkameen region. As well, extreme precipitation events could disrupt pollination and spraying schedules (i.e., reduced effectiveness and added costs), and could have a negative impact on productivity and quality by increasing crop damage and losses.

For grape growers, climate change has potential to exacerbate existing challenges such as winter injury, frost damage, severe heat, drought, or cooler temperatures during rainfall, and excess rainfall during the springtime or fall harvest (Laurentian University and MIRARCO 2015).

2.4.2 Possible Future Changes in the Agricultural Economy

Although it is difficult to identify singular trends and influences on BC's agricultural production because of the dynamic nature of the industry, the reports reviewed and input from specialists in the industry (cited in Section 2.3) suggest that historic changes are due to changing consumer demands, increased/changing competition from import and export markets, changing technology, and available crop varieties. In reviewing 30 years of horticultural crop production in BC (1976 to 2006), the following crops have decreased in production: potatoes (-21%), field vegetables (-7%), strawberries (-52%), and tree fruit (predominantly apples and pears, -39%); whereas the following crops have increased in production: greenhouse vegetables (+302%), blueberries (+44%), grapes (+154%), and sweet cherries (unknown percentage of total tree fruit) (Crawford and McNair 2012b).

The lack of clear trends and unpredictability of consumer demands make it difficult to predict the changes in the agricultural economy; however, studies show that consumer demand will remain consistent, and although automated harvesting equipment and other technology that is costly will come on the market, it is likely that only larger farms will be able to afford it (IBISWorld 2016). This may result in profit losses to smaller producers, pushing them out of the market (IBISWorld 2016). According to IBISWorld (2016), over the next five years the number of operators is expected to decline in Canada by 0.4%, specifically smaller producers leaving the market. That said, exports of Canadian fruit and nut produce have increased by 13.9% in the last five years (IBISWorld 2016). Based on this finding, the valley's proximity to the U.S. border is a benefit; however, the opportunity to export to the U.S. is both a benefit and a disadvantage. Canadian fruit producers are often challenged by U.S. farmers who can grow comparable crops year-round. Also, currency fluctuations create uncertainties for export development.

Overall, IBISWorld (2016) forecasts an increase in the agricultural industry revenue for fruit and nuts of an annualized 2% for the next five years. Further, a strong determinant of fruit purchases for consumers is whether or not it is locally produced. This trend will likely continue or increase, which will benefit the Similkameen Valley producers because of the growing population in the Okanagan region and the reasonable distance to Metro Vancouver. This trend extends beyond fruit and vegetables, as restaurants and markets promote local food. As well, in BC farmers produce a large share of Canada's apples, most of which are sold on the fresh market and therefore command a higher price. In this regard, the high percentage of apple production in the valley is also a positive for the future of agriculture.

2.5 POSSIBLE LOCAL TRENDS BASED ON PRODUCER AND AGRICULTURAL AGENCY INPUT

Feedback from the various agricultural organizations provided context for the possible changes to agriculture in the Similkameen. The pertinent feedback is summarized below, including the person who provided the feedback:

- Carl Withler, Industry Specialist Tree Fruit and Grapes, BC Ministry of Agriculture: Currently, there are the right crops for the climate and available water in the Similkameen; however, tree fruit crops are vulnerable to drought. In the event of repeated extreme drought years, there could be a move from tree fruit to grapes and possibly reduced forage production. Grapes are more tolerant of drought because of their deep rooting system, and generally have lower water requirements than tree fruit (Table 2-3). Conversely, the change in growing conditions in the Similkameen could lead to more crops that are typically grown further south being grown successfully in this region (C. Withler, personal communication, 2016).

- Glen Lucas, General Manager, BC Fruit Growers Association: The changes to the mix and number of cropped acres are driven by market more than water supply, but water supply does have an influence. Although the total area producing grapes has increased in recent years, fruit prices have been somewhat stable. This is a driver for new varieties of fruit, resulting in a lot of interest in replanting. In terms of variety and planting trends, growers in the Similkameen have renewed most of the orchards, so any changes would result in similar tree density as is in place, and therefore similar water demands. Note that cherry plantings seem to require more water (G. Lucas, personal communication, 2016).

- Clayton Botkin, Poultry Specialist, BC Ministry of Agriculture: Feed cost and transport to market are limitations to the expansion of meat, bird, and egg production in the Similkameen. Also, the climate is generally too warm in the region for birds, other than turkeys. The one turkey operation (grower/processor) is the only commercial flock. Only “backyard” flocks with local markets have potential to expand. However, the poultry industry is a limited water user (C. Botkin, personal communication, 2016).

- Susan L. Smith, Industry Specialist Organics and Vegetables, BC Ministry of Agriculture: There is limited potential for expansion of large scale vegetation production without access to processing. The only likely expansion is of local market and specialty market, particularly organic vegetables (S. Smith, personal communication, 2016). This information is supported by an Agriculture and Agri-Food Canada report, Opportunities Assessment of British Columbia’s Vegetable Sector (Gooch et al. 2012).

- Geoff Hughes-Games, Soil Specialist, Independent Consultant (previously BC Ministry of Agriculture): There likely will be only limited expansion in berry production other than to meet local market demands. Climate and soils are limitations to current common fruits, specifically cranberries from lack of water for harvest and frost risk; blueberries because soils are too alkaline and summers are too hot and dry; raspberries, which are limited by market demand; and strawberries because winters are too dry and cold. Non-traditional fruits or emerging fruits may be suitable, but so far there has been limited acreage of any across the province (including blackberry, current, gooseberry, kiwi, Saskatoon, haskap, and elderberry). Note that the use of technology, such as mulches, tunnels, poly covers, and even greenhouses, to modify environments to produce fruit could be used. The berries produced in shoulder seasons can often be sold at higher value in fresh (local) markets (G. Hughes-Games, personal communication, 2016).

Based on input from these specialists, large-scale agriculture is not expected to expand in the Similkameen due to limitations caused by climatic conditions, market access, and/or market stability for the current production. These factors all affect the willingness of producers or agri-food businesses to invest in new ventures. However, agriculture is expected to expand at the local and specialty market production level, i.e., smaller scale farming.

Based on feedback from producers in the region, 35% expect that agricultural production will increase in the future, and the rest expect it will stay about the same. Some growers have seen smaller farms disappear and larger ones become larger, and expect this trend to continue. Almost half of the producers expect that challenges to water supply will worsen in the future. However, the general consensus is that improved water management could offset constraints from reduced water supply, with more efficient irrigation systems and reduced leaks, as well as better water management. This includes improving irrigation scheduling, irrigating more precisely based on crop requirements, and maximizing available technology to determine watering efficiencies by crop type.

An additional practice to reduce irrigation demands on water is to improve the ability of the soil to take in and hold moisture. Practices that increase soil moisture content are categorized in three groups: (i) those that increase water infiltration; (ii) those that limit evaporation from soil; and (iii) those that increase soil moisture storage capacities. All three are influenced by soil organic matter content. Conservation practices that result in available water capacity favourable to soil function include (USDA NRCS 2011):

- Addition of soil organic matter;
- Conservation crop rotation;
- Cover cropping;
- Well managed grazing;
- Residue and tillage management; and
- Saline and sodic soil management.

2.6 SUMMARY

In summary, there is currently a well-established agricultural sector in the valley that is dominated by cattle ranching, followed by tree fruit and grape production. The spatial extent of agricultural production will likely increase slightly, but be limited by the arable land available and the proximity of this land to water supply. Based on history, economics, and trends seen by local producers, larger farms may get larger and some smaller farms may be removed from production or amalgamate with larger farms. However, the continued importance placed by consumers on buying locally produced foods as well as the expansion of local niche markets could lend well to continued farm success and minor expansion of small farm production in the valley.

Currently, water use issues do exist in the valley, and local producers anticipate these issues will continue to exist as they do now or with more frequency. Based on research and input from local producers, reduced pressure on water supply is possible through more efficient water use by agricultural operations. This could be implemented by adopting new technologies in irrigation management (e.g., changing sprinkler types, monitoring soil moisture to determine irrigation needs for specific crop types, and/or using automated systems), implementing soil conservation measures to improve soil moisture holding capacity, and changing crops (e.g., changing from tree fruit to grape production). Grape production requires about half of the volume of water that tree fruit production and cattle ranching (forage and alfalfa) require.

In general, local producers in the valley and members of agricultural organizations currently (2016) do not consider water to be a limiting factor in the total area or crop types that are currently farmed. Those that predict issues in the future with water supply generally believe that improved management measures could overcome supply issues, or there may be a reduction in forage and tree fruit production, which may be changed into grape production.

3 Groundwater Use by Agriculture

The Phase 1 and 2 studies indicate that there is a good understanding of the volume of water used by water suppliers within the Similkameen watershed. However, there are agricultural areas throughout the watershed that are not serviced by a public water supply (e.g., Irrigation District, municipality, or Improvement District), and instead rely on individual groundwater wells. During the Phase 2 study, Summit (2015) identified the areas within the Similkameen watershed that are serviced by water purveyors based on interviews with irrigation and improvement districts and municipalities. However, uncertainties remained about the irrigated areas that are serviced by the Lower Similkameen Indian Band (LSIB), the Upper Similkameen Indian Band (USIB), and from private wells.

3.1 BACKGROUND AND RECENT STUDIES

Current estimates of surface water and groundwater demand from private users for agriculture have been completed for the SWP using the AWDM (Section 4), which is based on the ALUI. The ALUI is based on ground surveys completed in 2008, and assigns each surveyed parcel in the watershed either a groundwater or surface water source. Water demand information from the AWDM was corroborated by comparing with surface water licences to extract water; however, anecdotal evidence and our experience in other watersheds in southern BC indicates that water users often use less than their licensed amount, and may keep their surface water licences even after switching to groundwater. The Phase 2 study confirmed that this was the case for most water purveyors, but it has not yet been investigated for private users.

With the *Water Sustainability Act* (WSA) now in place, the process of licensing groundwater extraction has begun in BC. To help support groundwater allocation decisions and ensure future water sustainability within the Similkameen watershed, the Ministry of Environment (MOE) commissioned a study in early 2016 to develop a preliminary water budget model for the Similkameen Valley Aquifer 259. The key findings from that study (Associated 2016) are as follows:

- Based on information presented during Phase 2, the water budget model that was developed for MOE assumes that groundwater and surface water systems are directly connected.
- Groundwater and surface water demand were both included in the water budget model, and were separated into annual (i.e., domestic – January to December) demand and seasonal (i.e., irrigation season – April to September) demand.
- Seasonal estimates of agricultural groundwater demand (i.e., irrigation use) from the AWDM were used in the model as this was the most robust dataset of groundwater use at the time of the project.
- Annual estimates of domestic groundwater demand (e.g., drinking water, washing, small gardens) were developed as follows:
    - Total monthly groundwater demands for the Town of Princeton, Keremeos Irrigation District, and Fairview Heights Irrigation District as reported by Summit (2015) during Phase 2 of the SWP.
    - Since no water use information for private domestic wells was available, estimates of private domestic use were generated following SRK Consulting Inc. (2013). This method

assumed that all private domestic wells within Aquifer 259 (318 wells) used the equivalent of 192.7 m^3/year/well and that 30% of the demand occurred during summer (June–August).

- Based on a set of simplifying assumptions, the water budget model was calibrated to observed groundwater level fluctuations in observation well #75 and provided estimates of groundwater available for future allocation on a monthly basis, under three different climate scenarios (i.e., dry, wet, and normal).
- Under normal conditions, and assuming that the water table can be drawn down to the lowest recorded level, the water budget model estimated that 220,285,776 m^3 of groundwater is available annually (Associated 2016).

3.2 INTERVIEWS

To assess whether there is a trend of moving from surface water to groundwater, we asked growers about the future of agriculture (Section 2) and their water source and whether or not they have faced water supply challenges. Of the 23 growers who responded to the questionnaire:

- 12 obtain water exclusively from a well;
- six obtain water from an Irrigation District;
- four obtain water from a combination of groundwater and surface water; and
- one obtains water from both a private well and a purveyor.

For those growers who use a well for at least part of their water supply, we asked how long they have been using the well. Of the 17 respondents that use water for at least some of their supply, 11 (65%) have been using their well for less than 15 years and three (18%) have been using their well for less than five years.

In-person interviews were also conducted with 10 growers and/or ranchers to discuss their groundwater use knowledge and to determine if they hold and use surface water licences and if they have experienced supply or quality challenges. These 10 growers and/or ranchers were part of the 23 who responded to the questionnaire, with the exception of one additional rancher identified during the field visit. The interviews were completed at the same time as the groundwater sampling task (Section 6). Of the 10 growers who were interviewed:

- four hold surface water licences, but get their water entirely from groundwater;
- one obtains water from surface water, but is planning to switch to groundwater;
- three obtain water entirely from groundwater and do not have any surface water licences;
- one obtains their irrigation supply from surface water and their domestic supply from groundwater, and is not looking at moving their irrigation supply to groundwater; and
- one obtains water from groundwater and surface water, and uses approximately their licensed amount of surface water.

Most growers are aware of the connection between groundwater and the Similkameen River, and most are aware of the need since early 2016 to license their groundwater wells. None of the growers interviewed said they had issues with either groundwater quality or quantity in the past. One rancher located north of Princeton is planning to switch the water supply entirely to groundwater to address issues with clogged surface water intakes and reduced surface water flows in the late summer/early fall. The rancher indicated that others in the area are likely doing the same, and that the current surface water licensed volumes do not reflect actual surface water use in the area. This latter observation is consistent with the findings of the Phase 2 report (Summit 2015).

3.3 AGRICULTURAL LAND USE INVENTORY

We confirmed with the Ministry of Agriculture that the 2008 ALUI included in the AWDM (van der Gulik et al. 2013) is the most current dataset (S. Lee, personal communication, 2016); therefore, there is insufficient information to update and refine estimates of agricultural groundwater estimates at this time. Water demand estimates generated using the AWDM (i.e., as presented during Phase 2) remain the best estimates of agricultural water use within the Similkameen watershed. However, understanding that the ALUI is based on ground surveys completed in 2008, this database could be updated in the future to confirm the boundaries of agricultural lands, water sources, and crop types. Figure 3-1 shows the agricultural areas within the watershed that are served primarily by groundwater and by surface water.

3.3.1 Private Water Users – Groundwater and Surface Water Comparison

Using water purveyor boundaries and the surveyed land parcel information from the ALUI (i.e., “agricultural lands”), we determined the following:

- There are 74.6 km^2 of agricultural land in the watershed. Of that area, approximately 48% (36.1 km^2) is serviced by private users (i.e., do not get their water from a purveyor or municipality).
- Of the private users, the ALUI suggests that 74% use surface water and 26% use groundwater.

To assess the accuracy of this breakdown, we completed a screening exercise to identify areas of land that the ALUI indicates is serviced by surface water but has a recorded[3] groundwater well within the surveyed boundary. The objective of this exercise was to better quantify the number of private users that may have switched from a surface water source (based on 2008 surveys) to a groundwater source.

Within the Similkameen watershed, there are 1,946 registered groundwater wells (Table 3-1). Of these wells, 537 are located within agricultural lands serviced by private wells.

The results of the screening exercise indicate the following for agricultural lands serviced by private users:

- A total of 174 registered groundwater wells are located within lands listed as being sourced by surface water.
- Of the 174 wells, 34 are registered specifically for irrigation use. The others are registered as private domestic, water supply system, other, abandoned, or unknown.
- The 34 irrigation wells are located within 26 different land parcels, representing an area of 4.0 km^2, or 11% of the total agricultural area within the watershed that is serviced by private users.

---

[3] Based on the BC Water Resource Atlas.

Table 3-1
Registered water wells in the Similkameen watershed

Purpose	Number of Registered Wells	
	Total	Within Agricultural Lands Serviced by Private Users
Private Domestic	765	78
Unknown Well Use	648	90
Unlisted	230	20
Irrigation	146	53
Water Supply System	74	2
Commercial and Industrial	51	0
Other	24	2
Observation Well	4	0
Abandoned	3	1
Test	1	0
Total	**1,946**	**246**

3.3.2 LSIB and USIB Lands

As part of the Phase 3 agricultural technical study, we confirmed that the lands included in the ALUI included the agricultural lands on the reserves of the LSIB and USIB. Therefore, estimates of agricultural water use in this report and in the Phase 2 report include the LSIB and USIB lands.

3.4 SUMMARY

Generally, the results of the interviews and screening exercise suggest that previous estimates of groundwater use by agriculture may be low, and that surface water use may be over-estimated. However, because groundwater and surface water in Aquifer 259 are hydraulically connected, whether the irrigation source is groundwater or surface water may not have a large impact on the overall water budget or on flows in the Similkameen River. As groundwater licensing moves forward under the WSA and groundwater use estimates are better defined, the total amount of extracted water could be over-estimated if land owners continue to keep their surface water licences. Therefore, periodic updates of actual water use (as opposed to licensed water use) will be needed to support water management decisions in the valley for the foreseeable future. Additional recommendations for groundwater management in the next decade are provided in Section 7.3.

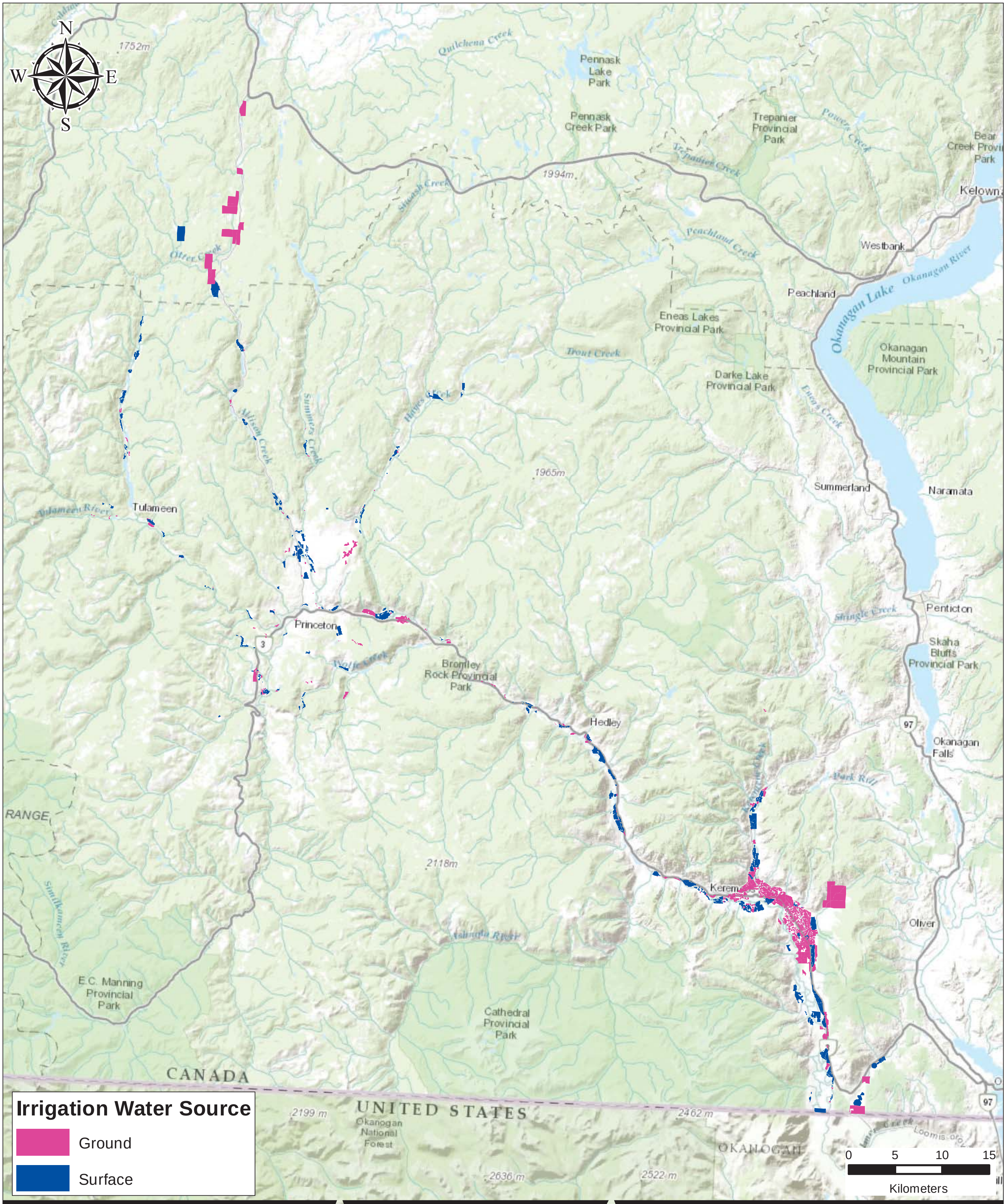

Fig 3-1.mxd / 12/16/2016 / 1:47:41 PM

Associated Environmental

PROJECT NO.: 2016-8063.000.003
DATE: Dec 2016
DRAWN BY: DA

FIGURE 3-1: ALUI WATER SOURCE

Regional District of Okanagan Similkameen

Similkameen Valley Watershed Plan Phase 2

4 Estimates of Future Agricultural Water Demand

4.1 DEVELOPMENT AND DESCRIPTION OF FUTURE SCENARIOS

AAFC recently completed detailed modelling of future agricultural water demand in 17 regions of BC, including the Similkameen Valley (Bakker et al. 2015). AAFC's modelling used the AWDM that was developed jointly by the BC Ministry of Agriculture and AAFC (van de Gulik et al. 2013). Dr. Denise Nielsen from AAFC provided Associated with the modelling output for use in this assessment.

As part of AAFC's recent modelling efforts, the AWDM was used to assess irrigation water demand (IWD) for the period 2000 to 2100 for 17 regions in BC (Bakker et al. 2015). Output from five different climate models was used, each under two representative concentration pathways (i.e., RCP4.5 and 8.5) that represent different greenhouse gas emission scenarios. The RCP emission scenarios represent different climate change scenarios, from a less drastic temperature change (i.e., RCP4.5) to a more significant temperature change (i.e., RCP8.5). The 10 combinations (i.e., five climate models and two RCPs) were used to model the projected IWD for the Similkameen Valley under the following land use scenarios:

1. Continued irrigation of existing agricultural land.
2. Continued irrigation of existing agricultural land plus irrigation of potential agricultural land (referred to as "buildout"). For the Similkameen Valley, potential agricultural land was defined as land that is below 800 m in elevation, within 1,000 m of water supply (including surface water, groundwater, or a water purveyor), within the ALR, with an agricultural capability rating of class 1 to 4, and under private ownership (Bakker et al. 2015).[4]

Therefore, the recent modelling work completed by AAFC provides a good understanding of:

- Projected increases in IWD for the Similkameen Valley under different climate change and land use scenarios;
- The uncertainty associated with the five different climate models and two greenhouse gas emission scenarios; and
- How the Similkameen Valley compares to others parts of BC.

With the availability of the AAFC modelling output, the assessment of agricultural water demand for this report comprised: 1) a summary of the key findings of AAFC's work for the Similkameen Valley (Section 4.3.1), and 2) new modelling to test the effectiveness of crop selection and water conservation on reducing agricultural water demand (Section 4.3.2). The steps taken to complete the assessment were:

1. Obtain the climate and AWDM output data from AAFC (November 2016).
2. Summarize the AAFC results for the recent past (2010–2015, n=6) and for two future climate normal (30-year average) periods: 2021–2050 and 2041–2070 by calculating descriptive statistics (e.g., average, median, minimum, and maximum) and graphing.
3. Conduct a series of modelling scenarios to evaluate the effectiveness of crop selection and water conservation techniques to adapt to climate change by reducing water demand. From our

---

[4] Parcels to the east of Richter Mountain were removed because of lack of access to water.

discussions with producers, an interest was identified for an understanding of how much water could be saved by the adoption of more efficient methods or other investments. Therefore, crop and water conservation adaptations were assessed for both the current and buildout land use scenarios. The AWDM was used to assess the effects of changing four variables:

   a) The mix of crop types (with reduction in forage crops);
   b) Irrigation method and efficiency;
   c) Irrigation management practices (poor, average, good – considering the tendency to over-water, maintenance, repairing leaks); and
   d) Soil management practices, specifically increasing soil organic matter to improve soil moisture retention (Section 4.2).

4. Complete the modelling and summarize the findings for three different time periods:
   a) 2010–2015 (base case);
   b) 2021–2050; and
   c) 2041–2070.

4.2 MODELLING METHODS

4.2.1 AAFC Summaries

As part of a project that researched agricultural water demand projections to the end of the century in BC, Dr. Denise Neilsen and her team at AAFC ran the AWDM under five available AWDM GCM datasets for the 2000–2100 period (Bakker et al. 2015). AAFC provided the raw outputs for the Similkameen Valley, which were summarized by the Associated consulting team to produce descriptive statistics.

Data

AAFC's assessment addresses only water demands for irrigated crops (i.e., IWD); animal (i.e., livestock) water demand is not included. Animal water demands are modelled in the AWDM as fixed daily amounts per inventoried animal (e.g., 50 litres per head per day for horses); these amounts do not change for different climate models or years (except for the one-day difference in leap versus non-leap years), and there are no additional animal water demand projections associated with buildout scenarios. Therefore, for comparing scenarios, animal water demand was not considered in order to allow for the modelling to emphasize conservation methods only.

Climate Models and RCPs

AAFC used output from five climate models under two RCP emission scenarios as follows:

<u>Climate Models</u>

- ACCESS 1-0 (Australian Community Climate & Earth-System Simulator; an ESM[5]);
- CanESM2 (Canadian Earth System Model; an ESM);
- CNRM-CM5 (Centre National de Recherches Meteorologiques Climate Model; a GCM[5]);
- INMCM4 (Institute of Numerical Mathematics Climate Model; a GCM); and

---

[5] ESM – Earth System Model. GCM – Global Circulation Model.

- CSIRO-Mk3-6-0 (Commonwealth Scientific and Industrial Research Organization climate model; a GCM).

Relative Concentration Pathway (RCP) Emission Scenarios

- RCP4.5 – a scenario that stabilizes radiative forcing at 4.5 Watts per m^2 in the year 2100 and considers the stabilizing of anthropogenic forces. This is moderate emissions scenario.
- RCP8.5 – a scenario that stabilize radiative forcing at 8.5 Watts per m^2 in the year 2100 and is the highest greenhouse gas emissions scenario and does not include any consideration of a climate mitigation target.

Modeling Periods

Three modelling periods were selected from the full dataset for summary:

2010–2015	recent past (base case)
2021–2050	near future
2041–2070	mid-future

Land Bases

The AWDM covers two land base categories for the Similkameen Valley:

- Current agricultural land use – 4,533 irrigated hectares
- Potential future agriculture buildout – 6,360 irrigated hectares (criteria defined above in Section 4.1).

4.2.2 New Modelling of Crop Changes and Water Conservation Methods

Following the modelling completed by AAFC, new modelling scenarios of crop changes and water conservation methods were completed by the consulting team using the latest (2016) version of the AWDM (Section 4.3.2). The specific crop change and water conservation scenarios that were modelled are described as follows:

Crops

Based on input from Carl Withler, P.Ag. (Industry Specialist of Tree Fruit and Grapes at the Ministry of Agriculture), two crop scenarios were modelled:

- The total land use area for grape crops increases by 8% by replacing lands currently in forage crops with grapes. This increase is more than currently anticipated (which is about 6%), but it indicates how a change to a crop that uses less water affects water demand.
- The total land use area for tree fruit-like crops increases by 10% on land that is currently forage crops (this increase includes olives, hazelnuts, pistachios, and other crops that are found further south, but may be able to be grown in the Similkameen Valley in future years, as olives and other fruit and nut production unique to the valley have similar water requirements to tree fruit). Based on the ALUI, of the 4,533 ha of lands irrigated with ground and surface water, 3,044 ha are alfalfa and forage. Therefore, 10% of this area converted to tree fruit is 304 ha under this scenario.

Irrigation Type and Efficiency

The AWDM assigns irrigation efficiency values for each type of irrigation practice (e.g., guns 55%, pivot 72%, micro-sprinkler 82%, and drip 92%). For simplicity, given the watershed-scale of the assessment, the irrigation efficiency values were increased on all lands by +8%, based on the following:

- This is the approximate range in efficiencies within the main categories of irrigation systems (i.e., sprinklers, guns, and centre pivot) as reported in the BC Sprinkler Irrigation Manual (Ministry of Agriculture 2014), suggesting this is the possible improvement a producer could achieve without changing the overall type of system.
- Alberta has set a 7% improvement target for efficiency (i.e., increase the average from 78% to 85%) for 2012–2025 (Alberta Agriculture and Rural Development 2014). This target is based on a review of realistic opportunities.
- Statistics Canada (2012) indicate a range in efficiencies for each irrigation type of 5% to 10%, so 8% reflects an optimistic middle ground about what is feasible.

Irrigation Management Practices

The AWDM allows the user to assess irrigation management factors (poor, average, and good) to account for inefficiencies such as leaks and over-watering, based on soil texture (i.e., Maximum Soil Water Deficit) and irrigation system combinations. Previous studies tested for differences by assuming that the whole watershed was poor, or average, or good (van der Gulik et al. 2013). For each period in the current assessment, two irrigation management distributions were modelled:

- Current practices scenario – **30% poor, 60% average, and 10% good.**
- Improved practices scenario – **10% poor, 50% average, 40% good**.

The current distribution of farm properties into the poor, average, and good categories is based on what was learned from discussions with the agriculture sector. The improved practices scenario indicates 20% of the land base going from poor to average, and 30% currently rated as average improving to good. This magnitude in improvement appears feasible based on recent data from the Okanagan Valley (D. Nielsen, personal communication, 2016).

Soil Management

Research by Hudson (1994) demonstrated that soils with high organic matter (OM) content have significantly higher available water capacity than soils of similar texture than contain less OM. Hudson (1994) reported that as OM increased from 1% to 3%, the available water capacity approximately doubled for all texture classes that were studied.

Based on the findings by Hudson (1994), the Available Water Storage Capacity (AWSC) factors included within the AWDM were increased by **+**24% for all soil textures (e.g., sandy loam goes from 125 mm/m to 155 mm/m). This is the typical gain in AWSC achieved by increasing the soil OM content by 1% when in situations where OM has been reduced by tillage and other agricultural practices over a period of time (Hudson 1994; Bot and Benites 2005).

4.3 AGRICULTURAL WATER DEMAND MODELLING RESULTS

4.3.1 Summary of AAFC Modelling Results for Similkameen Watershed

As outlined above, the AAFC study (Bakker et al. 2015) modelled the 2000–2100 increase in IWD for 17 BC regions including the Similkameen Valley, using two RCPs. Table 4-1 shows the results for the Similkameen Valley compared to several nearby regions and the maximum and minimum of the 17 areas that were modelled. Over this 100-year time frame, the IWD is expected to increase by 33% in the Similkameen Valley under the RCP4.5 emission scenario and by 48% under the RCP8.5 emission scenario. The projected percent increases are somewhat less than the neighbouring watersheds, reflecting differences in soils, crops, and irrigation practices (Note: the mix of crops and irrigation practices were assumed to remain the same). To put the Similkameen Valley irrigation volumes into context, the average total streamflow in the Similkameen River at Hedley is about 590 million m^3 between May and September inclusive (Water Survey of Canada 2016), so the RCP8.5 irrigation volume of 15,293,484 m^3 would represent about 3% of that streamflow if the water was all withdrawn from the river. Note that the May–September comparison is intended as a simple benchmark, and the streamflows in late summer are a fraction of freshet (e.g., the mean in September is 5.55 m^3/s compared to 91.2 m^3/s in June), so the late summer increase in irrigation would be a significant part of that average flow[6].

The values in Table 4-1 are the averages of the five climate model outputs. AAFC assessed uncertainty by calculating the coefficient of variation (CV)[7] of the outputs. For the Similkameen Valley, the CV was 14% in 2100 under both RCP emission scenarios, which was the lowest of the 17 regions. This indicates that the projected future increases in agricultural water demand are similar regardless of which model was used.

For the current assessment, the AAFC model output data were tabulated and summarized separately under the two land use scenarios: current agricultural land use area and buildout, then statistics were generated for the two RCP emission scenarios. Table 4-2 and Figure 4-1 provide a summary of the resulting modelled IWD.

---

[6] The Part 2 report provides more detail on water withdrawals related to natural flows in the river (Summit 2015).

[7] CV% = standard deviation ÷ average × 100%

Table 4-1
Predicted increase in irrigation water demand 2000–2100: Similkameen Valley and nearby regions

Region	RCP4.5		RCP8.5	
	Increase in Irrigation Volume (m^3)	Percent Increase over Year 2000 Volumes	Increase in Irrigation Volume (m^3)	Percent Increase over Year 2000 Volumes
Similkameen	**10,275,790**	**+33%**	**15,293,484**	**+48%**
Okanagan	42,429,511	+36%	63,498,743	+53%
Kettle	12,860,528	+40%	19,486,803	+60%
Nicola	21,314,816	+42%	33,716,861	+66%
Maximum of 17 watersheds	-	+64%	-	+114%
Minimum of 17 watersheds	-	+21%	-	+30%

Source: Bakker et al. 2015

The effect of buildout results is an increase in irrigation water demand of 31–32% under both RCP emission scenarios. However, at present, there appears to be low likelihood that full buildout would happen if the general agricultural economy remains in place in western North America (Section 2). Although, the lands included within the buildout scenario are those that can feasibly be farmed if there is increased demand for the products generated from the Similkameen Valley, and so it represents a scenario that could happen. As expected, the higher greenhouse gas emission scenario (i.e., RCP8.5) results in high irrigation water use, but only about 4% more compared to the RCP4.5 emission scenario.

In addition, climate change on its own, assuming no change in land use, would see a 16% increase in IWD from current conditions until the 2041–2070 normal period under the RCP4.5 emission scenario, and a 21% increase under the RCP8.5 emission scenario. However, if both climate change and buildout was to occur, the increases in IWD would be 48% and 60% under the RCP4.5 and RCP8.5 emission scenarios, respectively.

Table 4-2
Similkameen Watershed Average irrigation water demand for current (2010–2015) and two future normal periods (2021–2050 and 2041–2070)

Time Period	Units	RCP4.5		RCP8.5	
		Current Land Use	Buildout	Current Land Use	Buildout
2010–2015	Volume (m^3)	33,892,262	44,543,587	32,773,786	42,980,846
	Equivalent Depth (mm)	748	700	723	676
2021–2050	Volume (m^3)	34,933,871	45,885,291	36,349,728	47,745,588
	Equivalent Depth (mm)	771	721	802	751
2041–2070	Volume (m^3)	38,105,885	50,164,408	39,806,968	52,395,463
	Equivalent Depth (mm)	841	789	878	824

Note: Equivalent depth is average calculated by dividing volume by irrigated area (4,533 ha for current; 6,360 ha for buildout).

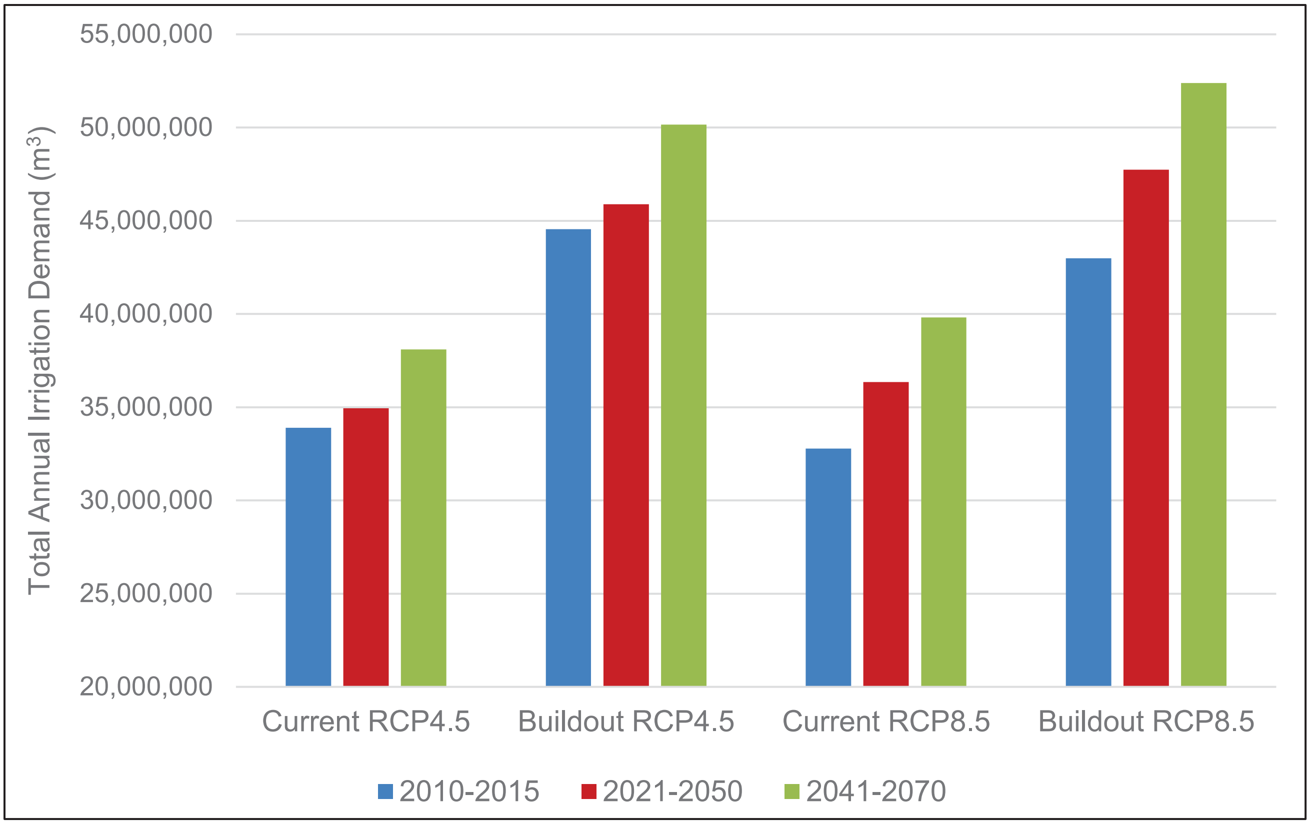

Figure 4-1
Modelled changes in total annual irrigation water demand – current and buildout land use with two RCP emission scenarios

4.3.2 Modelling the Effects of Crop Changes and Water Conservation Measures

This section describes a set of scenarios modeled to evaluate and compare the role of agricultural management strategies in reducing water use. These scenarios investigate the effects of changing one of the primary variables affecting the water demand calculations within the AWDM, while holding the other variables fixed. A final *maximum benefit* scenario models the changes in agricultural water demand by implementation of all the management improvements together. Complete implementation of all scenarios is unlikely, but the estimates that are generated provide an indication of what could be achieved if supply becomes severely constrained (e.g., if late summer low streamflow trends point towards significant effects on fish populations – see Section 4.4).

How does the AWDM determine which lands could change?
Some of the scenarios involved designating a portion of the irrigated landbase for the modification or the improvements in factors affecting the water demand calculations within the AWDM. As a result, a process was implemented to produce a *reasonably random* selection of areas, since it isn't possible to project which

property owners might implement change. The approach was not random in a formal statistical sense, although it does appear to produce a good range in terms of field sizes and geographic distribution.

The scenarios operate at the level of the *cropped field* – a portion of a property identified as growing a specific crop. For a crop change scenario, this corresponds to a farmer changing an alfalfa crop over to grape, for example, while keeping the apple crop intact. For an irrigation management improvement scenario, it could represent a single farmer starting with a range of management levels (poor/average/good) on different crop fields and changing some of those practices to an improved level. This may not be realistic, as a farmer may be more likely to reduce overwatering practices across the board rather than just on a single crop field. But for the purposes of this type of comparative analysis, it should not matter whether the improvements are related to one or many farmers.

The scenarios are slightly biased towards small crop fields at the end of the process. Because the scenarios are aimed at finding a specified total area (e.g., 303 ha of forage crop converted to tree fruits), larger crop fields selected near the end of the process are more likely to push the total past the required amount. The process in the AWDM rejects up to 20 candidates if using them would mean a total area selection of more than one hectare beyond the requested figure. This results in larger crop fields getting passed over in favour of small parcels at the end of the random selection. However, as noted earlier, for the purposes of this comparative analysis herein, the actual properties selected and the individual sizes do not have an impact on watershed-scale results.

The following points outline the key decisions that are reflected in the scenario modelling output:

- ***Base Case.*** The *Base Case* scenario represents the current status with respect to the ALUI for crop type, irrigation system and soil status, modeled under *average* irrigation management. This produces almost the same outcome as the results summarized from AAFC's data (Section 4.3.1), but there have been changes to the AWDM code since AAFC completed their work, which have a small effect on the water demand calculations. As such, the *Base Case* scenario provides a suitable starting point for the comparisons of management outcomes.

- ***Crop Change.*** The *Crop Change* scenario models the conversion of a portion of existing forage, alfalfa and grass areas to grapes and tree fruits, with the associated changes to irrigation systems that are appropriate for those new crops. The intent was to increase grape areas by assuming that 8% of the current forage area is converted to grapes, and increase tree fruits by assuming that 10% of the current forage area converts to tree fruit. There are 3,030 ha of irrigated forage, alfalfa or grass in Similkameen Valley (based on ALUI information); therefore 242.4 ha were converted to grapes in the model using drip irrigation and 303 hectares to tree fruits. Of the 877 ha currently in tree fruits (i.e., apples, apricots, cherries, nectarines, nuts, peaches, pears, plums), the most predominant irrigation system type is microsprinkler (82% efficiency) followed by microspray (88% efficiency) and solid state undertree (74% efficiency). Accordingly, microsprinkler was selected for the converted tree fruit areas. In addition, the growth curve and growing season characteristics of medium density apples was used for the converted areas rather than distributing the changes across different tree fruit types.

- ***Irrigation Efficiencies.*** The *Irrigation Efficiencies* scenario models an assumed improvement of the efficiencies for all systems of 8%.

- ***Irrigation Management Practices.*** The *Irrigation Management Practices* scenario models improvements in the way that farmers apply water to their crops, leading to less water being lost to deep percolation (overwatering). There are three settings in the AWDM for irrigation practices: *poor*, *average* or *good*. These settings, along with the soil characteristics and irrigation system types, dictate the amount of water calculated as being lost to deep percolation. In the standard use of the AWDM, the management practices setting applies to all crop areas, while an average setting was used for the other scenarios. However, for the *Irrigation Management Practices* scenario, the total crop irrigation practice distribution was assigned a starting position of 30% poor, 60% average, and 10% good and then adjusted to 10% poor, 50% average, 40% good. The assignment of the initial management setting was made randomly across all crop and irrigation system types and the adjusted values were improved incrementally (i.e. a poor field was bumped up to average, and average bumped up to good).

- ***Soil Management.*** The *Soil Management* scenario models improvements to the soil resulting in increased AWSC. All AWSC values were increased by a fixed 24%. For example, the value for *Sandy Loam* was increased from its standard setting of 125 mm/m to 155 mm/m. The AWSC value also affects the maximum evaporation factor, which plays a role in determining the stored moisture in the soil during the lead up period to the growing season.

- ***Maximum Benefit.*** The *Maximum Benefit* scenario implements all of the changes and improvements from all the other scenarios (i.e., crop changes, irrigation efficiencies, irrigation management practices, and soil improvements). The initial state for the *Maximum Benefit* scenario is the *before management improvement* scenario (i.e., initial crop irrigation practice distribution); it starts with a mix of irrigation management practices settings which gets improved upon as part of the full set of maximum benefit changes.

Table 4-3 summarizes the scenario modelling results, comparing the projected irrigation water demand for the three modelling periods. Table 4-4 presents the same information, converted to equivalent depth (in mm) based on the current irrigated area within the Similkameen Valley of 4,533 ha. Note that *before management improvement* (i.e., initial crop irrigation practice distribution) and *after management improvement* (i.e., adjusted crop irrigation practice distribution) scenarios together form the *Irrigation Management Improvement* analysis. The *before management improvement* scenario is the baseline for the irrigation management practices scenario and the maximum benefit comparison; it differs from the *Base Case* scenario in that it models a mix of management practices settings before applying the improvements to generate the *after management* and *maximum benefit* estimates.

The results in Tables 4-3 and 4-4 and Figure 4-2 are the averages of all 10 climate model and RCP emission scenario outputs. Note that the *Base Case* scenario represents the current status with respect to crops, irrigation systems, and soils using an *average* irrigation management practices setting. The *Base Case* is the scenario against which the crop change, irrigation improvement (efficiency improvements) and soil improvement scenarios should be compared – each of those changes a single characteristic away from the base case settings.

Table 4-3
Projected average change in total irrigation volume if water conservation methods are implemented

Period	**2010-2015**		**2021-2050**		**2041-2070**	
Scenario*	**Volume (m^3)**	**Percent of Base Case**	**Volume (m^3)**	**Percent of Base Case**	**Volume (m^3)**	**Percent of Base Case**
Base case	32904428	-	35257994	-	38531628	-
Crop change only	31165956	95%	33453385	95%	36531092	95%
Irrigation efficiencies only	30611553	93%	32797287	93%	35839944	93%
Soil improvement only	30863940	94%	33090416	94%	36198949	94%
Management improvement - before	33007217	100%	35368029	100%	38651465	100%
Management improvement - after	32713961	99%	35052380	99%	38306195	99%
Maximum potential benefit	27091245	82%	29088708	83%	31793078	83%

* Only the currently cropped and irrigated areas were modeled; demand under the buildout scenario were not modeled, but the percentage increase would be comparable to the numbers provided in Table 4-2.

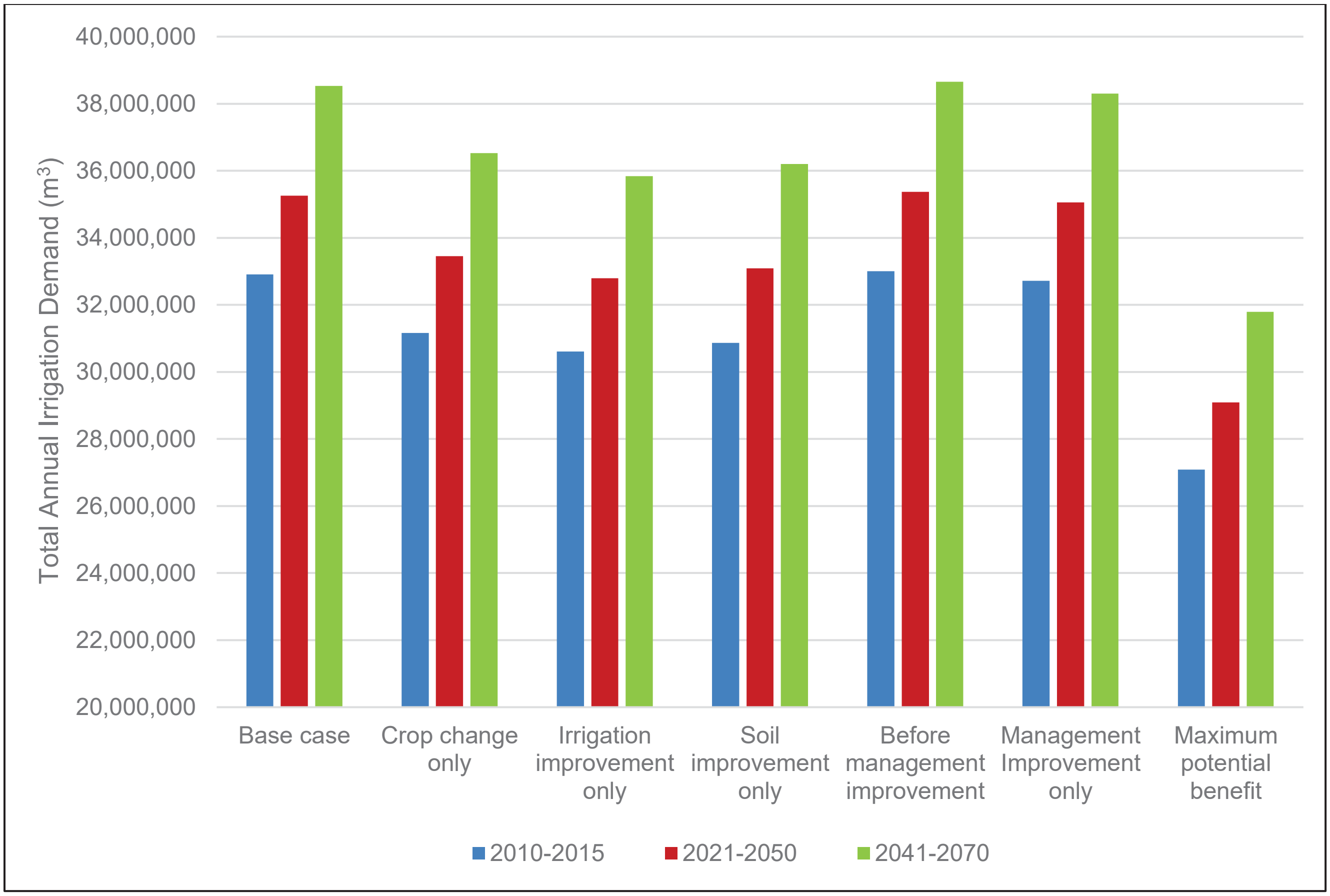

Figure 4-2
Predicated average change in total irrigation volume if water conservation methods are implemented

Table 4-4
Projected change in average irrigation equivalent depth (mm) if water conservation methods are implemented

Time Period	2010-2015		2021-2050		2041-2070	
Scenario	Equivalent Depth (mm)	Percent of Base Case	Equivalent Depth (mm)	Percent of Base Case	Equivalent Depth (mm)	Percent of Base Case
Base case	726	-	778	-	850	-
Crop change only	688	95%	738	95%	806	95%
Irrigation improvement only	675	93%	724	93%	791	93%
Soil improvement only	681	94%	730	94%	799	94%
Before management improvement	728	100%	780	100%	853	100%
After management improvement	722	99%	773	99%	845	99%
Maximum potential benefit	598	82%	642	83%	701	83%

Figures 4-3 and 4-4 show the projected variations in irrigation water demand from 2010-2070 using output from the ACCESS 1-0 model and RPC 4.5, and examples of the modelled trend over that period. Figure 4-3 compares the base case to what would happen if the irrigation system improvements and crop changes were to occur. By 2070, the irrigation improvements would save about 4 million m^3/year compared to the base case, and the crop changes could save about 3 million m^3/year. Figure 4-4 compares the base case to the maximum potential benefit, where by 2070 the difference is about 8 million m^3/year. Table 4-5 compares the median, maximum and minimum base case estimates and shows the maximum volume of irrigation water that can be achieved, which is about 16% of the base case volume.

Table 4-5
Comparison of base case and maximum benefit irrigation demand: 2020 to 2070

	Base Case	Maximum Benefit	Maximum Water Savings	% of Base Case
Median	39128683	32700879	6427804	16%
Maximum	48761307	40298975	8462332	17%
Minimum	28374645	23207339	5167306	18%

The conservation modelling results presented in this section are intended to serve as examples of the types of water savings that are possible, based on realistic estimates of changes in agricultural practices over the whole Similkameen watershed. As implementation of the SWP moves forward, the model can be used to predict water demand for specific areas (farm scale or larger) or sub-basins of interest. For example, if there is increased demand for irrigation water in the Keremeos Creek watershed, the model can be used to assess to what degree conservation can reduce current use in the sub-basin and thereby create “new” supply.

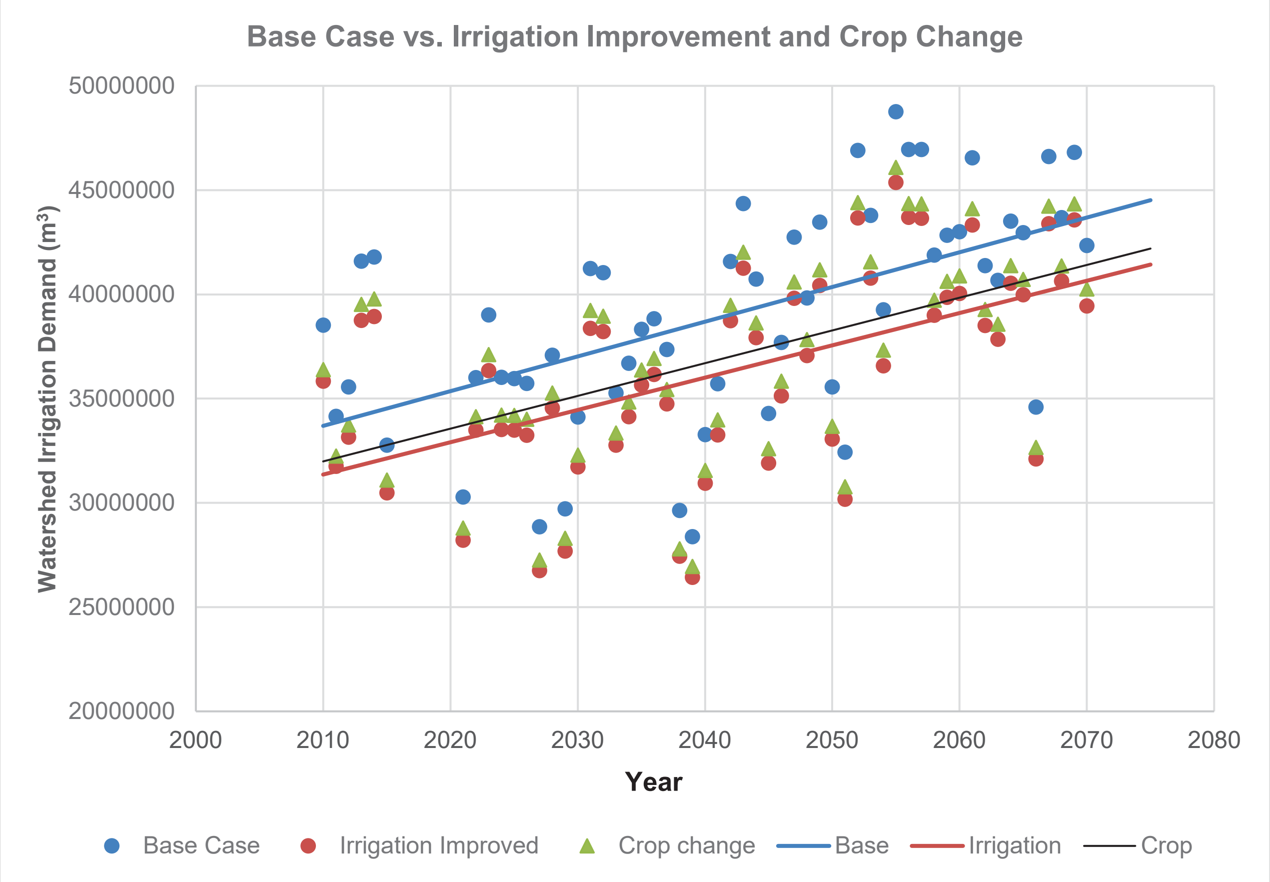

Figure 4-3
Annual base case irrigation demand compared to irrigation improvements and crop change scenarios: 2010-2070

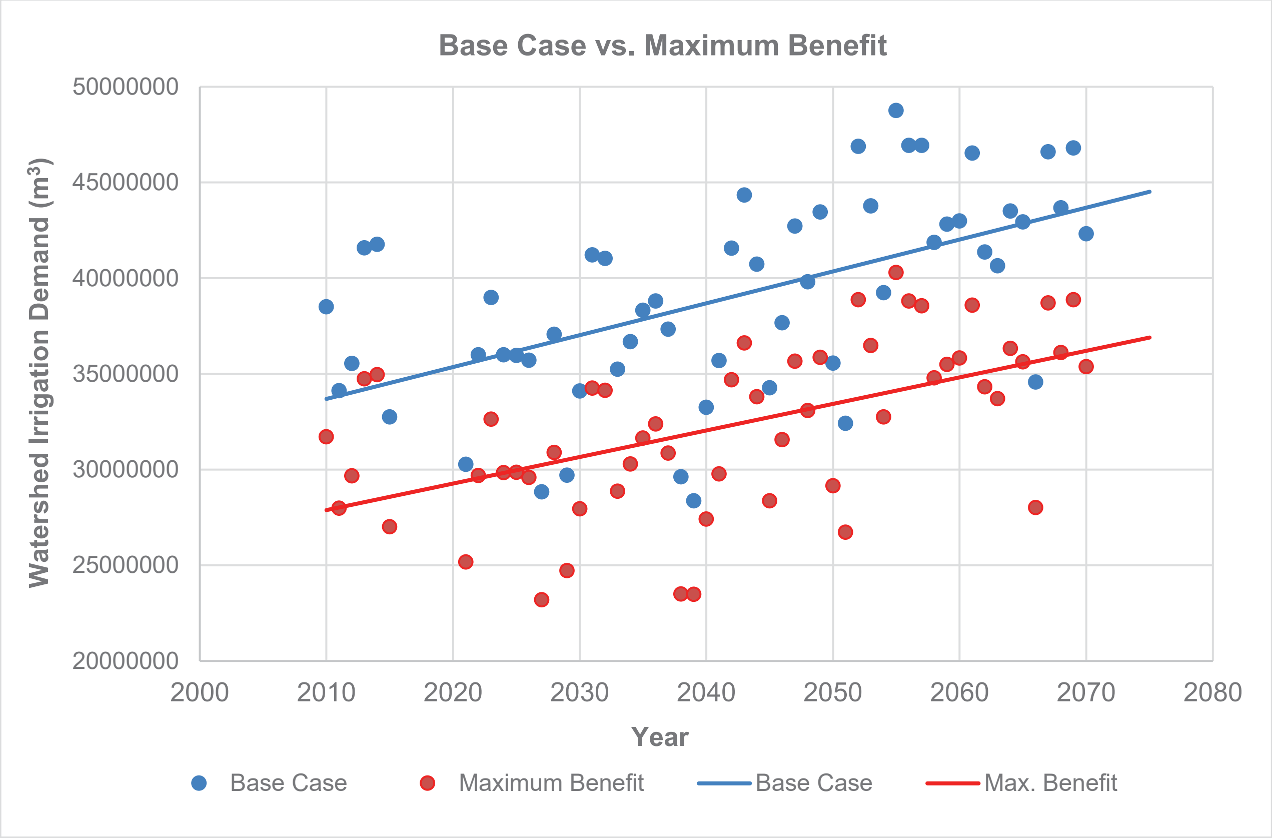

Figure 4-4
Annual base case irrigation demand compared to maximum benefit scenario: 2010-2070

4.4 DISCUSSION – HOW COULD WATER DEMAND CHANGE WITH RESPECT TO SUPPLY

The major findings of the modelling exercises completed by AAFC (Bakker et al. 2015) and specifically for this report (Section 4.3.2) are summarized as follows:

- Over the 2000-2100 (100 year) time frame, the IWD is expected to increase by 33% in the Similkameen Valley under the RCP4.5 emission scenario and by 48% under the RCP8.5 emission scenario.
- AAFC used five different climate models. The results were relatively consistent between models, with a CV of 14% for both RCP emission scenarios. This indicates broad agreement among the different models that irrigation demand will increase by a significant amount.
- At present, not all the land that could reasonably be used for agriculture is being used. If irrigated agriculture were to expand into those areas with suitable soils and proximity to water sources, the effect would be an increase in IWD of 31–32% under both RCP emission scenarios.

- If both climate change and the buildout were to occur, the increases in IWD would be 48% and 60% under the RCP4.5 and RCP8.5 emission scenarios, respectively.
- To date, farmers in the Similkameen Valley have been gradually adopting some conservation measures, especially in the grape and tree fruit sectors. However, there is room for greater adoption of water conservation methods.
- Modelling of the effects of conservation methods (i.e., change in crops, improved irrigation system efficiency, soil management, and overall better irrigation management) shows that individually these methods would result in only a modest reduction in irrigation demand at the watershed scale:
  - Crop change – about 5% reduction
  - Irrigation system changes – about 7% reduction
  - Soil improvements (organic matter addition) – about 6% reduction
  - Irrigation management – about 1% reduction
- The volume of water that could be saved would help offset the increased demand from climate change up until about the 2030s (Table 4-3), but would not offset the increased demand beyond that.
- If all four conservation methods were adopted according to the scenario that was assessed, the reduction in overall water demand would be significant at about 17-18% (the maximum benefit in Tables 4-3 and 4-4).

It is important to note that the above points apply to the entire irrigated part of the Similkameen Valley, and are based on estimates of how many farm owners would choose to make adjustments to soil and water management practices. At the farm scale, there is the potential for conservation technologies to make a significant reduction in water use. In addition to helping to keep within an individual's licenced water allocation, conservation technologies would help to better prepare for drought conditions when irrigation volumes could be restricted by order of the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) under the BC *Fish Protection Act* (Section 9).

Phase 1 of the SWP (Summit 2014) included a summary of the climate change projections that were made by the Columbia Basin Climate Change Scenarios Project (CBCCSP), documented in Hamlet et al. (2010). The CBCCSP includes future projections for a selection of hydro-climatic parameters including streamflow (runoff), peak flow, and low flow. Climate change projections were provided for many locations in the Columbia River Basin including seven sites in the Similkameen River watershed that correspond to these Water Survey of Canada hydrometric station locations:

- Pasayten River above Calcite Creek;
- Similkameen River at Princeton;
- Tulameen River at Princeton;
- Similkameen River near Hedley;
- Ashnola River near Keremeos;
- Similkameen River near Nighthawk; and
- Similkameen River at Oroville.

Examples of the model projections for Similkameen River near Nighthawk were provided in the Phase 1 report, and are summarized here to provide an indication of how the projected changes in IWD compare to the changes in streamflow that could be happening at the same time. Tables 4-6 to 4-8 show projections for the following three parameters: total streamflow (dam^3), peak flows (m^3/s), and low flows (m^3/s). The tables are reproductions of those presented by Summit (2014) and were derived from a 10 GCM model ensemble, under two emission scenarios for the periods centering on the 2020s, 2040s, and 2080s. They are compared to the baseline period of 1970-1999. Note that the climate models, time periods, and emission scenarios used by the CBCCSP are not the same as those used by the AWDM herein (Section 4.3), so care should be taken when comparing the results.

The following points summarize the general trends predicted for the Similkameen region:

Streamflow:

- Late fall, winter and early spring flows are forecast to be greater; while late spring, summer and early fall flows will be smaller;
- Shift in hydrograph to earlier in the year; and
- Total flows for the year increase.

Daily Peak Flows:

- Similkameen River near Nighthawk (US border) - average peak flows decrease under both carbon emissions scenarios; and
- Range of daily peak flow projections is considerable (i.e., ranges from less to greater than simulated baseline flows [1970-1999]).

Low Flows:

- Late summer/early fall low flows decrease, winter low flow flows increase.

Snow Water Equivalent (SWE):

- Average SWE predicted to decrease in all periods under both scenarios.

Table 4-6 shows that for all July and August scenarios modelled by CBCCSP, the average monthly runoff in the Similkameen River at the US border is projected to be notably less than the baseline situation (1970-1999):

- The average July runoff could decrease to 68% (2020s), 53% (2040s), and 35% (2080s) compared to baseline;
- The average reduction in August runoff is less severe, but is still 78% (2020s), 72% (2040s), and 63% (2080s) of baseline;
- The changes in the 10-year runoff minimums indicate very significant reductions, going from 44% of baseline in the 2020s down to 24% in the 2080s for July. Again, the drops in August are not as much but still show much lower minimum runoff values, becoming only about half of the baseline runoff by the 2080s.
- The more significant reduction in July runoff is because the annual freshet is expected to begin and be completed earlier.

- The reductions in runoff in average years suggest major challenges in balancing water supply needs in the Similkameen Valley, and the projected future changes in runoff in low flow years are even more severe.
- Outside of irrigation seasons, it is important to note that runoff is expected to increase. For example, average flows in February could be 24% greater in the 2020s, 58% greater in the 2040s, and 147% greater in the 2080s.
- Over the whole year, the average increases offset the decreases by a small amount – about +2% in the 2020s to about +9% in the 2080s. However, in dry years the dry season reductions offset the wet season increase (total is 70-80% of baseline). Nevertheless, the shift in monthly runoff volumes (less river runoff June-October, more during rest of year) points to the importance of considering water storage in the Similkameen to augment water supply during the irrigation season (see Section 7 for recommended directions for planning).

When comparing the IWD projections in Sections 4.3.1 and 4.3.2 to the projected changes in runoff, **it is apparent that the irrigation demand is expected to go up during the same critical July to September period when streamflows are expected to go down**, with the imbalance being greater during dry years. Note that the streamflow modelling incorporates changes in evapotranspiration in the watershed, so the predicted lower monthly runoff values partly reflects the changes in demand. Most of the reduction is related, however, to watershed-scale changes. Because the groundwater system in the valley is connected closely with surface water, the effect of lower surface runoff would also affect groundwater levels and recharge processes. The overall expectation is that water supply in summer for all uses will increasingly be constrained. The adoption of conservation technologies is likely to grow in importance for agriculture, but may not be sufficient without other tools like new upstream storage.

The potential benefits and costs of storage for agriculture and for environmental flow needs should be explored further during implementation of the watershed plan. As noted in the Phase 1 report, several public agencies and private companies have examined options for creating and managing storage in the Canadian portion of the Similkameen River watershed. Fortis Inc. has an active application for a storage water licence for 370,044,000 m^3/year for a site upstream of Princeton[8]. In about 2012-2013 Fortis evaluated the feasibility of a hydro-power facility with storage, but elected not to proceed. There are several other storage licences in the watershed, but they are comparatively small (Summit 2014). Although assessments of storage options have been assessed in the past, an overview-level update would be valuable because previous studies would not have considered climate change forecasts and recent legislation like the *Fish Protection Act* and *Water Sustainability Act*.

---

[8] Licence no. Z103235. Water licence query completed July 11, 2017. Fortis also has applied for a licence for hydro-power generation for 33.98 m^3/s. http://a100.gov.bc.ca/pub/wtrwhse/water_licences.input.

Table 4-6
Similkameen River near Nighthawk: projected future average monthly runoff (source: Hamlet et al. 2010)

nario	A1B									B1							
orical ulated umes	2020s			2040s			2080s			2020s			2040s			20	
0-99)	Ratio			Ratio			Ratio			Ratio			Ratio			Ra	
am^3	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	M
,593	0.996	0.805	1.143	1.029	0.85	1.315	1.051	0.799	1.392	0.983	0.872	1.045	0.999	0.738	1.151	1.013	0.8
,995	1.115	0.866	1.316	1.299	1.075	1.737	1.593	1.017	2.247	1.111	0.915	1.3	1.185	0.924	1.619	1.42	1.0
,961	1.18	0.899	1.448	1.448	1.12	1.809	2.118	1.423	3.026	1.133	0.975	1.399	1.274	0.888	1.649	1.705	1.2
,230	1.207	0.911	1.609	1.531	1.094	2.2	2.436	1.437	4.062	1.144	0.976	1.336	1.317	0.924	1.669	1.785	1.2
774	1.243	0.964	1.538	1.576	1.157	2.05	2.472	1.493	3.739	1.236	0.993	1.814	1.371	0.967	1.733	1.994	1.2
,484	1.281	1.021	1.591	1.542	1.139	1.939	2.287	1.403	3.025	1.261	1.055	1.577	1.379	1.015	1.68	1.898	1.1
,207	1.303	1.019	1.665	1.49	1.187	1.929	1.743	1.455	2.225	1.296	1.018	1.466	1.396	1.139	1.892	1.662	1.2
,940	1.123	1.032	1.253	1.167	1.007	1.406	1.018	0.589	1.44	1.109	1.014	1.397	1.124	1.002	1.393	1.115	0.9
,865	0.913	0.681	1.031	0.815	0.467	1.008	0.543	0.221	0.994	0.914	0.755	1.046	0.852	0.683	1.02	0.695	0.3
,685	0.682	0.444	0.81	0.529	0.304	0.696	0.352	0.24	0.453	0.711	0.562	0.83	0.618	0.445	0.837	0.451	0.
,261	0.782	0.738	0.871	0.719	0.613	0.863	0.627	0.533	0.805	0.818	0.684	0.937	0.753	0.655	0.882	0.689	0.6
,295	0.902	0.78	1.085	0.847	0.692	1.02	0.831	0.654	1.15	0.91	0.754	1.078	0.871	0.694	1.03	0.85	0.7
ar)	1.061	0.847	1.280	1.166	0.892	1.498	1.423	0.939	2.047	1.052	0.881	1.269	1.095	0.840	1.380	1.273	0.9
ril -)	0.951	0.782	1.119	0.928	0.712	1.154	0.852	0.615	1.178	0.960	0.798	1.126	0.936	0.770	1.176	0.910	0.7

s = more water forecasted and ‘red’ values = less water forecasted for irrigation season (April to September).

Table 4-7
Similkameen River near Nighthawk: projected daily flood statistics (source: Hamlet et al. 2010).

Emission Scenario		**A1B**									**B1**								
Recurrence Interval (years)	**Historical Simulated Peak Flow (1970-99)**	**2020s**			**2040s**			**2080s**			**2020s**			**2040s**			**2080s**		
		Ratio			Ratio			Ratio			Ratio			Ratio			Ratio		
	m^3/s	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
20	760	0.981	0.895	1.049	0.991	0.890	1.163	1.040	0.878	1.328	0.967	0.868	1.081	0.966	0.834	1.089	0.983	0.884	1.105
50	832	0.976	0.889	1.038	0.987	0.898	1.159	1.055	0.878	1.352	0.966	0.860	1.079	0.964	0.829	1.079	0.986	0.878	1.101
100	879	0.972	0.876	1.037	0.986	0.904	1.157	1.068	0.877	1.370	0.966	0.853	1.101	0.963	0.827	1.073	0.989	0.873	1.099

Note: Under both scenarios, the *average* peak flows are not expected to change significantly, but the change in maximum peak flow is considerable (e.g. about +16% by 2040s and +35% by 2080 under Emission Scenario A1B).

Table 4-8
Similkameen River near Nighthawk: projected 7Q10 low flow statistics (source: Hamlet et al. 2010)

Emission Scenarios		**A1B**									**B1**								
Recurrence Interval (years)	**Historical Simulated Low Flow (1970-99)**	**2020s**			**2040s**			**2080s**			**2020s**			**2040s**			**2080s**		
		Ratio			Ratio			Ratio			Ratio			Ratio			Ratio		
	m^3/s	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
7Q10	24	0.994	0.932	1.068	0.992	0.916	1.053	0.962	0.878	1.033	1.012	0.949	1.096	0.998	0.887	1.090	0.992	0.919	1.094

Note: Under both scenarios, the average monthly flows in the winter are expected to increase, but the 7Q10 flows are not expected to change significantly. However, the range of low flows is considerable.

5 Cumulative Effects of Forest Disturbance & Climate Variability on Water (UBCO)

Dr. Adam Wei and Dr. Qiang Li of University of British Columbia Okanagan (UBCO) completed a recent assessment of the cumulative effects on forest disturbance and climate variability in the Similkameen watershed (Wei and Li 2016). This section provides a summary of their findings, drawn from the executive summary.

Forest cover change and climate variability are recognized as two major drivers influencing water resource change in forested watersheds. In the Similkameen there is concern over the effects of recent mountain pine beetle (MPB) infestation and climate change on water resource sustainability in the watershed. To address this concern, RDOS contracted UBCO to investigate the possible effects of forest disturbance and climate variability on hydrology in the watershed.

Until the year 2011, the cumulative equivalent clear-cut area (CECA) reached 45.5% of the Similkameen River watershed. Logging accounted for 18.6% and the recent major MPB infestation, which began in 2003, accounted for approximately 22.6% in 2011. Forest fires occurred occasionally and the resulting CECA was about 0.8% in 2011. In addition, forest disturbance in three nested sub-watersheds including Similkameen River at Princeton (SRP: 1810 km^2), Tulameen River (1780 km^2), and Similkameen River near Hedley (SRH: 5580 km^2) are 37.1%, 36.7%, and 55.7% of the respective watershed areas. In summary, the whole Similkameen River watershed is judged to be “heavily disturbed” (Wei and Li 2016).

Wei and Li (2016) then examined the impacts of forest disturbance on annual mean flows in those three sub-watersheds, which was possible because of the availability of long-term hydrology and disturbance data. Two commonly used methods including modified double mass curves (MDMC) and sensitivity-based methods, along with various other statistical analyses, were employed for this study. Wei and Li’s (2016) results showed that forest disturbance increased annual mean flows of 22.15 mm in the SRP watershed, 21.53 mm in the Tulameen River watershed, and 17.37 mm in the SRH watershed. The relative contributions of forest disturbance to the annual mean flows were 47.70%, 54.89%, and 47.49% in the SRP, Tulameen River, and the SRH watersheds, respectively, demonstrating that forest disturbance and climate variability played a co-equal role in annual mean flow changes, but in opposite directions. Forest disturbance increased annual mean flows, while climate variability decreased them. The impacts of forest disturbance on annual mean flows were greater than those from climate variability in the Tulameen River watershed. In contrast, climate variability played a more dominant role than forest disturbance in the SRP and SRH watersheds. Thus, the authors concluded that forest disturbance and climate interactively and significantly affected annual mean flows in terms of both magnitude and direction in all three selected watersheds.

The effects of forest disturbance on high flows were also assessed in those three watersheds. Wei and Li’s time series cross-correlation tests showed that forest disturbance significantly increased high flows in the SRP and SRH watersheds, while no significant correlations were detected in the Tulameen

River watershed. Wei and Li's further analyses using the paired-year approach revealed that high flows in the disturbance periods were 13.7% and 11.0% higher than those in the reference periods in the SRP and SRH watersheds, respectively. In summary, forest disturbance has significantly increased high flows in the SRP and SRH watersheds, which may have significant implications for managing floods and protecting public safety.

Wei and Li (2016) also sought to predict how forest disturbance and climate change may affect future water resource in the study watersheds. Two greenhouse emission scenarios (RCP4.5 and RCP8.5) from the average of six General Circulation Models were used to define future climate trends from 2020 to 2050 in the three study watersheds. The average precipitation does not show a significant trend, while the temperature indicates an increasing trend for each scenario. For example, the increased rate of annual mean temperatures in RCP4.5 and RCP8.5 are 0.037 ºC/year and 0.045 ºC/year in the SRH watershed. Wei and Li's (2016) preliminary simulations show that future annual mean flows are likely to decrease in all three study watersheds. Forest disturbance might alleviate water stress in terms of annual mean flows in the SPR and Tulameen River watersheds to some extents, but it may play a limited role in the SRH watershed.

According to Wei and Li (2016), the Similkameen River watershed is currently facing water stress, especially in dry seasons. Under a drier climate in the future, this situation would become even more severe. Even though forest disturbance would increase water availability in terms of annual mean flows, it may not be a good tool to alleviate the effects of future climate changes as forest disturbance has negative impacts on other hydrological variables (e.g. high flows) and various ecosystem functions. Nevertheless, the key findings from this study will provide regional resource managers with useful information on how forest disturbance and climate interactively affect water resource availability so that they can make better decisions to manage water resources sustainably under future forest and climate changes scenarios.

The key recommendations made by Wei and Li (2016) are:

- Further evaluate effects of forest disturbance on low flows, considering information on irrigation demand and actual use collected for the Similkameen Watershed Plan (including this report);
- Carry out a more detailed study of cumulative effects of forest disturbance and climate change using a process-based mathematical model; and
- Carry out additional process-based studies such as groundwater-surface water interaction to augment the statistical analyses in Wei and Li's (2016) report.

6 Groundwater Quality Assessment

6.1 SUMMARY OF EXISTING INFORMATION

Based on the results of previous SWP phases, little was known before 2016 about groundwater quality in aquifers in the Similkameen watershed. To address this data gap, Associated completed a review of the provincial water quality database to obtain existing data and identify areas without groundwater quality data, and completed a groundwater sampling program to address those data gaps.

6.1.1 Hydrogeological Setting

Aquifer mapping by the MOE identifies 17 aquifers within the Similkameen watershed. These aquifers are listed and their properties summarized in Table 6-1. The two largest are Aquifer 259 and Aquifer 1024. Aquifer 259 is the primary aquifer used for water supply. It is located in the valley bottom, extending from Princeton to the U.S. border. The mapped aquifer length is approximately 94 km with a spatial extent of 120 km^2. The aquifer is bounded on the edges by bedrock fractured aquifers with steep gradients. Aquifer 1024 is a bedrock aquifer in the Princeton area. Of the 17 identified aquifers, 11 (65%) are unconfined with high hydraulic permeability and moderate to high yields. They are also mostly connected to the Similkameen River.

6.1.2 Available Groundwater Quality Data

Associated searched the BC Environmental Monitoring System (EMS) for available groundwater data within the Similkameen watershed (MOE 2016a). The EMS indicates there are 59 EMS sites that have been sampled for groundwater quality at least once. The date of that available data ranges from 1984 to 2016. Over half of the EMS sites are located in the vicinity of the Nickel Plate Mine, and the remaining EMS sites are generally in the Princeton, Keremeos, and Cawston areas.

With the exception of Observation Wells, the EMS sites generally represent locations that are authorized to discharge some form of treated effluent under a permit issued by MOE. The goal of this project is to assess general groundwater quality throughout the watershed, rather than localized variations. Therefore, EMS data were only used for sites that are not associated with a permitted activity or that represent an assumed upgradient sample (i.e., background) for a permitted activity. Table 6-2 lists those selected EMS sites, their location, the number of samples collected, and the years for which there are available data. All the sites in Table 6-2 are groundwater wells that were installed in Aquifer 259.

Table 6-1
Key mapped aquifers in the Similkameen watershed

Aquifer Number	Aquifer Location	Aquifer Type	Aquifer Materials	Productivity	Vulnerability	Demand	Area (km^2)
1024 IIB (12)	Princeton	Confined	Bedrock	Moderate	Moderate	Low	122.3
259 IIA (14)	Similkameen River Aquifer	Unconfined	Sand and Gravel	High	High	Moderate	120.0
1026 IIB (8)	Hayes Creek, N of Finnegan Creek	Confined	Bedrock	Low	Moderate	Low	22.5
1031 IIB (9)	Hayes Creek south of Trehearne Creek	Confined	Bedrock	Low	Moderate	Low	14.3
1029 IIA (13)	North of Princeton	Unconfined	Gravel	High	High	Moderate	8.2
258 IIC (10)	Richter Pass (near U.S border)	Unconfined	Sand and Gravel	Moderate	Low	Moderate	7.6
1028 IIA (12)	Confluence of Hayes and Siwash Creeks	Unconfined	Gravel	Moderate	High	Moderate	7.0
935 IIB (12)	Keremeos Creek Valley	Unconfined	Sand and Gravel	High	Moderate	Moderate	5.2
937 IIB (9)	Keremeos Creek Valley	Confined	Bedrock	Low	Moderate	Moderate	4.7
1027 IIC (7)	Chain Lake	Confined	Bedrock	Moderate	Low	Low	1.8
1012 IIA (10)	Riddle Mountain, SE slope	Confined	Bedrock	Moderate	High	Moderate	1.2
1010 IA (11)	Tulameen	Unconfined	Sand and Gravel	Moderate	High	High	0.9
1011 IIA (10)	Coalmont, 5 km SE of Tulameen	Unconfined	Sand and Gravel	Moderate	High	Moderate	0.9
1025 IIB (10)	Allison Lake	Unconfined	Sand and Gravel	Moderate	Moderate	High	0.9
1030 IIB (9)	12km North of Princeton	Unconfined	Sand and Gravel	Moderate	Moderate	Moderate	0.8
1013 IIA (10)	Otter Lake, NW shoreline	Unconfined	Gravel	Moderate	High	Moderate	0.6
1033 IIC (9)	Chain Lake	Unconfined	Sand and Gravel	Moderate	Low	High	0.4

Table 6-2
Summary of available groundwater data from existing EMS sites

EMS ID	EMS Name	General Location	Aquifer Number	Number of Samples	Years
E258960	Princeton Tulameen Well	Princeton	259	2	2005
E258958	Princeton Memorial Park Well		259	2	2005
1401423	Observation Well 220		259	3	1987–2001
E296194	Central City Foundation[1]	Between Hedley and Keremeos	259	6	2014–2016
E251772	RDOS Keremeos Landfill Well[2]	Keremeos	259	14	2003–2015
1401030	Observation Well 75		259	6	1987–2010
1401031	Observation Well 76		259	4	1991–2010
1401032	Observation Well 77		259	1	2010
1401377	Observation Well 203	Cawston	259	3	1987–1994

Notes:
[1] The Central City Foundation is authorized to discharge treated effluent to ground and has a total of four EMS groundwater sites. EMS E296194 was selected for data analysis because it is reportedly upgradient.
[2] There are four EMS groundwater sites registered under the Keremeos Landfill. EMS E251772 was selected for data analysis because it is reportedly cross-gradient to the landfill, based on local topography.

6.2 2016 GROUNDWATER SAMPLING PROGRAM

The available EMS data primarily covered locations within Aquifer 259 in the Princeton and Keremeos areas. In October and November 2016, Associated staff visited eight properties throughout the watershed and collected 10 groundwater samples to improve the spatial coverage of the existing data. Primary areas of interest included sand and gravel Aquifer 1029 (north of Princeton), the Coalmont area (no mapped aquifer), Aquifer 259 between Princeton and Keremeos, and Aquifer 259 between Cawston and the Canada-U.S. border. Groundwater samples were collected from the locations listed in Table 6-3, following the methods described in the British Columbia Field Sampling Manual (MWLAP 2013).

Table 6-3
2016 groundwater sampling locations and descriptions

Sample Location ID	Well Type	Approximate Well Depth	Aquifer and Location Description
2016-02	Drilled well	53.3 m[A]	Aquifer 259, between Cawston and the Canada-U.S. border (approximately 4 km north of the border). The available well log for the drilled well shows unconsolidated material until approximately 83 m, and the water level is similar to the level in the river.
2016-03	Dug well	6.7 m[A]	
2016-04	Dug well	6.1 m[B]	Aquifer 259, between Cawston and the Canada-U.S. Border (approximately 10 km north of the border).
2016-05	Drilled well	50–60 m[C,D]	
2016-07	Drilled well	14 m[B]	Aquifer 259 in Cawston, near the Similkameen River.
2016-08	Drilled well	25 m[B]	Aquifer 259 in Cawston, near Manuel Creek
2016-09	Drilled well	25–35 m[D]	Aquifer 1029 – well owner reported well installed in sand and gravel (approximately 7 km north of Princeton).
2016-10	Drilled well	24 m[B]	Approximately 13 km north of Tulameen (no mapped aquifer, but local well logs indicate the presence of a sand and gravel aquifer).
2016-11	Drilled well	11 m[B]	Aquifer 259, approximately 11 km east of Princeton.
2016-12	Drilled well	20–25 m[D]	Aquifer 259, approximately 12 km southeast of Hedley.

Notes:

[A] Well depth taken from well log.

[B] Approximate well depth provided by well owner.

[C] Well is presumed to be in the sand and gravel. Based on its depth it could be installed in bedrock; however, the well owner did not think that was the case.

[D] Well depth estimated based on nearby well logs in the BC Water Resource Atlas and discussions with well owners.

The samples were analyzed for variables of interest to agriculture and for general water quality, including phosphorus (dissolved and total), nitrogen (including nitrate, nitrite, ammonia, organic nitrogen, and total nitrogen), pH, conductivity, salinity, chloride, sodium, calcium, magnesium, potassium, sodium adsorption ratio (SAR), sulphate, total dissolved solids (TDS), dissolved metals, total coliforms, and *E. coli*. A duplicate sample (2016-05 and 2016-06) was collected at one well to assess quality assurance and quality control (QA/QC). The results were tabulated and compared with the BC Approved and Working Water Quality Guidelines for irrigation, livestock, and drinking water (MOE 2015, 2016b) and the Guidelines for Canadian Drinking Water Quality (Health Canada 2017).

Figure 6-1 shows the locations of the sites listed in Table 6-2 and 6-3, which were used for the groundwater quality assessment.

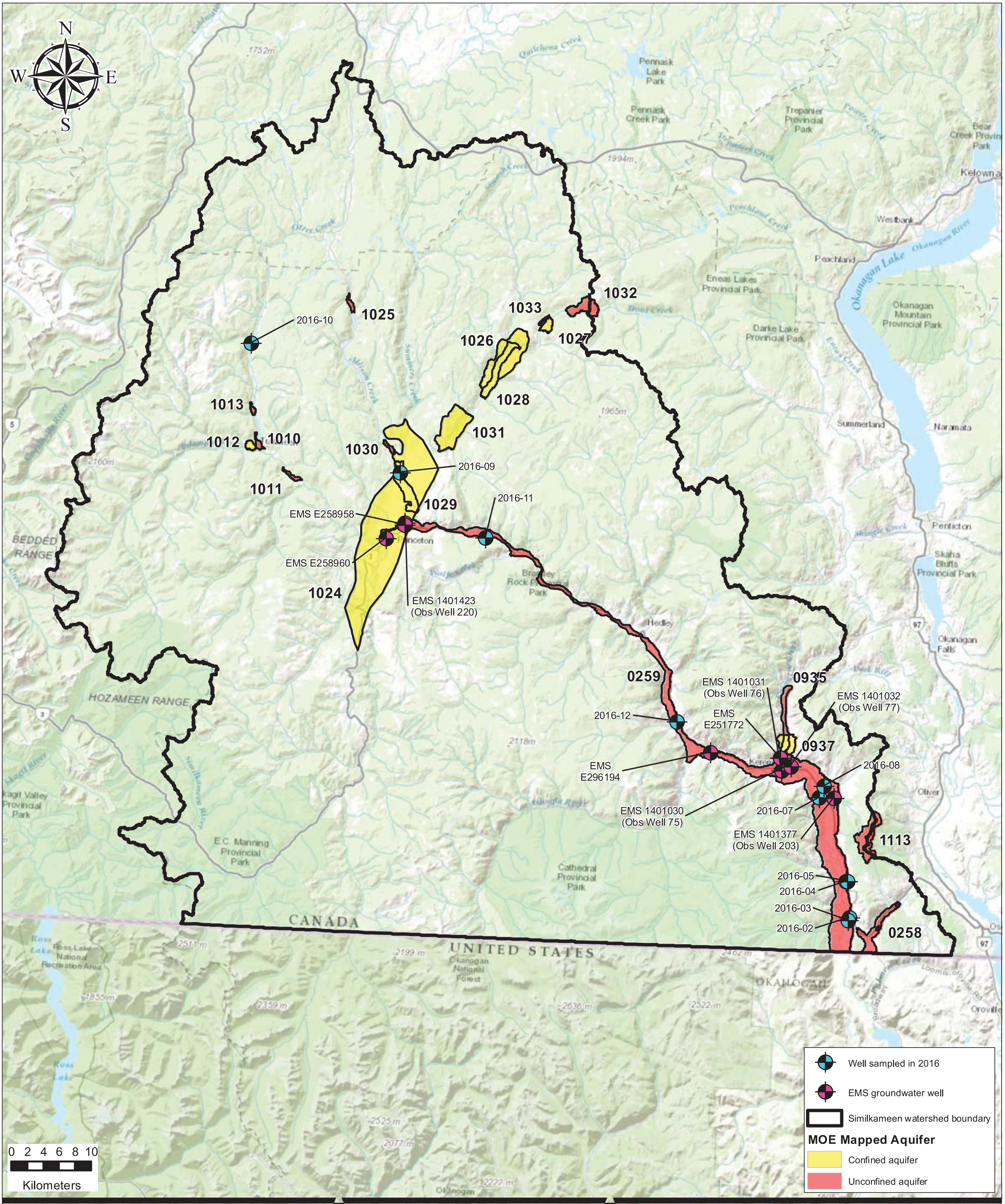

Fig 5-1.mxd / 12/22/2016 / 9:08:19 AM

Associated Environmental

PROJECT NO.: 2016-8063.000.003
DATE: Dec 2016
DRAWN BY: DA

FIGURE 6-1: GROUNDWATER QUALITY SITES

Regional District of Okanagan Similkameen

Similkameen Valley Watershed Plan Phase 2

6.3 COMPARISON OF GROUNDWATER QUALITY DATA WITH GUIDELINES

Table 6-4 lists the concentrations of key water quality parameters from the data collected by Associated in 2016 (the ‘2016 sites’). A complete list of all data, tabulated and compared with guidelines, is provided in Table B-1, Appendix B. Historical data from the EMS sites (‘the EMS sites’) listed in Section 6.1.2 were also compiled, tabulated, and compared with applicable guidelines (Table B-2, Appendix B). Laboratory reports from 2016 are provided in Appendix C.

Generally, the **groundwater quality appears to be good throughout the tested areas of the Similkameen watershed.** In both the 2016 sites and EMS sites, there were few exceedances of the applicable guidelines, and many of the exceeding parameters (e.g., TDS, metals, total coliforms) are commonly found at elevated levels in groundwater in BC. The following sections summarize key parameters and parameters that were found to exceed guidelines.

							North of Princeton	Northwest of Coalmont	East of Princeton	Southwest of Hedley	Cawston (near Similkameen River)	Cawston (near Manual Creek)	Between Cawston and Ca Border (approx. 10 km Border)	
						Date Sampled	09-Nov-16	09-Nov-16	09-Nov-16	09-Nov-16	12-Oct-16	12-Oct-16	12-Oct-16	12-Oct-16
Unit	**Guideline[1]**													
	BCAWQG I	BCWWQG I	*BCAWQG L*	*BCWWQG L*	GCDWQ MAC	GCDWQ AO								
mg/L	100	NG	600	NG	NG	250	8.92	0.71	5.37	3.07	7.85	7.19	6.55	2.66
µS/cm	NG	700	NG	NG	NG	NG	440	143	232	241	330	489	1060	1390
mg/L	NG	NG	NG	NG	NG	NG	205	58.2	98.6	103	143	225	556	680
	5.0 - 9.0	NG	5.0 - 9.5	NG	NG	7.0 - 10.5	7.79	7.35	7.75	7.77	7.64	7.90	7.70	7.77
	NG	NG	NG	NG	NG	NG	0.2	<0.1	0.1	0.1	0.2	0.2	0.6	0.7
	NG	NG	NG	NG	NG	NG	0.3	0.2	0.2	0.3	0.2	0.5	0.4	0.7
mg/L	NG	NG	1000	1000	NG	500	35.2	14.5	13.6	18.1	30.1	64.3	401	665
mg/L	NG	500	NG	1000	NG	500	252	83	130	147	205	299	804	*1170*
mg/L	0.1	NG	0.025	NG	0.01	NG	<0.0005	<0.0005	<0.0005	0.0012	0.0006	0.0014	0.0025	0.0065
mg/L	NG	NG	NG	NG	NG	0.3	<0.010	0.016	<0.010	<0.010	<0.010	<0.010	<0.010	0.233
mg/L	NG	NG	NG	NG	NG	NG	14.0	3.04	4.84	4.36	8.43	11.4	39.4	33.7
mg/L	NG	0.200	NG	NG	NG	0.05	0.0002	0.0111	<0.0002	<0.0002	0.0002	0.0925	0.0016	0.170
mg/L	0.05	NG	0.05	NG	NG	NG	0.0035	0.0004	0.0034	0.0012	0.0025	0.0020	0.0098	*0.0560*
mg/L	NG	NG	NG	NG	NG	NG	1.34	0.33	0.88	1.10	1.80	2.27	7.14	7.71
mg/L	NG	NG	NG	NG	NG	200	9.54	3.00	4.63	6.16	6.85	9.61	19.7	42.7
CFU/100 mL	385	NG	200	NG	0	NG	<1	<1	<1	<1	<1	<1	<1	<1
CFU/100 mL	NG	NG	NG	NG	0	NG	<1	<1	<1	<1	<1	<1	1	<1
mg/L	NG	NG	NG	NG	NG	NG	0.021	0.028	0.027	0.026	0.058	0.054	0.040	0.196
mg/L	NG	NG	100	NG	10	NG	0.162	0.051	0.200	0.188	0.784	0.060	0.434	<0.010
mg/L	NG	NG	10	NG	1	NG	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
mg/L	NG	NG	NG	NG	NG	NG	0.256	0.135	0.302	0.288	0.842	0.226	0.541	0.305
mg/L	NG	NG	NG	NG	NG	NG	0.009	0.011	0.006	0.007	0.010	0.011	0.022	0.021
mg/L	NG	NG	NG	NG	NG	NG	0.006	0.007	0.005	0.007	0.010	0.011	0.012	0.017

ess than reported detection limit
lo Guideline
lighlighted value exceeds the BC Approved Water Quality Guidelines for Irrigation (BCAWQG I)
lighlighted value exceeds the BC Working Water Quality Guidelines for Irrigation (BCWWQG I)
lighlighted value exceeds the BC Approved Water Quality Guidelines for Livestock (BCAWQG L)

6.3.1 Chloride, Sodium, Sulphate, and Total Dissolved Solids

Chloride, sodium, sulphate, and total dissolved solids are routinely tested in groundwater, and may be naturally sourced or indicate anthropogenic inputs. Chloride is a conservative ion, meaning that once it is dissolved in water it tends to stay in solution. It can result from agricultural or industrial activities, municipal wastewater, the application of road salt, and atmospheric deposition. Across all sites, chloride concentrations were low (<15 mg/L) compared to the most stringent of the applied guidelines (irrigation): 100 mg/L. Sodium, which can result from road salt, municipal wastewater, and industrial effluents, was also low (typically <20 mg/L; maximum 49 mg/L). The most stringent guideline is 200 mg/L (drinking water).

Sulphate concentrations, which can result from parent rock weathering, atmospheric deposition, mining operations, agricultural runoff, or municipal wastewater, vary throughout the watershed. Generally, based on the EMS and 2016 data, sulphate is lower in wells upstream of Keremeos (from 13.6 to 35.2 mg/L) than those found downstream (from 29.9 to 667 mg/L). At well 2016-05, which was sampled in 2016, the sulphate concentration (667 mg/L) exceeded the drinking water aesthetic objective of 500 mg/L. Intermediate levels of sulphate were found in Keremeos Well E251772 (average, 223 mg/L) and Observation Well 77 (average, 190 mg/L). These levels likely represent localized variations or connection with bedrock aquifers. TDS and conductivity were also elevated in wells 2016-04 and 2016-05 with respect to the other 2016 sites.

6.3.2 Nutrients

Nitrogen is one of the key indicators of potential effects on water from agriculture/livestock operations. The proportions of the different forms of nitrogen within the measured total nitrogen (i.e., organic nitrogen, nitrate-N, nitrite-N, and ammonium-N) can provide information on the proximity to sources of contamination, and help to evaluate the potential for the types of possible effects. In groundwater, nitrogen is most commonly found as nitrate-N.

Despite the prevalence of agricultural activities throughout the watershed, nitrate-N concentrations were generally below 1 mg/L. The highest nitrate-N concentration was in Keremeos Well E251772, which has an average nitrate-N concentration of 3 mg/L. This level is well within the applicable drinking water guideline of 10 mg/L, but is indicative of human-caused inputs (likely either from nearby agricultural activity or the landfill). For comparison, the most stringent of the applicable guidelines (drinking water) for nitrate-N is 10 mg/L. Nitrite-N was not detected. Ammonia-N was detected at each site but found in low concentrations, ranging from 0.021 mg/L (2016-09) to 0.196 mg/L (2016-05).

Total phosphorus ranged from 0.006 mg/L (2016-09) to 0.033 mg/L (2016-02). In the EMS sites, the highest average total phosphorus concentration was in Well E296194 at 0.05 mg/L. There are no guidelines for phosphorus in groundwater.

6.3.3 Dissolved Metals

Previous and current sampling and analysis for metals in groundwater has found several metals to be present at concentrations that are above guidelines:

- Manganese (dissolved) exceeded the drinking water guidelines (0.05 mg/L) in wells 2016-02, 2016-03, 2016-05, and 2016-08 and in a number of the EMS sites. This is a common finding in groundwater in BC.
- Iron (dissolved) was below guidelines in all 2016 groundwater samples, but has been reported as elevated in some of the EMS data. Exceedances of the drinking water guidelines for iron (0.30 mg/L) have occurred in Keremeos Well E251772 and all Observation Wells except 77. Observation Wells 75, 76, 203, and 220 have had concentrations of total iron greater than 10 mg/L (max 68.75 mg/L; Observation Well 75 in 2001), which is considered high. Although iron is often found above guidelines in BC, levels such as this are not common and could reflect either natural water-rock interaction or potentially an anthropogenic source.
- Molybdenum in well 2016-05 (0.0577 mg/L) exceeded the irrigation guideline of 0.05 mg/L, which is specific to forage crops. Given that it was below guidelines in all other wells, it is likely a localized effect. Molybdenum was also tested in several of the EMS sites, and never exceeded guidelines.
- Cadmium (total), chromium (dissolved and total), and lead (total) were detected above guidelines once in Observation Well 75, and lead (total) once in Observation Well 76. Chromium (total) was detected above guidelines twice in Observation Well 220. None of these parameters were above guidelines in the 2016 sites, and no other metals exceedances (with the exception of iron and manganese, as noted above) were recorded in the EMS sites. See Appendix B for the measured concentrations.

Dissolved arsenic was tested sporadically at the EMS sites and at all the 2016 sites. Although none of the measured concentrations exceeded the irrigation (0.100 mg/L), livestock (0.025 mg/L), or drinking water (0.010 mg/L) guidelines, there was a spatial trend in the 2016 sites. Dissolved arsenic was not detected in wells 2016-09 (North of Princeton), 2016-10 (North of Otter Lake), or 2016-11 (West of Princeton), but was detected in the remaining downstream 2016 sites. Dissolved arsenic was also detected in the Keremeos Well E251772 and Observation Wells 75, 76, and 77, but results never exceeded guidelines. The presence of arsenic in groundwater may be a legacy of mining activities, or may be naturally occurring in bedrock.

6.3.4 Bacteriological

Total coliform bacteria were detected in the two shallow dug wells that are located next to the Similkameen River (2016-03 and 2016-04). This suggests that these wells are hydraulically connected to the river. *E. coli* was not detected in any of the wells. In the EMS sites, total coliforms and *E. coli* were tested only in Well E296194 and Keremeos Well E251772, but were not detected.

6.4 GROUNDWATER CLASSIFICATION

Using data from the samples collected in 2016 and the data available from the EMS sites, groundwater types were classified using tri-linear diagrams (i.e., Piper, Extended Durov, and Stiff diagrams[9]), which provide six major ions or combinations of ions plotted onto one diagram (Hounslow 1995).

Because well logs were not available most of the sampled locations, we were not able to assess stratigraphic (i.e., with depth) differences in groundwater quality. Instead, this classification gives a general overview of spatial differences in water quality throughout the tested areas of the watershed. The assessment provides a single image of what groundwater quality looks like, despite samples being collected at different times. It was not intended to represent the evolution of groundwater over time due to intricate chemical reactions or anthropogenic changes.

6.4.1 Piper and Expanded Durov Diagrams

The Piper Diagram (Figure D-1, Appendix D) indicates that three different groundwater types are evident throughout the aquifers with water quality data. Six of the wells cluster within the left centre quadrant of the main diamond, indicating freshly recharged groundwater. Some mixing and ion exchange processes are also evident in samples that plot towards the centre and top quadrants of the diagram.

The Expanded Durov Diagram (Figure D-2, Appendix D) was used to define the groundwater types more precisely, and shows the three distinct groundwater types found in the aquifers throughout the area (Table 6-5). The different groundwater types are not confirmed to specific areas; rather, they are found throughout the aquifers. Therefore, the geochemical differences likely represent localized variations (either from variability in nearby bedrock or recharge from other aquifers).

---

[9] Diagrams were created using Windows Interpretation System for Hydrogeologists (WISH), Institute for Groundwater Studies (IGS), South Africa.

Table 6-5
Groundwater types, characteristics, and locations

Water Type	Water Type Characteristics	Wells and Locations
Calcium Bicarbonate	Typically, freshly recharged water from precipitation or surface water connected aquifers.	Observation Well 77, Observation Well 220, 2016-02, 2016-03, 2016-07 through 2016-12
Bicarbonate Magnesium or Calcium Magnesium	Indicates ion exchange where surface water is mixing with groundwater, which is to be expected due to the connection between the unconsolidated aquifers and the Similkameen River.	Observation Well 75, Observation Well 76, Observation Well 203, Keremeos (K251772)
Sulphate and/or Calcium	Indicates simple mixing and dissolution process where sulphate is being added, possibly associated from bedrock aquifers in the area.	Wells 2016-04 and 2016-05

6.4.2 Stiff Diagrams

The Stiff Diagrams (Figure D-3, Appendix D) are a way of plotting the major-ion composition of water to produce a symbol whose shape indicates the relative proportions of the different ions and whose size indicates total concentrations. It is particularly useful to show similarities and differences between different groundwater types[10] at a glance (Drever 1997). Well 2016-10 (northwest of Coalmont) and Observation Well 220 (Princeton) are typical of groundwater in direct connection with surface water. They have low TDS and concentrations of major ions, indicating short residence times in the aquifers and very little interaction with aquifer material. This is expected where aquifer discharge from the unconfined valley bottom aquifer occurs into the surface water during dry periods. During freshet, high river levels and losing stream conditions cause the adjacent aquifer to be recharged.

Out of the 16 wells assessed, four wells displayed a different geochemical signature: wells 2016-04, 2016-05, Keremeos (E251772), and Observation Well 77. These wells are likely associated with bedrock aquifers where the groundwater residence time is longer, and the water undergoes water-rock interactions. Alternatively, they are in zones where mixing between deeper unconsolidated material and recharge from bedrock aquifers occurs. The groundwater quality at site E251772 near Keremeos likely reflects a combination of bedrock and potential impact from the landfill. Observation Wells 75 and 77 have different signatures, with reduced calcium probably due to precipitation. There is insufficient information to determine what would cause this to occur. Both wells are more than 800 m away from the river, but are far apart from each other.

---

[10] Groundwater type refers to the major ionic composition of water found in a specific aquifer hosted by a specific geological formation and yields some information on residence time and water-rock (material) interaction, typically surface water flow is too high to have significant water-rock interaction and ionic concentrations are low.

In general, the Stiff diagrams show freshly recharged groundwater with some mixing, but the wells are likely connected to the surface water environment to a large extent. Bedrock wells show a large proportion of sulphate. Usual sources of sulphate in bedrock are the minerals pyrite, gypsum, and anhydrite (Hounslow 1995).

6.4.3 Sodium Adsorption Ratio

The sodium adsorption ratio (SAR) of groundwater measures the degree to which sodium replaces calcium and magnesium in soil clays when groundwater is applied as irrigation water. This process damages the soil structure (Hounslow 1995). The SAR Diagram (Figure D-4, Appendix D) indicates most groundwater presents a low sodium hazard; however, wells with bedrock interaction or mixing have high salinity hazards and may not be suitable for irrigation purposes. In general, the SAR results indicate that the unconsolidated and unconfined aquifers have both low sodium hazard and a low to medium salinity hazard, and should be suitable for irrigation.

6.5 SUMMARY

The results of the groundwater quality assessment indicate that the water quality in the unconsolidated aquifers is good. There were very few exceedances of applicable water quality guidelines, and those that were found to exceed (such as manganese, sulphate, TDS, and conductivity) are likely naturally occurring. Concentrations of key parameters that are associated with agricultural activities (e.g., nitrate, chloride, phosphorus) were relatively low, despite the prevalence of agriculture throughout the watershed. This may be because of the short residence time of the groundwater in the aquifer, which is believed to be freshly recharged and hydraulically connected to the Similkameen River.

Water quality was also relatively consistent spatially, with similarities in groundwater type noted between wells located near the U.S. border and wells in the Princeton area. Most of the wells are located in the unconsolidated, freshly recharged aquifer. Small localized variations are likely due to either nearby sources (e.g., the landfill near Keremeos E251772) or influences from the bedrock aquifers in the area.

7 Groundwater Management Strategy for Agricultural Water Supply

7.1 REGULATORY FRAMEWORK

7.1.1 Water Licencing

Under the previous *Water Act*, extraction of surface water required a licence, but extraction of groundwater did not. Therefore, little was known about groundwater extraction volumes throughout the province. On February 29, 2016, the *Water Act* was replaced by the *Water Sustainability Act* (WSA) (SBC 2014, c. 15). Under the new regulations, all groundwater users, except for domestic water users extracting 2,000 L/day or less, must now apply for a water licence from MFLNRO, and pay an annual water rental rate. Domestic water use is generally defined as water that is used by a dwelling for drinking water, food preparation, irrigation of small gardens (less than 1,000 m^2), and providing water to animals kept as pets or for household use (including poultry). Water extracted for all other purposes, including irrigation water, must be licensed. The WSA allows for a three-year transitional period: all existing, non-domestic users can lawfully continue using groundwater without a licence until February 28, 2019. By March 1, 2019, all groundwater users must have applied for a licence.

These changes will allow decision makers to manage surface water and groundwater as a single resource. Prior to 2016, surface water licences could be restricted by the provincial government during times of scarcity. The same regulations will now apply to groundwater. Groundwater extraction can be restricted; for example, in cases where reducing groundwater withdrawals will augment flows in adjacent streams and protect fish populations. The licensing process will also provide valuable information about the amount of groundwater currently extracted in the province, including in the Similkameen watershed.

7.1.2 Groundwater Protection

The Groundwater Protection Regulation (GWPR) under the WSA controls activities related to wells and groundwater to protect groundwater resources and human health. It regulates minimum standards for well construction, maintenance, deactivation and decommissioning, and establishes the required qualifications for the persons that drill wells, install well pumps, and perform related services. Wells used to supply water for any aspect of agriculture are covered by the GWPR. For planning, a key requirement of the GWPR is that all new wells must be registered with the provincial government, and detailed information on the geology, yield, and construction methods must be submitted.

7.1.3 Other

Other regulations or government guidelines that apply to groundwater include:

- The BC *Drinking Water Protection Act* and the Drinking Water Protection Regulation include requirements for the management and protection of aquifers and wells used to supply drinking water. Section 36 of the Act enables the provincial government to restrict certain groundwater activities. With the Regulation, Section 5 requires drinking water wells to be disinfected if at risk of pathogen contamination, and Section 14 requires wells to be flood-proofed.

- RDOS Subdivision Servicing Bylaw No. 2000, 2002 requires that new parcels created by subdivision must either connect to a community system where available, or have a supply of potable water according to the specifications of the bylaw.
- The Village of Keremeos and the Keremeos Irrigation District have been developing a Groundwater Protection Plan in a series of phases. Work to date has included numerical modeling to delineate the capture zones supplying water to the wells, preliminary identification of potential contaminant sources, and a preliminary risk assessment of those contaminant sources. The third phase identified one of the next steps as developing management strategies to protect the groundwater supply (Golder 2008). Preliminary steps for developing groundwater protection plans were also investigated for Olalla and Princeton (Golder 2005a, b), and included capture zone delineation and contaminant source inventories.
- In early 2016, MOE commissioned a study to develop a preliminary water budget model for the Similkameen Valley Aquifer 259 to help support groundwater allocation decisions under the WSA, and ensure future water sustainability within the Similkameen watershed.

7.2 KEY GROUNDWATER MANAGEMENT ISSUES

The key issues related to groundwater in the Similkameen watershed are summarized as follows:

- Water Supply
    - Water in the Similkameen Valley is “one resource”. Will extraction of water from the main valley bottom aquifers affect surface water supply and visa versa?
    - Although SWP Phases 1, 2 and 3 has improved understanding of agricultural use of groundwater, there are still some gaps and estimates of use by private agricultural land owners not serviced by a community supply and are based primarily on models. This will be rectified as the groundwater wells in the valley become licensed and information on the wells are compiled (see Section 7.3.2 for recommendations).
    - Similarly, the scientific understanding of groundwater recharge processes and the valley aquifer (Aquifer 259) water balance has improved recently, but some key gaps remain that have a bearing on decision-making around water use.
- Groundwater quality
    - Unconfined aquifers are vulnerable to contamination. Available evidence indicates groundwater quality is currently good for agriculture and other uses, but care must be taken to maintain this situation.
    - Historic effects of mining may have a legacy effect on groundwater quality in localized areas.
- Environment and Ecosystems
    - Could increases in agricultural water use reduce streamflows enough to have a detrimental effect on fish and other forms of aquatic life?
    - Could agricultural practices have an adverse effect on water quality and on aquatic life?

7.3 GROUNDWATER MANAGEMENT STRATEGY: 2017–2027

7.3.1 Strategic Direction

The results of this technical assessment and preceding studies (Summit 2015, Associated 2016) indicate that groundwater is now the main source of water supply for agriculture as both water purveyors and individual farms have moved away from surface water over the past 5-15 years, but most have not given up their surface water licenses. Other key findings include that the quality of groundwater is good and poses few constraints on agriculture, and that there are still some gaps in our understanding of how the valley bottom aquifers are recharged and how groundwater and surface water interacts, although it is clear that the main valley bottom aquifer (Aquifer 259) is physically and hydraulically connected to the Similkameen River and the lower reaches of tributary streams. Based on these findings, groundwater management should be a priority for the Similkameen Valley Watershed Plan. The major strategic components of the plan with respect to groundwater are:

- Groundwater and surface water should be valued and managed as a single source of water in the Similkameen watershed, especially in the valley bottom portions where there is agricultural land use and where most people reside.
- Recognizing their connected nature, the SWP should include direction that all proposals for new development that would increase water use be supported by an assessment of potential effects on both surface water and groundwater.
- In addition to strengthening groundwater protection, the implementation of the *Water Sustainability Act* provides opportunities to expand and improve the database on groundwater quantity and quality, aquifer characteristics, and surface water linkages. SVPS and RDOS should work closely with the provincial, First Nation, and federal governments to harmonize information collection, management, and communication to support decision-making.
- The recommended partnerships with others should be facilitated through a "Similkameen Groundwater Working Group" that meets regularly to share information and coordinate the groundwater-related work[11]. In addition to government, the working group should include representation from agricultural producer groups, industry (e.g. Copper Mountain), and academia.
- Although groundwater supply is adequate through much of the watershed, consider limiting additional groundwater use in the Keremeos Creek sub-basin (#7 in Phase 2 report), until there is better information on how groundwater withdrawals are affecting streamflow. Applications for new groundwater withdrawals in Sub-basin #9 (Similkameen River from Hedley to the US border) should be supported by project-specific groundwater-surface water interaction studies to evaluate effects on neighbouring supplies and surface flows (see below).
- The watershed plan should provide direction on an overall water conservation strategy, of which agriculture is a component. It is important that there be a single water conservation strategy to reinforce the need to manage water as one resource.

---

[11] The SWP draft document (in development) will include recommendations for several such working groups (WG) to guide plan implementation (e.g. Riparian Areas WG, Groundwater WG), depending on the governance model selected.

- There are opportunities to conserve water by implementing improvements to irrigation systems through a mixture of technology and best management practices. The potential improvements and associated costs are well understood by the agricultural sector, so funding is one of the constraints on implementation that should be addressed in the watershed plan. A cost-benefit analysis of water conservation improvements is suggested as an initial step in determining how such a program would be implemented.
- Communication and education initiatives within the SWP should include a groundwater component, emphasizing the “one resource” message and the level of pressure on aquifers in each sub-basin (as per the Phase 2 report). Practical matters, such as the requirement to registers wells before March 2019, should also be communicated out on a regular basis.
- Options for storage or water supply redundancy should be evaluated to prepare for drought years when groundwater extraction could be constrained and surface water flows are expected to be reduced compared to baseline low-flow years (Section 4.4). This should be considered at all spatial scales, from the farm to the watershed.

7.3.2 Recommended Investigations to Support Groundwater Management

We recommend the following studies to improve understanding of groundwater supply and use in light of the implementation of the WSA and the projected changes in agricultural demand due to climate change effects and possible changes to the agricultural economy:

- By early 2019, most groundwater users (or at least most of the larger users) will have licensed their wells. At that time, it would be beneficial to confirm the status of all existing water licences (surface and groundwater) within the Similkameen watershed through a combination of data analyses (e.g., identification of parcels with both types of licences) and interviews. These interviews would be completed with all water purveyors in the valley and with land owners where groundwater wells were identified in surface water sourced parcels.
- Similarly, the ALUI and AWDM should be updated in 2019 to reflect the improved groundwater use information that will be available by that time.
- In the meantime, RDOS should engage with MFLNRO to ensure both surface water and groundwater use volumes are declared properly under the new licensing system. If feasible, both types of licences should be compiled in a public domain database for use by utilities, water purveyors, water and fisheries managers, stakeholders, and the general public. If confidentiality is a concern, the licensee names and parcel identifiers can be hidden, with sub-basin being the only geographic identifier.
- There are still spatial gaps in information on groundwater quality, notably in the valley bottom between the major communities. Land owners or others that install new wells in those areas should be encouraged to test and analyze the groundwater quality after the wells are established, with the analyses to include the variables that are important to agriculture (consistent with the analyses in Sections 6.3 and 6.4 of this report).
- As suggested in Phases 1 and 2, mapping of the spatial variation in Aquifer 259 is needed, with updated classification of the sub-units. This will enable management to be customized at a more practical scale and help stakeholders and the public to understand their sources of water better.

In addition, the 2016 report Monthly Water Budget for the Similkameen Valley Aquifer, British Columbia made nine technical recommendations to improve understanding of the Aquifer 259 water budget (Associated 2016). Aquifer 259 is the main aquifer in the valley bottom that underlies the river and floodplain. Those recommendations are under consideration by the province. The key ones that would provide benefit to agriculture if implemented are:

- Increase the number of Observation Wells by two – one at Princeton (reactivate #220) and one at the US border.
- Install new hydrometric stations at key locations where the data will provide improved information on the aquifer water balance (e.g. Similkameen River at the US border, Allison Creek, Hayes Creek and Wolfe Creek).
- Complete an Environmental Flow Needs assessment for the Similkameen River and major tributaries to assist MFLNRO allocation staff to determine whether or not new water licences can be granted without increasing risk to aquatic life and/or existing agricultural water users. This recommendation was also made in the Phase 2 SWP report. This should be done for each sub-basin, with Keremeos Creek and Similkameen River near Keremeos/Cawston being the highest priorities.
- Complete a detailed groundwater-surface water interaction assessment within Aquifer 259 near Keremeos and Cawston, which is the area with the highest density of groundwater pumping to support agriculture.
- In general, the current understanding of recharge processes is somewhat limited and warrants additional research. For example, investigate the role of groundwater recharge in the rocky uplands of the Similkameen valley on the water balance of the valley Aquifer 259. An improved understanding of this process, termed Mountain Block Recharge, will help in future evaluations of water supply options for agriculture.

8 References

Agriculture and Agri-Food Canada. 2015. Impact of Climate Change on Canadian Agriculture. Available at: http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/climate/future-outlook/impact-of-climate-change-on-canadian-agriculture/?id=1329321987305. Accessed May 30, 2016.

Alberta Agriculture and Rural Development. 2014. Alberta's Irrigation – a strategy for the future. Irrigation and Farm Water Division. Lethbridge.

Associated Environmental Consultants Inc. (Associated). 2016. Monthly Groundwater Budget for the Similkameen Valley Aquifer, British Columbia. Water Science Series, WSS2016-03. Prov. B.C., Victoria, B.C. Available at: http://a100.gov.bc.ca/appsdata/acat/documents/r50846/SimilkaWaterBudg_1473194954914_3194880156.pdf

Bakker, M., D. Neilsen, and S. Losso. 2015. Water Use in British Columbia (2000–2100): An Application of the Irrigation Water Demand Model. Agriculture and Agri-Food Canada Internal Report. Summerland Research and Development Centre. 68 pages.

Bot, A. and J. Benites. 2005. The importance of soil organic matter: Key to drought-resistant soil and sustained food production. FAO Soils Bulletin 80. Food and Agriculture Organization of the United Nations. Rome.

Botkin, C. 2016. Personal communication (telephone conversation). Poultry Specialist. BC Ministry of Agriculture. Abbotsford, BC.

Crawford, E., and E. McNair. 2012a. BC Agricultural Climate Change Adaptation Risk and Opportunity Assessment Series- Wine Grape and Tree Fruit Production, Okanagan Region Snapshot Report. Published by the BC Agriculture and Food Climate Action Initiative.

Crawford, E., and E. McNair. 2012b. BC Agricultural Climate Change Adaptation Risk and Opportunity Assessment - Provincial Report. Published by the BC Agriculture and Food Climate Action Initiative.

Drever, J.I. 1997. The geochemistry of natural waters; surface and groundwater environments. 3rd ed. Prentice Hall. ISBN 0-13-272790-0.

Golder Associates Ltd. (Golder). 2005a. Preliminary Steps in the Development of a Groundwater Protection Plan – Village of Olalla. Submitted to the Regional District of Okanagan Similkameen. Available at: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=16815

Golder Associates Ltd. (Golder). 2005b. Preliminary Steps in the Development of a Groundwater Protection Plan – Town of Princeton. Submitted to the Town of Princeton. Available at: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=16644

Golder Associates Ltd. (Golder). 2008. Phase Three Groundwater Protection Planning – Keremeos, B.C. Submitted to the Keremeos Irrigation District. Available at: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=16462

Gooch, M., C. Schmidt, N. Marenick, L. Martin, and A. Simo. 2012. Opportunities Assessment of British Columbia's Vegetable Sector. Completed by the Value Chain Management Centre. Funded by Agriculture and Agri-Food Canada.

Hamlet, A.F., Carrasco, P., Deems, J., Elsner, M.M., Kamstra, T., Lee, C., Lee, S., Mauger, G.S., Salathe, E.P., Tohver, I. and Binder, L.W. 2010. Final Report for the jClimate Change Scenarios Project. http://www.hydro.washington.edu/2860/report/

Health Canada. 2014. Guidelines for Canadian Drinking Water Quality. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. Available at: http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/sum_guide-res_recom/index-eng.php.

Hounslow, A.W. 1995. Water Quality Data, Analysis and Interpretation. CRC Press LLC. ISBN 0-87371-676-0.

Hudson, B.D. 1994. Soil organic matter and available water capacity. J. Soil and Water Conservation. 49(2): 189-194.

Hughes-Games, G. 2016. Personal communication (telephone conversation). Soil Specialist. Independent Consultant. Abbotsford, BC.

IBISWorld. 2016. Fruit and Nut Farming in Canada: Market Research Report. NAICS 11135CA. Available at: https://www.ibisworld.ca/.

Laurentian University and MIRARCO. 2015. Agriculture in a changing climate. Prepared by Ontario Centre for Climate Impacts and Adaptation Resources. Available at: http://www.climateontario.ca/doc/factsheets/Agriculture-final.pdf. Accessed May 31, 2016.

Lee, S. 2016. Personal communication (email). Spatial Data Analyst. Ministry of Agriculture.

Lucas, G. 2016. Personal communication (telephone conversation). General Manager. BC Fruit Growers Association. Kelowna, BC.

Ministry of Agriculture. 2014. BC Sprinkler Irrigation Manual. T. van der Gulik (ed.), S. Tam and A. Peterson. Available at: http://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/water/irrigation/sprinkler-irrigation-manual.

Ministry of Environment (MOE). 2015. British Columbia Working Water Quality Guidelines. Ministry of Environment, Water Protection and Sustainability Branch. Updated April 2015. Available at: http://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/bc_env_working_water_quality_guidelines.pdf.

Ministry of Environment. 2016a. Environmental Monitoring System Web Reporting. Available at: http://www.env.gov.bc.ca/emswr/

Ministry of Environment (MOE). 2016b. British Columbia Approved Water Quality Guidelines Summary Report. Ministry of Environment, Water Protection and Sustainability Branch. Updated March 2016. Available at: http://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/final_approved_wqg_summary_march_2016.pdf.

Ministry of Water, Land and Air Protection (MWLAP). 2013. British Columbia Field Sampling Manual for Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples. 2013 Edition. Available at: http://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/monitoring/emre/field_sample_man2013.pdf.

Neilsen, D. 2016. Personal communication (telephone conversation). Research Scientist, Agriculture and Agri-Food Canada (AAFC), Summerland, BC.

Neilsen, D. 2016. Personal communication (email to H. Hamilton). Research Scientist, Agriculture and Agri-Food Canada (AAFC), Summerland, BC. November 25, 2016.

Smith, S. 2016. Personal communication (telephone conversation). Industry Specialist Tree Fruit and Grapes. BC Ministry of Agriculture. Abbotsford, BC.

SRK Consulting Inc. (SRK). 2013. Water Budget Project: RDN Phase One (Gabriola, DeCourcy, and Mudge Islands). Prepared for the Regional District of Nanaimo, April 2013.

Statistics Canada. 2012. GeoSearch. 2011 Census of Agriculture. Statistics Canada Catalogue no. 92-142-XWE. Ottawa, Ontario. Data updated October 24, 2012. Available at: http://geodepot.statcan.gc.ca/GeoSearch2011-GeoRecherche2011/GeoSearch2011-GeoRecherche2011.jsp?lang=E&otherLang=F. Accessed November 11, 2016.

Summit Environmental Consultants Inc. (Summit). 2014. Similkameen Watershed Plan – Phase 1 Report. Prepared for the Regional District of Okanagan-Similkameen and the Similkameen Valley Planning Society. January 2014.

Summit Environmental Consultants Inc. (Summit). 2015. Similkameen Watershed Plan – Phase 2: Water Supply, Quality, and Groundwater-Surface Water Interaction Technical Studies. Prepared for the Regional District of Okanagan-Similkameen. June 2015.

Unites States Department of Agriculture National Resources Conservation Service (USDA NRCS). 2011. Soil Quality for Environmental Health – Soil Management Practices. Prepared by the Natural Resources and Environmental Sciences Program, University of Illinois, Urbana-Champaign, Illinois. Available at: http://soilquality.org/management/soil_management_practices.html. Accessed December 15, 2016.

Van der Gulik, T., D. Neilsen, R. Fretwell, A. Petersen, and S. Tam. 2013. Agriculture Water Demand Model. Report for the Similkameen Watershed. Funded by Canada-British Columbia Water Supply Expansion Program.

Water Survey of Canada. 2016. Historical Hydrometric Data. Available at: http://wateroffice.ec.gc.ca/mainmenu/historical_data_index_e.html.

Water Sustainability Act, SBC 2014, c. 15.

Wei, A. and Q. Li. 2016. The cumulative effects of forest disturbance and climate variability on water resources sustainability in the Similkameen River watershed. Prepared for the Regional District of Okanagan Similkameen, Department of Earth, Environmental, and Geographic Sciences, University of British Columbia, Okanagan. 85 pp.

Withler, C. 2016. Personal communication (telephone conversation). Industry Specialist Tree Fruit and Grapes. BC Ministry of Agriculture. Kelowna, BC.

DELIVERED BY

Investment Agriculture Foundation of British Columbia

FUNDING PROVIDED BY

BRITISH COLUMBIA

Canada